Online ISSN : 0975-4172
Print ISSN : 0975-4350
DOI : 10.17406/GJCST

Global Journal

of Computer Science and Technology: A

Hardware & Computation

Constrained Electronic Puzzle

MIMO Wireless Communication

Highlights

Simulation with Active Elements

Reduction of Power Consumption

Discovering Thoughts, Inventing Future

VOLUME 17 ISSUE 1 VERSION 1.0

Global Journal of Computer Science and Technology: A
Hardware and Computation

Global Journal of Computer Science and Technology: A
Hardware and Computation

Volume 17 Issue 1 (Ver. 1.0)

Open Association of Research Society

Incorporation No.: 0423089
License No.: 42125/022010/1186
Registration No.: 430374
Import-Export Code: 1109007027
Employer Identification Number (EIN):
USA Tax ID: 98-0673427

Global Journals Inc.

*(A Delaware USA Incorporation with "Good Standing"; **Reg. Number: 0423089**)*

Sponsors: *Open Association of Research Society*
Open Scientific Standards

Publisher's Headquarters office

Global Journals® Headquarters
945th Concord Streets,
Framingham Massachusetts Pin: 01701,
United States of America
USA Toll Free: +001-888-839-7392
USA Toll Free Fax: +001-888-839-7392

Offset Typesetting

Global Journals Incorporated
2nd, Lansdowne, Lansdowne Rd., Croydon-Surrey,
Pin: CR9 2ER, United Kingdom

Packaging & Continental Dispatching

Global Journals Pvt Ltd
E-3130 Sudama Nagar, Near Gopur Square,
Indore, M.P., Pin:452009, India

Find a correspondence nodal officer near you

To find nodal officer of your country, please email us at *local@globaljournals.org*

eContacts

Press Inquiries: *press@globaljournals.org*
Investor Inquiries: *investors@globaljournals.org*
Technical Support: *technology@globaljournals.org*
Media & Releases: *media@globaljournals.org*

Pricing (Excluding Air Parcel Charges):

Yearly Subscription (Personal & Institutional)
250 USD (B/W) & 350 USD (Color)

Contents of the Issue

i. Copyright Notice
ii. Editorial Board Members
iii. Chief Author and Dean
iv. Contents of the Issue

1. Spatial Intelligence as Related to Success on Regular and Constrained Electronic Puzzle Formats. *1-7*
2. Scheduling Techniques for Operating Systems for Medical and IoT Devices: A Review. *9-26*
3. Encrypted Color Image Transmission in LDPC Encoded MIMO Wireless Communication System with implementation of MP-WFRFT based Physical Layer Security Scheme. *27-38*
4. Reduction of Power Consumption Using Different Coding Schemes Using FPGA in NoC. *39-43*
5. Tool Support of Developing Systems Simulation with Active Elements. *45-51*

v. Fellows
vi. Auxiliary Memberships
vii. Process of Submission of Research Paper
viii. Preferred Author Guidelines
ix. Index

Global Journal of Computer Science and Technology: A Hardware & Computation
Volume 17 Issue 1 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Spatial Intelligence as Related to Success on Regular and Constrained Electronic Puzzle Formats

By Rani Deepika Balavendran Joseph, Tika Malla, Thomas Miles, Jeanne Tunks & Gayatri Mehta

University of North Texas

Abstract- This paper is focused on how spatial learners perform on regular and constrained puzzles in an online scientific game. We used UNTANGLED, an interactive game to conduct the study presented in this manuscript. Players were presented a set of puzzles in both regular and constrained versions. The motivation behind this study was to examine the success rate of spatial learners in regular and constrained settings of the same puzzles. Our results suggest that spatially intelligent participants who played both regular and constrained puzzle format of the same game showed significant differences at the p=.05 level, indicating a level of spatial intelligence that is unprecedented. These participants showed signs of spatial intelligence necessary to solve electrical engineering problems. Our findings suggest a valuable use for electronic puzzles/games to determine which students are spatially intelligent, and potentially suited to engineering.

Keywords: *spatial intelligence, engineering games, scientific puzzle games, STEM games.*

GJCST-A Classification: *I.2.1, I.2*

SPATIALINTELLIGENCEASRELATEDTOSUCCESSONREGULARANDCONSTRAINEDELECTRONICPUZZLEFORMATS

Spatial Intelligence as Related to Success on Regular and Constrained Electronic Puzzle Formats

Rani Deepika Balavendran Joseph [α], Tika Malla [σ], Thomas Miles [ρ], Jeanne Tunks [Ѡ] & Gayatri Mehta[¥]

Abstract- This paper is focused on how spatial learners perform on regular and constrained puzzles in an online scientific game. We used UNTANGLED, an interactive game to conduct the study presented in this manuscript. Players were presented a set of puzzles in both regular and constrained versions. The motivation behind this study was to examine the success rate of spatial learners in regular and constrained settings of the same puzzles. Our results suggest that spatially intelligent participants who played both regular and constrained puzzle format of the same game showed significant differences at the $p=.05$ level, indicating a level of spatial intelligence that is unprecedented. These participants showed signs of spatial intelligence necessary to solve electrical engineering problems. Our findings suggest a valuable use for electronic puzzles/games to determine which students are spatially intelligent, and potentially suited to engineering. In addition, teachers could use the data from spatially directed puzzles to challenge students to heighten levels of spatial intelligence by using puzzles in non-STEM environments.

Keywords: spatial intelligence, engineering games, scientific puzzle games, STEM games.

I. Introduction

The theory of multiple intelligences (Gardner, 1983) that included: linguistic, logical, visual/spatial, bodily/kinesthetic, musical, interpersonal, and intrapersonal intelligences has undergone scrutiny (Almeida et al., 2010; Visser, Ashton, & Vernon, 2006), resulting in his further explanation of the theory (Gardner, 1993b). In the sequel a decade later, Gardner reiterates that each human being has intelligences that operate discreetly in the brain. In addition to the previous books, in *Creating Minds* (Gardner, 1993a), he examined the lives of seven individuals whose heightened capacity in one of the intelligences elevated them to success and further supported the theory. However, Gardner reiterates that the theory was never intended for the development of pedagogy to elevate intelligences. He suggests however that should educators use the theory pedagogically that teachers should individualize and pluralize (p. xvi). The former means to assist the development of intelligences in each child and the latter to present topics employing multiple means that incorporate intelligences identified in the theory.

For a decade following the unveiling of the theory, educational settings applied the theory in various ways to align and create curricula that include the intelligences (Armstrong, 1994; Hoerr, 1994; Krechevsky, Hoerr, & Gardner, 1995; Tamilselvi & Geetha, 2015). The studies showed ways in which the theory was applied, however limited evidence from these studies suggest that measures of intelligences were engaged and progress toward increasing intelligences were observed. Since the advent of standardized testing, ushered in by No Child Left Behind legislation (Klein, 2015), the primary intelligences that are tested and taught are linguistics and mathematics.

STEM education, with focus on science, technology, engineering, and mathematics, supports testing in mathematics, and in some situations science, particularly at the middle and high school levels, was initiated by the National Science Foundation in 2001 (White, 2014). Since that time, mathematics and science have remained the most emphasized of the four disciplines. According to White most school personnel are familiar with math and science, and/or have no mandated/tested curriculum for engineering. In 2009, the Educate to Innovate Initiative, signed by President Obama ("Education: Knowledge and skills for the jobs of the future," 2016), set out to challenge science and mathematics achievement, promoting STEM, rather than all four disciplines of STEM.

Though the initiative showed progress toward promoting improved math and science learning, support for the spatial intelligence necessary for engineering and technology remained elusive. The location of objects, relationships to one another, and the paths taken when in motion, all necessary for the development of engineers (Newcombe, 2010), remains unsupported in initiatives. However, spatial intelligence, if supported and promoted could serve as meaningful building blocks in developing engineers. As pointed out by Gardner, a learner endowed with a particular intelligence will seek the highest levels of learning in that area. For spatially intelligent learners, this would require seeking support for that learning outside of normal schooling and testing, possibly in virtual gaming environments.

Author ¥: University of North Texas, Denton, TX, USA.
e-mail: gayatri.mehta@unt.edu

As of this writing, few studies investigate the relationship between spatial intelligence and engineering education. A recent study (Ha & Fang, 2016) laments the lack of scholarly attention given to this aspect of skill acquisition in engineering mechanics. A foundational understanding of mechanics, they argue, lies not only in understanding the physics and mathematics involved, but also the ability to make abstract connections between concepts and to understand spatial relationships. Yet, this connection remains largely unexplored. We were only able to locate one study on spatial learning, which focused on using a web-based drawing tool for engineering graphics, with learners who had no prior technical drawing experience (Pedrosa, Barbero & Miguel, 2013). While their study did demonstrate a small marginal gain in understanding among spatial learners, the study focused on drawing schematics rather than on problem solving through spatial reasoning.

Virtual gaming that involves problem solving has potential to tap into multiple intelligences. A recent study demonstrated that problem solving in mathematics classrooms engages more types of learning and can lead to increased comprehension (Rahbarnia, Hamedian & Rhadmehr, 2014). Beyond mathematical instruction, virtual gaming also has the potential to elucidate the ties between intelligence and problem solving skill. Bühner and colleagues (2008), echoing previous work (Ackerman & Lohman, 206; Ackerman, Neier & Boyle, 2005), find that spatial intelligence related to problem solving is different from working memory, defined as the memorization and application of rules. Game simulations can engage both intelligence and memory as players find ways to apply rules in order to solve more complex types of problems.

The mapping game, UNTANGLED described below, extends this research. In it, players operate within a spatial environment and must find ways to create a compact arrangement of circles within blocks. There are a number of rules, or types of moves, they are allowed to make. Then, a constraint is added in which they must adhere to a more general rule. We predict that spatial learners, under the constraint, will find ways to solve the problem by using more moves, and multiple moves, in order to obtain higher scores. Successful players are not merely applying the same rules, they are finding novel ways to combine moves to reach a spatially-oriented objective.

II. Problem Statement

Spatial learners are rarely challenged to increase spatial intelligence in normal school settings. There are currently few means by which to determine spatial intelligence among learners within the educational setting.

III. Purpose of the Study

The purpose of the study was to examine the success rate of spatially capable learners in regular and constrained versions of the same game puzzles.

IV. Question

Are there significant differences, at the p=.05 level, between selected moves made, scores obtained, and number of moves, made by spatial learners, in regular and constrained forms of electrical engineering puzzles.

V. Background

In this study, we have used an interactive online scientific puzzle game, UNTANGLED. The game is available at *https://untangled.unt.edu.* UNTANGLED was created to uncover human mapping strategies and discover better, efficient mapping algorithms which reflect the human characteristics such as creativity, pattern recognition, learning with experience. The game has been online continuously since 2012 and it has attracted large number of players who have contributed towards database of solutions. It has been recognized in several press releases. The game is created to be broadly accessible to everyone. Players do not need to have any special engineering background to play this game. The in-depth tutorials in the game help them learn about the game interface, and goals and objectives of the game. Several incentives such as medals, badges are given to players in order to motivate them. There is a leader board in the game where players can check their standings as compared to the rest of the players. More details about the game can be found in (Mehta 2013).

VI. Experimental Set-Up

In this section, we describe the experimental set-up that is used to conduct this case study. The experimental protocol for all studies was determined to qualify for an exemption from the Institutional Review Board (IRB) of our university. IRB protocols were followed in all cases. We considered six games, three of them are regular games and the other three are constrained games in which players have to follow some additional constraints. There are seven levels/puzzles in each game. The puzzles considered in this study are selected from the signal and image processing application domain. These include sobel (P1), laplace (P2), gsm (P3), adpcm decoder (P4), adpcm encoder (P5), idct row (P6), and idct col (P7). The number of blocks and connections in these puzzles are shown in Table 1.

Table 1: Basic information related to puzzles/levels considered in this study

Puzzles	P1	P2	P3	P4	P5	P6	P7
Blocks	24	29	29	29	36	52	61
Connections	29	29	34	36	53	63	72

In total, we have 42 cases (six games and 7 levels per game) considered in this study. An example of a puzzle in a regular game and its constrained counterpart is shown in Figure 1.

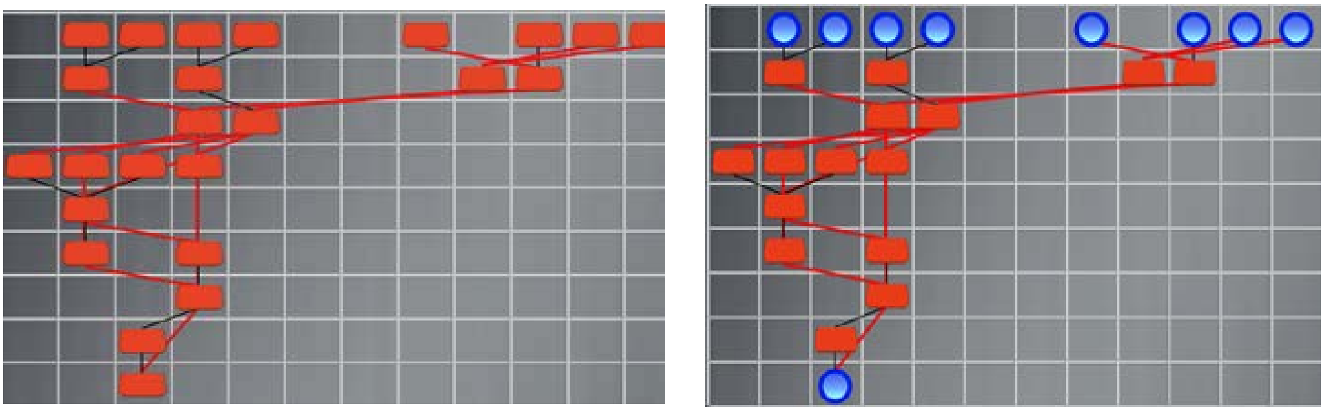


Figure 1: An example puzzle from a regular game (Left) and its constrained version (Right)

In the constrained games, there are two kinds of blocks – red rectangles and blue circles. Players have to follow the constraint of keeping blue circles around the periphery of the puzzle in addition to follow the connectivity and reach ability rules. Regular games only have red rectangles and they can be placed anywhere on the grid as long as connectivity and reach ability rules are met. The connectivity rules used in these games are 8way, 4way1hop, and 4way2hops. In an 8way, a block can connect to any of the eight neighboring blocks – top, bottom, left, right, and diagonally. In a 4way1hop, a block can connect of any of its four immediate neighbors (top, bottom, left, and right) and it can also make one hop in each direction (horizontal and vertical). In a 4way2hops, a block can connect to four of its immediate neighbors and it can also make two hops in horizontal and vertical directions. The goal of the players is to come up with compact arrangements of the blocks on a grid. We use a scoring function that guides players during the game play. We also show a violation count that helps players keep track of their progress and moving forward towards feasible or valid solutions. We record all the moves players make during the game play. Moves of all the levels of the games were analyzed thoroughly and results are presented in the next section.

VII. Results

Two statistical tests are used to measure the strength of game type and game level under the unconstrained and constrained conditions. The results of the ANCOVA are displayed in Table 2. The dependent variable is “total moves” and the category variable is “game session.” The model, therefore, tells us the between subject effects of “game level” and “game type” on total moves under the regular and constrained versions of the game. The effect of the covariate, game session, is highly significant. The subsequent ANOVA of the residual further tells us that the game type and game level variables also have a strongly significant effect on total moves even after the effect of the covariate has been calculated. This provides support for the hypothesis that each variable exerts a strong effect on the number of total moves employed by the player under differing conditions of the game. However, since the ANCOVA is an omnibus statistical test, it cannot really tell us much about the direction of the relationship, but only the strength of the covariation.

Table 2: ANCOVA Results of Total Moves, with Game Session Covariate

Source	Mean Square	df	F
Game Session	28925.622	1	10.853***
Game Type	449926.502	2	186.809***
Game Level	283823.301	6	106.489***
Intercept	587275.654	1	220.432***
Error	2665.293		1586

**** p < .001*
N = 1608; R Squared = .478 (Adjusted R Squared = .471)

Table 3 is a multi-level fixed effects model, testing the effect of the constraint as a grouping variable on total moves. A mixed effects model allows us to examine independent between-subject effects of each variable and how they vary or co-vary under the categorical variable. Game type and game level are nested variables in this analysis. The model performs similarly to the ANCOVA; both game type and game level are strongly associated with the number of total moves. The intercept is also notable, as it shows that the unconstrained version results in fewer total moves than is seen in the constrained version of the game. Thus under the constraint, game players are likely to employ more moves in order to reach the objective.

Table 3: Multi-Level Mixed Effects Model of Total Moves, Grouped by Game Session Variable

Variable	Coefficient	Standard Error
Game Type	10.088	2.067***
Game Level	18.759	0.898***
Intercept	-26.233	6.198***
Residual	62.429	1.102
Wald $\chi2$ = 465.46		

**** p < .001 N = 1608*

LR test vs. linear model: ChiBar2(01) = 2.79 Prob >= ChiBar2 = 0.0474

It is useful to look at the relationship graphically. The number of total moves under the unconstrained and constrained conditions is displayed in the bar graph in Figure 2. Under the unconstrained version, the mean number of total moves is 49.83 (SD=55.53) and increases to 58.31 (SD=83.49) under the constrained condition. Not only do players employ more moves under the constraint, but there is a much wider variance in the number of moves between constraint conditions.

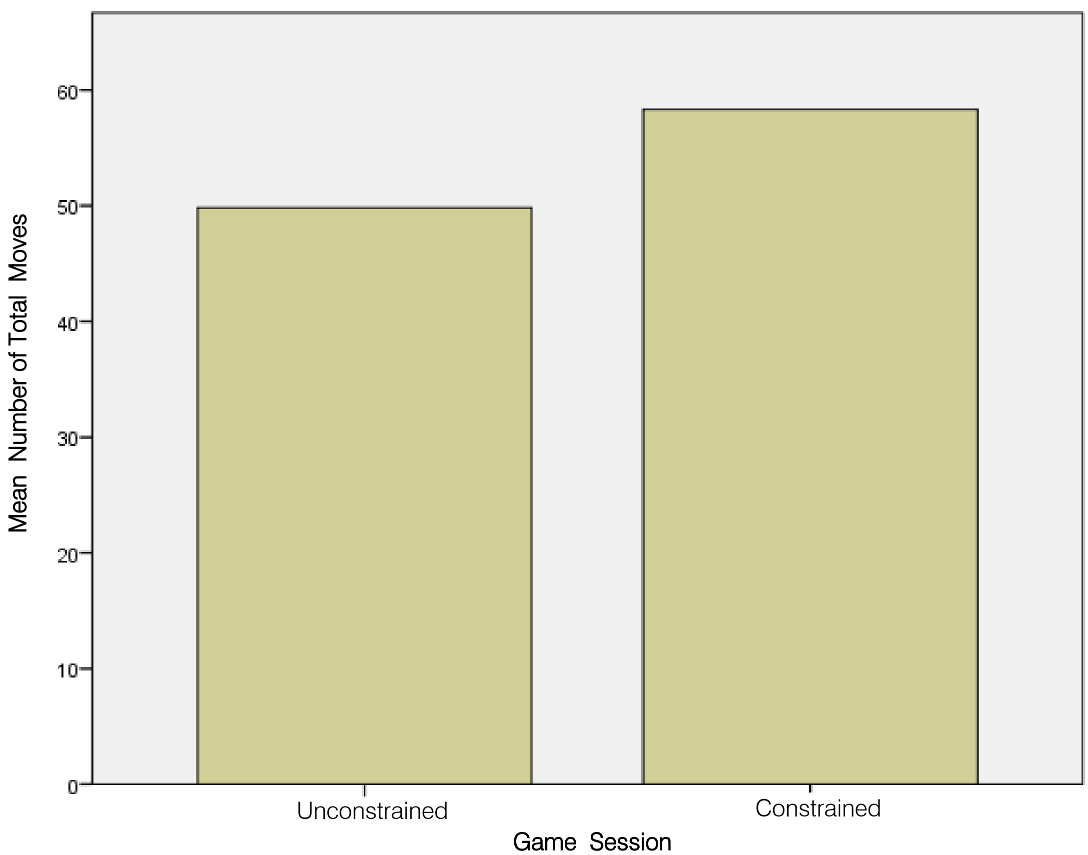


Figure 2: Mean Number of Total Moves under the Constrained and Unconstrained Conditions

Also illustrative is the types of moves employed under the constraint. As shown in Figure 3, not only does the number of total moves increase, but specific types of moves increased under the constrained condition. As described above, the number of single moves increased substantially (F=4.979; p<.026). However, multi moves increased slightly between the conditions (F=0.501) as did swap moves (F=0.057), indicating that the number of these types of moves did not vary substantially between the two game regimes. The number of add-pass moves, on the other hand, doubles under the presence of constraint (F=15.725; p<.001). These two types of moves, the single and add-pass, were frequently employed by game players as a means of overcoming the constraint.

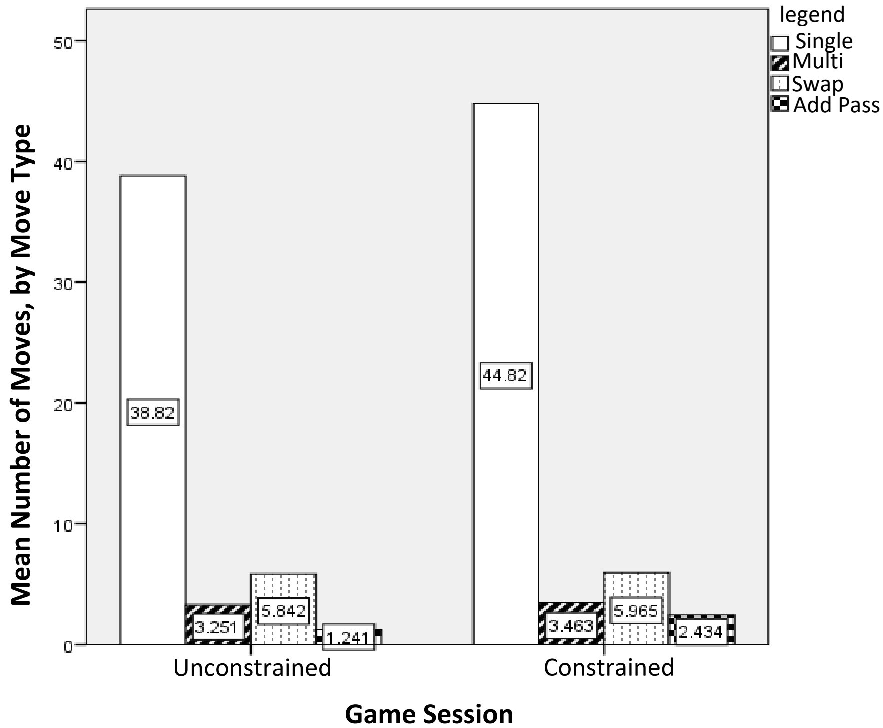


Figure 3: Comparison of Mean Number of Move Types under the Constrained and Unconstrained Conditions

VIII. Discussion

Spatially intelligent responders to the regular and constrained puzzle format of the same game showed significant differences at the p=.05 level, indicating a level of spatial intelligence that is unprecedented, due to the low percentage of players who responded. These respondents showed signs of spatial intelligence necessary to solve electrical engineering problems. In addition, the findings demonstrate that when spatially intelligent participants have the chance to challenge themselves, they seek the opportunity, using additional moves and more complex moves to solve the electrical engineering puzzles. The findings suggest a valuable use for electronic puzzles/games to determine which students are spatially intelligent, and potentially suited to engineering. When STEM was defined, the engineering definition stated that: Engineering is the art or science of making practical application of the knowledge of pure sciences, as physics or chemistry, as in the construction of engines, bridges, buildings, mines, ships, and chemical plants (White, 2014) p. 4. Findings from a study of architecture students (D'Souza, 2007) noted that students who excelled in spatial intelligence showed higher levels of skills and competencies needed for success as architects. The Design Intelligence Assessment Scale was used to determine both pedagogy and admissions for students into engineering programs that lead to architectural design. This tool extends the understanding of spatially intelligent learners, providing a means by which to ascertain later success.

The highly significant covariation in the results section shows that players are indeed responding to both the constraint and to the game level by learning new strategies. The fact that these moves are generally more complex indicates that spatial learners are employing a dynamic process of reasoning as the conditions of the game change. Since the game is designed to measure the ability to use intuition and pattern recognition to solve complex spatial puzzles directly related to engineering problems, this study builds upon the previous research on engineering competence. Understanding this type of competency can be useful in not only predicting success in engineering education, but also as a means of studying the ways that spatial reasoning is employed by engineers in solving design problems.

When STEM was defined, the engineering definition stated that: Engineering is the art or science of making practical application of the knowledge of pure sciences, as physics or chemistry, as in the construction of engines, bridges, buildings, mines, ships, and chemical plants (White, 2014) p. 4. Findings from a study of architecture students (D'Souza, 2007) noted that students who excelled in spatial intelligence showed higher levels of skills and competencies needed for success as architects. The Design Intelligence Assessment Scale was used to determine both pedagogy and admissions for students into engineering programs that lead to architectural design. This tool extends the understanding of spatially intelligent learners, providing a means by which to ascertain later success.

The highly significant covariation in the results section shows that players are indeed responding to both the constraint and to the game level by learning new strategies. The fact that these moves are generally more complex indicates that spatial learners are employing a dynamic process of reasoning as the conditions of the game change. Since the game is designed to measure the ability to use intuition and pattern recognition to solve complex spatial puzzles directly related to engineering problems, this study builds upon the previous research on engineering competence. Understanding this type of competency can be useful in not only predicting success in engineering education, but also as a means of studying the ways that spatial reasoning is employed by engineers in solving design problems.

IX. Conclusion

In addition to tools for assessing spatial intelligence, game designers can support spatial intelligence diagnosis and learning through game design. As in the case of UNTANGLED, the participants who chose to engage in extended spatial challenges demonstrated both skill and tenacity as they worked through both regular and constrained games. STEM educators could use spatial puzzles to identify potential STEM students, with a propensity for engineering. In addition, teachers could use the data from spatially directed puzzles to challenge students to heighten levels of spatial intelligence by using puzzles in non-STEM environments.

Among the intelligences studied and supported by years of research by Howard Gardner and those who followed, spatial intelligence remains on the fringe of consideration. The advent of STEM in the past twenty years has primarily supported mathematics and science learning, rather than engineering and technology. The results of this study demonstrate that supporting spatial intelligence can lead to valuable solutions to engineering problems. It would seem prudent for STEM educators to review Gardner's theory of multiple intelligences and consider the importance of all, including spatial intelligence, as well as mathematics and scientific thought.

Acknowledgments

We would like to thank the National Science Foundation for supporting this work with grants NSF CCF-1218656 and NSF CCF-1617475. We would like to acknowledge Alok Pal and Satyanarayana Chivukula for their contributions to this work. We would like to thank all the UNTANGLED players.

References Références Referencias

1. Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2005). Working memory and intelligence: The same or different constructs? *Psychological Bulletin*, 131, 30–60.
2. Ackerman, P. L., & Lohman, D. F. (2006). Individual differences in cognitive functions. In P. R. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (pp. 139-161), 2nd edition, Mahwah, NJ: Lawrence Erlbaum Associates.
3. Almeida, L. S., Prieto, M. D., Ferreira, A. I., Bermejo, M. R., Ferrando, M., & Ferrándiz, C. (2010). Intelligence assessment: Gardner multiple intelligence theory as an alternative. *Learning & Individual Differences, 20*(3), 225-230. doi:10. 1016/j.lindif.2009.12.010
4. Armstrong, T. (1994). Multiple intelligences: seven ways to approach curriculum. *Educational Leadership, 52*, 26-28.
5. Bühner, M., Kröner, S., & Ziegler, M. (2008). Working memory, visual–spatial-intelligence and their relationship to problem-solving. *Intelligence*, *36*(6), 672-680.
6. D'Souza, N. S. (2007). *Design intelligences: A case for multiple intelligences in architectural design.* (67), ProQuest Information & Learning, US. Retrieved from https://libproxy.library.unt.edu:9443/login? url= http://search.ebscohost.com/login.aspx?direct=true &db=psyh&AN=2007-99011-003&scope=site Available from EBSCO host psyh database.
7. Education: Knowledge and skills for the jobs of the future. (2016). Retrieved from https://obamawhite house. archives.gov/issues/education/k-12/educate-innovate.
8. Gardner, H. (1983). *Frames of Mind*. New York, New York: Basic Books.
9. Gardner, H. (1993a). *Creating minds*. New York, New York.
10. Gardner, H. (1993b). *Multiple intelligences: the theory in practice*. New York, New York: Basic Books.

11. Ha, O., & Fang, N. (2015). Spatial Ability in Learning Engineering Mechanics: Critical Review. *Journal of Professional Issues in Engineering Education and Practice*, *142*(2), 04015014.
12. Hoerr, T. R. (1994). How the New City School applies the multiple intelligences. *Educational Leadership, 52*, 29-33.
13. Klein, A. (2015). No child left behind: an overview. Retrieved from http://www.edweek.org/ew/section/multimedia/no-child-left-behind-overview-definition-summary.html
14. Krechevsky, M., Hoerr, T. R., & Gardner, H. (1995). Complementary energies: implementing MI theory from the laboratory and from the field. *Yearbook (National Society for the Study of Education), 94th*(1), 166-186.
15. Mehta, G. et al. (2013). "Untangled: A game environment for discovery of creative mapping strategies." *ACM Transactions on Reconfigurable Technology and Systems (TRETS), vol.* 6, no. 3 pp.13, 2013.
16. Newcombe, N. S. (2010). Picture This. *American Educator, 34*(2), 29-43.
17. Pedrosa, C. M., Barbero, B. R., & Miguel, A. R. (2014). Spatial visualization learning in engineering: traditional methods vs. a web-based tool. *Journal of Educational Technology & Society*, *17*(2).
18. Rahbarnia, F., Hamedian, S., & Radmehr, F. (2014). A Study on the relationship between multiple Intelligences and mathematical problem solving based on Revised Bloom Taxonomy. *Journal of Interdisciplinary Mathematics*, *17*(2), 109-134.
19. Science, 2013. “2012 International Science & Engineering Visualization Challenge.” http://www.sciencemag.org/site/special/vis2012/, Science, 2013.
20. Tamilselvi, B., & Geetha, D. (2015). Efficacy in teaching through "multiple intelligence" instructional strategies. *Journal on School Educational Technology, 11*(2), 1-10.
21. Visser, B. A. b. v. c. c., Ashton, M. C. m. b. c., & Vernon, P. A. v. u. c. (2006). Beyond g: Putting multiple intelligences theory to the test. *Intelligence, 34*(5), 487-502. doi:10.1016/j.intell.2006.02.004
22. White, D. (2014). What is stem education and why is it important. *Florida Association of Teacher Educators Journal, 1*(14), 1-9.

This page is intentionally left blank

Global Journal of Computer Science and Technology: A
Hardware & Computation
Volume 17 Issue 1 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Scheduling Techniques for Operating Systems for Medical and IoT Devices: A Review

By Vipan Kakkar
Shri Mata Vaishno Devi University

Abstract- Software and Hardware synthesis are the major subtasks in the implementation of hardware/software systems. Increasing trend is to build SoCs/NoC/Embedded System for Implantable Medical Devices (IMD) and Internet of Things (IoT) devices, which includes multiple Microprocessors and Signal Processors, allowing designing complex hardware and software systems, yet flexible with respect to the delivered performance and executed application. An important technique, which affect the macroscopic system implementation characteristics is the scheduling of hardware operations, program instructions and software processes. This paper presents a survey of the various scheduling strategies in process scheduling. Process Scheduling has to take into account the real-time constraints. Processes are characterized by their timing constraints, periodicity, precedence and data dependency, pre-emptivity, priority etc. The affect of these characteristics on scheduling decisions has been described in this paper.

Keywords: process scheduling, hardware software synthesis, implantable medical devices (IMD), internet of things (IoT) devices, dynamic voltage and frequency scaling (DVFS), multiprocessor, fault tolerant scheduling.

GJCST-A Classification: *J.3*

SCHEDULINGTECHNIQUESFOROPERATINGSYSTEMSFORMEDICALANDIOTDEVICESAREVIEW

Strictly as per the compliance and regulations of:

Scheduling Techniques for Operating Systems for Medical and IoT Devices: A Review

Vipan Kakkar

Abstract- Software and Hardware synthesis are the major subtasks in the implementation of hardware/software systems. Increasing trend is to build SoCs/NoC/Embedded System for Implantable Medical Devices (IMD) and Internet of Things (IoT) devices, which includes multiple Microprocessors and Signal Processors, allowing designing complex hardware and software systems, yet flexible with respect to the delivered performance and executed application. An important technique, which affect the macroscopic system implementation characteristics is the scheduling of hardware operations, program instructions and software processes. This paper presents a survey of the various scheduling strategies in process scheduling. Process Scheduling has to take into account the real-time constraints. Processes are characterized by their timing constraints, periodicity, precedence and data dependency, pre-emptivity, priority etc. The affect of these characteristics on scheduling decisions has been described in this paper.

Keywords: process scheduling, hardware software synthesis, implantable medical devices (IMD), internet of things (IoT) devices, dynamic voltage and frequency scaling (DVFS), multiprocessor, fault tolerant scheduling.

I. Introduction

The scheduling problem in portable and mobile systems has many facets [1] [2]. Scheduling algorithms have been developed in both the operation research and computer science community, with different models and objectives. The techniques that are applicable today to the design of hardware and software systems draw ideas from both communities.

Generally speaking, hardware and software scheduling problems differ not just in the formulation but in their overall goals. Nevertheless, some hardware scheduling algorithms are based on techniques used in the software domain, and some recent system-level process scheduling methods have leveraged ideas in hardware sequencing.

Scheduling can be loosely defined as assigning an execution start time to each task in a set, where tasks are linked by some relations (e.g., dependencies, priorities, etc.). The tasks can be elementary operations (like hardware operations or computer instructions) or can be an ensemble of elementary operations (like software programs). The tasks can be periodic or aperiodic, and task execution may be subject to real time constraints or not.

Scheduling under timing constraints is common for hardware circuits, and for software applications in embedded control systems. Task execution requires the use of resources, which can be limited in number, thus causing the serialization of some task execution. Most scheduling problems are computationally intractable, and thus their solutions are often based on heuristic techniques. Scheduling algorithms as applied to design of operating systems are explained below.

Scheduling in High-Level Synthesis (HLS) is an optimization problem [3]. The different entities that should be optimized here are speed, cost (area or resources) and power consumption. By making use of these entities, scheduling problems can be listed as (i) time constrained scheduling (ii) resource constrained scheduling (iii) feasible constrained scheduling and (iv) power constrained scheduling. There are also other factors that are important in evaluating designs such as pin limitations, package selection, testability, variety of latches, library of cells, clock skew etc. These are not discussed here.

II. Scheduling in Different Operating Systems

Process scheduling is the problem of determining when processes execute and includes handling synchronization and mutual exclusion problem [3]. Algorithms for process scheduling are important constituents of operating systems and run-time schedulers.

The model of the scheduling problem is more general than the one previously considered. Processes have a coarser granularity and their overall execution time may not be known. Processes may maintain a separate context through local storage and associated control information. Scheduling objectives may also vary. In a multitasking operating system, scheduling primarily addresses increasing processor utilization and reducing response time. On the other hand, scheduling in real-time operating systems (RTOS) primarily addresses the satisfaction of timing constraints.

First consider the scheduling without real-time constraints. The scheduling objective involves usually

Author: Shri Mata Vaishno Devi University, Katra.
e-mail: vipan.kakar@smvdu.ac.in

variety of goals, such as maximizing CPU utilization and throughput as well as minimizing response time. Scheduling algorithms may be complex, but they are often rooted on simple procedures [97] such as shortest job first (SJF) or round robin (RR). The SJF is a priority-based algorithm that schedules processes according to their priorities, where the shorter the process length (or, more precisely, its CPU burst length) the higher the priority as shown in Fig. 1. This technique arranges the processes with the least burst time in head of the queue and longest burst time in tail of the queue. This requires advanced knowledge or estimations about the time required for a process to complete. This algorithm would give the minimum average time for a given set of processes, their (CPU-burst) lengths were known exactly. In practice, predictive formulas are used. Processes in a SJF may allow preempting other processes to avoid starvation.

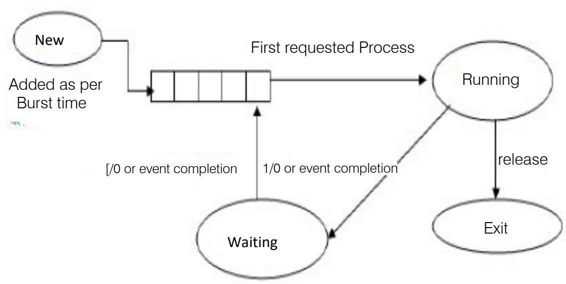


Fig. 1: Shortest Job First (SJF) Scheduling

The round robin scheduling algorithm as shown in Fig. 2, uses a circular queue and it schedules the processes around the queue for a time interval up to a predefined quantum. The queue is implemented as a first-in/first-out (FIFO) queue and new processes are added at the tail of the queue. The scheduler pops the queue and sets a timer. If the popped process terminates before the timer, the scheduler pops the queue again. Otherwise it performs a context switch by interrupting the process, saving the state, and starting the next process on the FIFO.

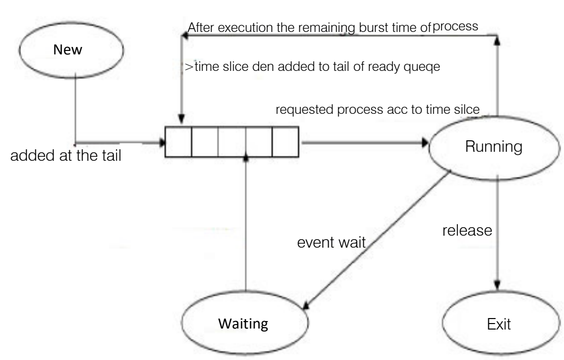


Fig. 2: Round Robin (RR) Scheduling

Different goals and algorithms characterize process scheduling in real-time operating system. Schedules may or may not exist that satisfy the given timing constraints. In general, the primary goal is to schedule the tasks such that all deadlines are met: in case of success (failure) a secondary goal is maximizing earliness (minimizing tardiness) of task completion. An important issue is predictability of the scheduler, i.e., the level of confidence that the scheduler meets the constraints.

The different paradigms for process scheduling in RTOS can be grouped as static or dynamic. In the former case, a schedule ability analysis is performed before run time, even though task execution can be determined at run time based on priorities. In the latter case, feasibility is checked at run time. In either case, processes may be considered periodic or aperiodic. Most algorithms assume periodic tasks and tasks are converted into periodic tasks when they are not originally so.

Rate monotonic (RM) analysis is one of the most celebrated algorithms for scheduling periodic processes on a single processor. RM is a priority-driven preemptive algorithm. Processes are statically scheduled with priorities that are higher for processes with higher invocation rate, hence the name. Liu and Lay land showed that this schedule is optimum in the sense that no other fixed priority scheduler can schedule a set of processes, which cannot be scheduled by RM. The optimality of RM is valid under some restrictive assumptions, e.g., neglecting context-switch time. Nevertheless, RM analysis has been the basis for more elaborate scheduling algorithms. Deadline Monotonic (DM) executes at any time instant the instance of the ready task with the shortest deadline, first. If two or more tasks have the same deadline, then DM randomly selects one for execution next. DM becomes equivalent to the RM algorithm when the deadlines of tasks are equal to their period [95].

Process scheduling plays an important role in the design of mixed hardware/software systems, because it handles the synchronization of the tasks executing in both the hardware and software components. For this reason, it is currently a subject of intensive research. A description on process scheduling is given in the next chapter.

III. Process Scheduling

This section presents various process scheduling algorithms available in the literature. Section 3.1 gives an overview of Real-time system and its characteristics have been given in section 3.2. Definition and the terminology used in process scheduling are given in section 3.3. Section 3.4 details various approaches taken for real-time scheduling. Various scheduling schemes have been compared.

Also, many references have been suggested for every scheduling scheme for an interested reader to get more details.

a) Real-time System

Real-time systems are broadly classified into soft real-time systems and hard real-time systems. In soft real-time systems, the tasks have either soft deadlines or do not have deadlines at all. Scheduler performs task scheduling as fast as possible. If the task with soft deadline finishes late, it does not lead to serious problems, but results in degraded system performance. On the other hand, in hard real-time systems, tasks have timing constraints and if these timing constraints are not met, the outcomes may be fatal. Missing the deadline of critical tasks leads to system malfunction or breakdown. Therefore, scheduling algorithm employed for task scheduling in a hard real-time system has to work satisfactorily and ensure that every task completes before its deadline. In practice, hard real-time systems invariably have many soft real-time jobs and vice versa.

Clearly, scheduling pure soft real-time tasks is a trivial job and scheduling hard real- time tasks is quite complex. In the remainder of this paper, scheduling in hard real-time systems is considered only. It is good to note that task scheduling is among the most important and critical services real-time operating system should provide. Task scheduling in hard real-time can be static or dynamic as will be seen in this paper.

b) Characteristics of the Real-Time Tasks

i. Timing Constraints

Their timing constraints, precedence constraints and resource requirements typically characterize real-time tasks. Real-time tasks should have the information about their timing constraints so that they can be scheduled and managed efficiently. Various timing parameters used to characterize the hard real-time tasks are given below:

Deadline: Deadline of a request for a task is defined to be the time of the next request for a task. This is the time by which the task must finish.

Response time: The response time of the task is the time span between the request and the end of the response to that request.

Arrival time or Release time (r): It is the time at which a task is invoked in the system. However, in many real time systems, we do not know the exact instant r_j at which the task J_i will be released. We only know, r_j is in the range $[r_i^- \; r_i^+]$, that is, r_j can be as early as r_i^- and as late as r_i^+. This range of r is sometimes called as release time jitter or simply jitter.

Relative Deadline: Relative deadline is the maximum allowable response time of the job.

Ready time: It is the earliest time at which the task can begin execution. Obviously, the ready time of a task is equal to or greater than the arrival time.

Execution time: It is the amount of time required to complete the execution of a task when it executes alone and has all the resources it requires. The actual amount of time taken may however differ for many reasons. The actual execution for a task is known only after it finishes. Hence, the execution time is mentioned as minimum and maximum execution times. Knowing the maximum execution time is enough for determining whether the task meets its deadline. Therefore, in many hard real time systems, the execution time specifically means its maximum execution time. In hard real-time systems, tasks can be periodic, sporadic or aperiodic in nature.

Slack time: Time difference between execution time and the deadline

ii. Periodic Task Model

The periodic task model is a well-known deterministic workload model. With its various extensions, the model characterizes accurately many traditional hard real-time applications. Many scheduling algorithms based on this model have good performance and well-understood behavior. In this model, each computation and data transmission that is repeated at regular or semi regular intervals in order to provide a function of the system on a continuing basis is modeled as a periodic task. Specifically, each periodic task, denoted by T_i is a sequence of jobs. The period p_i of the periodic task T_i is the minimum length of all time intervals between release times of consecutive jobs in T_i. Its *execution time* is the maximum execution time of all the jobs in it. We use e_i to denote the execution time of the periodic task T_i, as well as that of all the jobs in it. At all times, the period and execution time of every periodic task in the system are known.

iii. Aperiodic and Sporadic Tasks

Aperiodic and sporadic tasks are used to characterize the external events to the real- time system. Aperiodic and sporadic tasks are the streams of aperiodic and sporadic jobs respectively. The release times for aperiodic and sporadic tasks are not known a priori.

Real-time system has to respond to the external events while it is executing some other tasks. Real-time system executes certain routines in response to the external events. These routines or tasks to be executed in response to an external event may have soft or hard timing constraints. If the task has soft deadline or no deadline, we call it as an aperiodic task. Since the aperiodic tasks have soft deadline, we want that the real-time system to be

Global Journal of Computer Science and Technology (A) Volume XVII Issue I Version I Year 2017

responsive in a sense that it completes the job as soon as possible. Although late response is annoying, it is tolerable, so the need is to optimize the responsiveness of the system for aperiodic tasks, but never at the expense of the hard real-time tasks whose deadlines must be met at all times.

If the task has hard real-time constraints, it has to meet its deadline. Failure in meeting deadlines lead to catastrophic results. Task of recovering from transient fault in time, for example, should complete before system goes down. The jobs that execute in response to these events have hard deadlines. Tasks containing jobs that are released at random time instants and have hard deadlines are sporadic tasks. Sporadic jobs may arrive at any instant, even immediately after each other. Moreover their execution times may vary widely, and their deadlines are arbitrary. In general, it is impossible for some sporadic jobs to meet their deadlines no matter what algorithm we use to schedule them. The only alternatives are (1) to reject the sporadic jobs that cannot complete in time or (2) to accept all sporadic jobs and allow some of them to complete them. Primary concern for sporadic tasks is to ensure that their deadlines are always met; minimizing their response times is of secondary concern.

iv. *Precedence Constraints and Data Dependency*

Jobs are said to be independent of each other if they can execute in any order without affecting the end result. In practice, however, jobs wait for the control and data inputs from other jobs and hence cannot execute independently. Therefore, control and data dependencies constrain the order in which the jobs can execute. Presence of dependency complicates the job scheduling, especially on a multiprocessor system.

v. *Functional Parameters*

Though scheduling and resource access-control decisions are generally taken without considering the functional characteristics of the task, several functional parameters do affect these decisions. Therefore, task workload model should explicitly mention the relevant functional parameters. Following functional parameters are generally described in the task workload model:

a. *Preemptive Jobs*

Preemption of the task is provided in the real-time systems to suspend the execution of the current job for giving processor to a higher priority or urgent task. However, some jobs need to be executed from start to finish without interruption to avoid errors in the system and to keep the switching overheads to a minimum. Such jobs are said to be non-preemptive.

b. *Priority of Jobs*

Priority of the job is the measure of the criticality or importance of the job with respect to other jobs in the system. Higher the priority, the larger its importance. Tasks scheduling algorithm decisions are mainly based on the priority of the tasks and hence the priority assignment to the task is very important. As we will see, scheduling algorithms uses static and dynamic priority assignment schemes for assigning priority to the tasks. Assigning priorities to the tasks so that all tasks meet their deadline is a difficult problem and usually some sort of heuristic is employed.

c. *Energy Aware Scheduling*

The trend in the industry towards Dynamic Power Management (DPM), where hardware technologies for dynamic frequency scaling (DVS) and dynamic voltage scaling (DVS) are being used to reduce the power consumption of individual processing elements (PE) at run-time. However, crucial to the success of this approach is a presence of intelligent software that adjusts the system performance level to maximize energy savings while still meeting application real-time deadlines.

Moreover, another trend is to build SoCs/ NoC/ Embedded System for Implantable Medical Devices (IMD) and Internet of Things (IoT) devices, which includes multiple PEs (Microprocessors+DSPs), allowing designing complex systems, yet flexible with respect to the delivered performance and executed application. The energy management of multi-PE SoCs should manage several elements with shared resources, each running their own OS, and a plurality of both real-time and non real-time applications.

Therefore, there is a need to directly address the energy problem. Intelligent energy management has impact on the hardware as well as on the software architecture of system, both implementing an infrastructure for energy management.

The objective of this energy-aware scheduling is to design a Generic Adaptive Power optimized design, which can be used in IoT and IMD devices. Its main purpose is to enable intelligent as well as adaptive power management, including the ability to make dynamic changes to the voltages and frequencies being applied to these devices. Peng *et.al* (2010) presented a novel wireless integrated power management design for biomedical telemetry systems. They designed a model such that it draws ultra-low standby current [30]. Gaurav *et.al* (2008) evaluated the effectiveness of power management using DVFS from a system level energy savings perspective [100]. However, simple policies they justified their work using benchmarks ranging from memory intensive workloads to CPU intensive workloads.

Global Journal of Computer Science and Technology (A) Volume XVII Issue I Version I Year 2017

In order to introduce intelligence in any system, different learning techniques have been developed so far such as TD-learning and Q-learning, which are two powerful in terms of saving power. The "wake-up" operation after sleep mode creates a significant power-draw from the battery supply (energy overhead). To deal with this issue Siyu *et.al* (2012) proposed a hybrid power supply using continuous Q-Learning and Discrete Q-Learning for reinforcement learning respectively [101] with good improvement in efficiency.

Umair and Bernard (2012) proposed a novel, model-free RL (reinforcement learning) Technique for the power management of a portable traffic monitoring system having the computer hardware which is the major contributor to the entire power consumption. Unlike the previous works they have proposed to use Timeout policy for RL in sleep as well as idle state [102]. They used MLANN (Multi-layer artificial neural network) for the workload estimation as shown in Fig. 3. In addition to this they used multiple state update in idle as well as sleep modes to increase the convergence speed of the algorithm. Their work proves that using Timeout policy in idle as well as sleep state is more efficient than using Timeout in idle state and N-policy in sleep state.

Although the DPM techniques effectively reduce the power consumption, they do not provide an optimal policy to extend the battery service lifetime of the battery. Maryam *et.al* (2013) proposed a power management policy claiming to extend the battery service lifetime by 35% compared to previous methods [103] as shown in Fig. 4. They have presented a model-free reinforcement learning technique used to define the optimal battery threshold value for a closed loop policy and used the same to specify the system active mode. Their power manager automatically adjusts the power management policy by learning the optimal timeout value. It performs power management in an "event-driven" and "continuous-time" manner. Their algorithm has a fast convergence rate and has less reliance on the Markovian property.

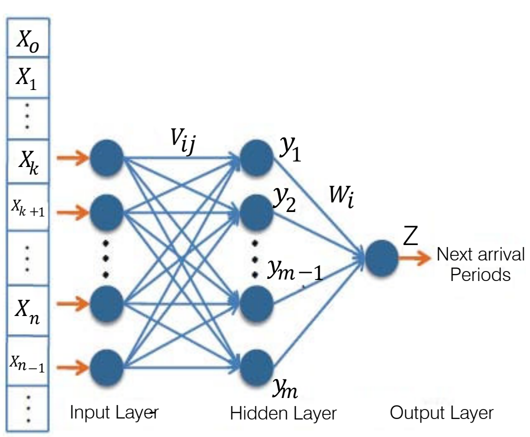


Fig. 3: ML-ANN based Workload Estimator

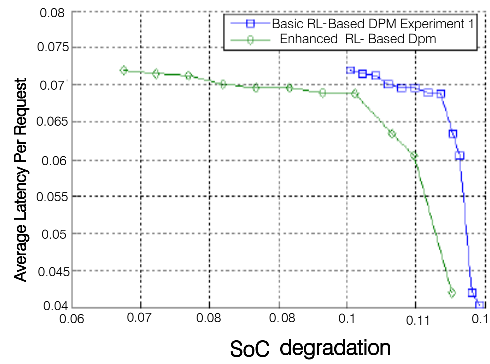


Fig. 4: Model-free Reinforcement Learing based Energy saving

M. Triki *et.al* (2015) proposed a novel, online, as well as adaptive RL based hierarchical approach to directly schedule the service request traffic that reaches the power managed components through SFC [104], using the technique is robust and has a faster convergence rate, the authors performed continuous time and event driven power management using the same. They were able to achieve a maximum energy saving of almost 63% during testing.

Based on the literature survey it is seen that a lot of work has been done in DPM for portable systems. Various low power design techniques have been used at circuit level to manage power consumption in IMDs in [18][20][27]. However no or very less work has been done in Power Management in IMDs at architectural level. Hence, there is a scope to work in this area.

c) *Process Scheduling Techniques*

Process scheduling involves allocating the tasks (ready for execution) to the available hardware resources. As the available hardware resources are often less in number than the tasks, tasks compete for it and the winner is scheduled for execution. Optimal task scheduling algorithm is a one that always keeps the available hardware resources occupied with tasks. The basic goal of any scheduling algorithm is to maximize the processor utilization. If the processor utilization is equal to or less than 1, then the schedule is said to be feasible.

The complexity of the scheduling algorithm increases when many tasks are to be scheduled on a large number of processing elements. In such systems, complexity of the scheduling algorithm decides the overall system performance.

Scheduling the tasks on more than one processor is a NP-complete problem and no optimal solution exists for such a system. Therefore, heuristics are applied.

i. *Terminology used in Scheduling*

a. *Scheduler*

Scheduler is a module that schedules tasks using some scheduling algorithms and resource access-control protocols.

b. *Schedule*

By schedule it means assignment of the jobs to the available processors as per the guidelines from the scheduler.

c. *Feasible Schedule*

A feasible schedule is a one that schedules the set of tasks meeting their deadlines. The feasible schedule is represented by timed labeled transition system.

d. *Optimal Scheduling or Scheduler*

A scheduling algorithm or scheduler (static or dynamic) is said to be optimal if it always constructs a feasible schedule for every task that has feasible schedule.

A static scheduling algorithm is said to be optimal if, for any set of tasks, it always produces the feasible schedule whenever any other algorithm can do so.

A dynamic scheduling algorithm is said to be optimal if it always produces a feasible schedule whenever a static scheduling algorithm with complete prior knowledge of all the possible tasks can do so.

An aperiodic scheduling algorithm is optimal if it minimizes wither the response time of the aperiodic job or the average response time of all the aperiodic jobs for a given task set.

An algorithm for scheduling sporadic jobs is optimal if it accepts each sporadic job newly offered to the system and schedules the job to complete in time if and only if the new job can be correctly scheduled.

e. *Static Scheduling Algorithm*

A scheduling algorithm is said to be static if priorities are assigned to tasks once and for all. A static priority algorithm is said to be fixed-priority scheduling algorithm also.

f. *Dynamic Scheduling Algorithm*

A scheduling algorithm is said to be dynamic if priorities of tasks might change from request to request.

g. *Mixed Scheduling Algorithm*

A scheduling algorithm is said to be mixed scheduling algorithm if the priorities of some of the tasks are fixed yet the priorities of the remaining tasks vary from request to request.

ii. *Definition of Scheduling Problem*

Task Scheduling involves determining the schedule, for a set of given tasks, such that the timing constraints, precedence constraints and resource requirements for the tasks are met and to compute the schedule if it is found to exist.

Real-time system has a mix of periodic and non-periodic (aperiodic and sporadic) tasks. Out of which periodic and sporadic tasks have hard deadlines to follow while aperiodic tasks have soft deadlines. The basic aim of any scheduling algorithm or scheme is to model these task characteristics with various changing parameters. Therefore, scheduling scheme should provide following things:

1. Assumptions made for the tasks.
2. Scheduling of non-periodic tasks that include soft aperiodic and hard sporadic tasks.
3. Schedulability test and analysis.
4. Performance analysis.

a. *Schedulability Analysis*

Its required to analyze schedulability to determine whether a set of tasks meets its timing constraints.

One way to analyze schedulability is to compute the worst case response time (WCRT) of each task as proposed in Balarin, L. Lavagno, Murthy and Vincentelli [2]. A task's WCRT is the maximum possible length of an interval that begins with the task being enabled and ends with the task completing its execution. It includes both the task's runtime and interference from other tasks. The WCRT concept is useful regardless of the scheduling approach.

However, finding WCRT for a real life embedded system is a difficult task due to the presence of varying parameters like runtimes, dependency between tasks, and non- periodic events in the environment.

b. *Performance Analysis of Scheduling Algorithms*

Performance analysis of scheduling algorithm is required to find out its effectiveness in scheduling the set of tasks. The most often used measure of the performance is the ability of the scheduling algorithm to find out the feasible schedule for a set of tasks provided such a schedule exists. Schedulable utilization and fast response time to urgent tasks are also used as main performance measures. Other commonly used performance measures include maximum and average tardiness, lateness, and response time and the miss, loss, and invalid rates. Generally, only the relevant performance measures are used in the performance analysis of a particular scheduling algorithm. This depends on the task characteristics and the environment.

d) Approaches Taken to Real-Time Scheduling

The approaches taken to real-time scheduling can be broadly classified into three categories: clock-driven scheduling, round robin scheduling and priority-driven scheduling. Priority driven scheduling can be further classified into fixed and dynamic priority scheduling. The scheduling scheme may support either preemptive or non-preemptive scheduling etc. The scheduling algorithms found in the literature target the topic of scheduling the hybrid of real-time periodic and non-periodic (aperiodic and sporadic) tasks with hard or soft deadlines respectively. In literature the work of scheduling covers specific cases of uniprocessor, multiprocessor and distributed systems (with identical or heterogeneous processors). Each scheduling algorithm assumes certain task characteristics. Some assumptions are often made for the real-time task [9] that may include:

The real time tasks with hard deadlines are periodic.

The tasks are independent i.e. the tasks release time does not depend on the initiation or completion of other tasks.

Run-time for each task remain constant; run-time here means the time taken by the processor to execute the task.

Any non-periodic (aperiodic and sporadic) tasks are special cases; they are initialization and failure-recovery routines; and do not have hard deadlines. All parameters of the periodic jobs are known a priori. In particular, variations in the inter-release times in any periodic job are negligibly small.

Different scheduling algorithms try to relax one or more of the above assumptions so as to make the task model more realistic. The way the aperiodic and sporadic tasks are scheduled distinguishes various scheduling schemes.

i. *Static and Dynamic Task Scheduling*

Task scheduling in hard real-time system can be either static or dynamic. In static task scheduling, the schedule for the tasks is prepared offline and requires complete prior knowledge of the task characteristics. In dynamic task scheduling, on the other hand, tasks are accepted for scheduling during run-time (if a feasible schedule is obtained). If the tasks' characteristics are well known and doesn't vary, static scheduling schemes always produce feasible schedule. We can use complex static scheduling scheme, as schedule is computed offline. However, static scheduling schemes are inflexible and cannot adapt to changing environment. The schedule needs to be recomputed if the system is reconfigured. In contrast, dynamic schemes have high run-time cost as the schedule is found on the fly. However, they are flexible and can easily adapt to the changes in the environment.

ii. *Preemptive vs. Non-preemptive Scheduling*

Most of the scheduling algorithms assume that the tasks are preemptive. However, non-preemptive scheduling of a set of periodic and sporadic tasks on a uniprocessor is important for variety of reasons such as:

In many practical real-time scheduling problems such as I/O scheduling, properties of device hardware and software either make preemption impossible or prohibitively expensive.

Non-preemptive scheduling algorithms are easier to implement than preemptive algorithms, and can exhibit dramatically lower overhead at runtime.

The overhead of preemptive algorithms is more difficult to characterize and predict than that of non-preemptive algorithms. Since scheduling overhead is often ignored in scheduling models, an implementation f a non-preemptive scheduler will be closer to the formal model than an implementation of a preemptive scheduler.

Non-preemptive scheduling on a uniprocessor naturally guarantees exclusive access to shared resources and data, thus eliminating both the needs for synchronization and its associated overhead.

The problem of scheduling all tasks without preemption forms the theoretical basis for more general tasking models that include shared resources.

Jeffay et al. [17] focus on scheduling a set of periodic or sporadic tasks on a uniprocessor without preemption and without inserted idle time. The paper gives necessary and sufficient set of conditions C for a set of periodic or sporadic tasks to be schedulable for arbitrary release time of the tasks. They have shown that a set of periodic or sporadic tasks that satisfy C can be scheduled with an earlier-deadline-first (EDF) scheduling algorithm. For a set of sporadic tasks with specified release times conditions C are necessary and sufficient for schedulability. However, for sets of periodic tasks with specified release times, conditions C are sufficient but not necessary.

iii. *Clock-driven Scheduling*

In clock-driven scheduling, the jobs are scheduled by the scheduler at specific time instants. These time instants are chosen a priori before the system starts execution. The timing instants may or may not be at regular intervals. All the parameters of hard real-time jobs should be fixed and known before hand. In other words, the clock driven scheduling is possible for a system that is by and large deterministic.

To keep the information ready for the scheduler, the schedule for the jobs is computed off-line and is stored in the form of a table for use at run-time. Each entry in this table gives time instant at which a scheduling decision is made. Scheduler makes use of a timer. Upon receiving a timer interrupt, the scheduler sets the timer to expire at the next decision instant (from the table entry). When the timer expires again, scheduler repeats this operation.

iv. *Weighted Round Robin Scheduling*

The round robin approach is commonly used for scheduling time-shared applications. When jobs are scheduled on a round robin basis, every job joins a

Global Journal of Computer Science and Technology (A) Volume XVII Issue I Version I Year 2017

First-in-first-out (FIFO) queue when it becomes ready for execution. The job at the head of the queue executes for at most one time slice. If the job does not complete by the end of the time slice, it is preempted and placed at the end of the queue to wait for its next turn. When there are n ready jobs in the queue, each job gets one time slice every n time slices, that is every round. In essence, each job gets 1/nth share of the processor when there are n jobs ready for execution. The problem with round robin scheduling is that it provides poor service to urgent tasks. It is possible that even the most urgent task needs to wait for all other tasks to execute before it gets its turn. Thus to satisfy the timing constraints a very fast processing unit may be necessary, which may not be available. Then round robin may not produce the feasible schedule.

Therefore, weighted round robin scheduling scheme is used. It builds basic round robin scheme. Rather than giving all the ready jobs equal shares of the processor, different jobs may be given different weights. Here, the weight of a job refers to the fraction of processor time allocated to the job. By adjusting the weight of the jobs, we can speed up or retard the progress of each job toward its completion.

If round robin scheme is used to schedule precedence constrained jobs; the response time of a chain of jobs can be unduly large. For this reason, the weighted round robin approach is not suitable for scheduling such jobs. On the other hand, a successor job may be able to incrementally consume what a predecessor produces. In this case, weighted round robin scheduling is a reasonable approach, since a job and its successors can execute concurrently in a pipelined fashion.

v. *Priority Driven Scheduling*

The term priority-driven algorithms refer to a large class of scheduling algorithms that never leave any processor idle intentionally. Priority driven algorithms assign priorities to the tasks either statically or dynamically. Scheduling decisions are taken when events such as releases and completions of jobs occur and hence priority-driven algorithms are also known as event-driven. As any scheduling decision time, the jobs with the highest priority are scheduled and executed on the available processors.

Compared with the clock-driven approach, the priority-driven scheduling approach has many advantages. Many well-known priority-driven algorithms use very simple priority assignments, and for these algorithms, the run-time overhead due to maintaining a priority queue of ready jobs can be made very small. A clock-driven scheduler requires the information on the release times and execution times of the jobs a priori in order to decide when to schedule them. In contrast, a priority-driven scheduler does not require most of this information, making it much better suited for applications with varying time and resource requirements.

Despite its merits, the priority-driven approach has not been widely used in hard real- time systems, especially safety-critical systems, until recently. The major reason is that the timing behavior of a priority-driven system is non-deterministic when job parameters vary. Consequently, it is difficult to validate that the deadlines of all jobs scheduled in a priority-driven manner indeed meet their deadlines when the job parameters vary.

vi. *Static or Fixed Priority Scheduling Algorithms*

One way of building hard real-time systems is from a number of periodic and sporadic tasks and a common way of scheduling such tasks is by using a static priority pre- emptive scheduler; at runtime the highest priority runnable job is executed. Rate-Monotonic scheduling scheme proposed by Liu and Layland [9] and Deadline- Monotonic scheme proposed by Leung [62] are used to assign static priorities to the real-time jobs. In this section, both these scheduling schemes are explained and how they are used to schedule periodic and non-periodic jobs is covered.

a. *Rate Monotonic Priority Assignment*

Liu and Layland [9] in 1973 proposed a fixed priority scheduling scheme known as Rate Monotonic Scheduling. In rate monotonic priority assignment, priorities are assigned to tasks according to their request rates, independent of their runtimes. Specifically, tasks with higher request rates will have higher priorities. They also derived a schedulability analysis that determines if a given task set will always meet all deadlines under all possible release conditions. However, original rate monotonic scheme had several restrictions:

All tasks are independent to each other and they cannot interact.
All tasks are periodic.
No task can block waiting for an external event.
All tasks share a common release time (critical instant).
All tasks have a deadline equal to their period.

Liu & Layland's work has had a wide impact on research in real-time computing and embedded systems. However, every assumption of their model is violated to some extent in the design of embedded systems.

Tasks are rarely independent and generally events in the environment or execution of other tasks invoke them. In many systems, request for tasks do not arrive at regular periods. Only some constraints on the request rate are known. In many low-cost

Global Journal of Computer Science and Technology (A) Volume XVII Issue I Version I Year 2017

embedded systems preemption cost is not affordable due to context switch overhead. In addition, tasks' runtime is almost never constant. It may vary with different input patterns as well as with the state of the task.

Because of all the above real life issues, research community has come up with more realistic models in which some of the assumptions of Liu and Layland have been relaxed.

The first assumption that tasks cannot interact has been removed by Sha et al. [31]. Sha also provided a test to incorporate processes that synchronize using semaphores in [47]. Sha [31] addresses the issue of priority inversion (if synchronization primitives like semaphores, monitors and ada task model [47] are directly applied). Two priority inheritance protocols called the basic priority inheritance protocol and Priority Ceiling Protocol (PCP) have been presented. This protocols also shown to avoid deadlocks. Baker [15] proposes a Stack Resource Policy (SRP) which is a resource allocation policy that permits processes with different priorities to share a single runtime stack. SRP is a refinement of PCP [31], which strictly bound priority inversion and permits simple schedulability analysis. The related work on this topic can also be found in [12, 48, 49].

Sha [61] reported work that includes test to allow aperiodic processes to be included in the theory.

Rajkumar [58] used external blocking (i.e. when a task is blocked awaiting an external event) with the Rate Monotonic approach to model the operation of a multiprocessor priority ceiling protocol [12] and provided schedulability analysis to bound its effects.

The restriction that tasks are assumed to share a common critical instant has been relaxed by Audsley [57].

Leung [62] suggested a Deadline-Monotonic priority assignment that removed the constraint that the deadline and period of a process must be equal. Audsley et al. [7] provided schedulability test for the scheme proposed by Leung.

b. *Deadline Monotonic Priority Assignment*

In deadline-monotonic scheduling theory, processes to be scheduled are characterized by the following relation:

Computation time <= deadline <= period

Deadline monotonic priority assignment is similar in concept to rate-monotonic priority assignment. Priorities assigned to processes are inversely proportional to the length of the deadline [62]. Thus, the process with the shortest deadline is assigned the highest priority and the longest deadline process is assigned to lowest priority. This priority assignment defaults to a rate-monotonic assignment when period = deadline.

Deadline monotonic priority assignment is shown to be optimal static priority scheme [62]. The implication of this is that if any static priority scheduling algorithm can schedule a process set where process deadlines are unequal to their periods an algorithm using deadline-monotonic priority ordering for processes will also schedule that process set.

Audsley et al. [7] also showed that since deadline-monotonic scheme guarantees that computation time is less than or equal to deadline, it is possible to schedule sporadic tasks within the existing periodic framework. They also discussed problems involved for guaranteeing deadlines of sporadic processes using sporadic servers within the rate-monotonic scheduling framework.

c. *Related Work*

Lehoczky [14] considers the problem of fixed priority scheduling of periodic tasks *with arbitrary deadlines* and an exact schedulability criterion has been developed. A worst case bound for the case of rate-monotonic scheduling is developed generalizing the original bounds of Liu and Layland in that the tasks are allowed to have deadlines $D = \Delta T$ for any $\Delta > 0$. The bounds show that when one additional period ($\Delta = 2$) is given to tasks to complete their computation requirement, the worst case schedulable utilization increases from 0.693 to 0.811. Also, average schedulable utilization is shown to have increased from 0.88 to over 0.95 that often goes to 1.00.

Audsley et al. [20] have given exact schedulability analysis for real-time systems scheduled at runtime with static priority preemptive scheme. Exact analysis of sporadic tasks is given and analysis extended to include release jitter. Schedulability analysis to predict worst case response times for a set of periodic and sporadic tasks under any given priority assignment and scheduled by a static priority preemptive scheduler can be found in [20].

Lehoczky et al [63] provides an exact characterization and stochastic analysis for a randomly generated set of periodic tasks scheduled by rate-monotonic algorithm.

Shih et al. [65] presents modified rate-monotonic algorithm for scheduling periodic jobs with deferred deadlines. The deadline of the request in any period of a job with deferred deadline is some time instant after the end of the period. The paper describes a semi-static priority-driven algorithm for scheduling periodic jobs with deferred deadlines: each job is assigned two priorities, the higher one of the old request and the lower one for the current request. The optimal schedulability analysis and the applications where the algorithm will be useful are also discussed.

Global Journal of Computer Science and Technology (A) Volume XVII Issue I Version I Year 2017

Predictive periodic and non-periodic algorithms are given by Singh [64]. A predictive preemptive scheduling algorithm avoids unnecessary preemption while a non-preemptive algorithm is predictive in a sense that it looks for future task arrival times and schedules them non-preemptively.

Recent work on scheduling has focussed on scheduling of flexible applications (or imprecise computation). The work in [28,30,38-46,54] provides sufficient material for the interest reader.

d. *Scheduling Non-Periodic Tasks in Fixed Priority Real-Time Systems*

Till now, the focus was only on the scheduling of periodic tasks. In practice, real- time systems comprise of a hybrid of hard periodic jobs and soft/hard aperiodic jobs. The mixed scheduling problem is important, because many real-time systems have substantial aperiodic task workloads.

Aperiodic job and sporadic job scheduling algorithms are solutions to the following problems:

1. Sporadic job scheduler decides whether to accept or reject the newly arrived sporadic job depending on its execution time and the deadline. If it accepts a job, it schedules a job such that all other hard deadline periodic tasks and previously accepted sporadic tasks meet their deadlines. Here the problem lies in determining how to do acceptance test and how to schedule accepted sporadic jobs.
2. Aperiodic job scheduler tries to complete each aperiodic job as early as possible. The problem with this scheduler is to do so without causing other hard periodic and sporadic tasks to miss their deadline. Obviously, average response time is a measure of performance of these schedulers.

Within the framework of fixed priority preemptive scheduling, a number of approaches have been developed for scheduling mixed task sets. The simplest and perhaps least effective of these is background scheduling of aperiodic tasks. In background scheduling, soft deadline tasks are executed at a lower priority than any hard deadlines tasks. Clearly, this method always produces correct schedules and is simple to implement. However, the execution of aperiodic jobs may be delayed and their response times prolonged unnecessarily. An obvious way to make the response times of aperiodic jobs as short as possible is to make their execution interrupt driven.

Whenever an aperiodic job arrives, the execution of periodic tasks is interrupted, and the aperiodic job is executed. However, if aperiodic tasks always execute as fast as possible, periodic tasks may miss some deadlines. Another approach for scheduling aperiodic tasks is to use a periodic task that looks for the ready aperiodic tasks in an aperiodic task queue. Such a periodic task is called as polling server. A polling server has a fixed priority level (usually the highest) and an execution capacity. The capacity of the server is calculated off-line and is normally set to the maximum possible, such that the hard task set, including server, is schedulable. At run-time, the polling server is released periodically and its capacity is used to service soft real-time tasks. Once this capacity has been exhausted, execution is suspended until it can be replenished at the server's next release. The polling server will usually significantly improve the response times of soft tasks over background processing. However, if the ready soft tasks exceed the capacity of the server, then some of them will have to wait until its next release, leading to potentially long response times. Conversely, no soft tasks may be ready when the server is released, wasting its high priority capacity.

This drawback is avoided by the Priority Exchange, Deferrable server [60, 67, 68] and Sporadic servers [61,68] algorithms. These are all based on similar principles to the polling server. However, they are able to preserve capacity if no soft tasks are pending when they are released. Due to this property, they are termed as "bandwidth preserving algorithms". These three algorithms differ in the ways in which the capacity of the server is preserved and replenished and in the schedulability analysis needed to determine their maximum capacity.

In general, all three offer improved responsiveness over the polling approach. However, there are still disadvantages with these more complex server algorithms. They are unable to make use of slack time that may be present due to the often favorable phasing of periodic tasks. Further, they tend to degrade to providing essentially the same performance as the polling server at high loads. The deferrable and sporadic servers are also unable to reclaim spare capacity gained, when for example, hard tasks require less than their worst case execution time. This spare capacity termed gain time, can however be reclaimed by the extended priority exchange algorithm [69].

Chetto [66] and Lehoczky [18] proposed the slack stealing algorithm. This algorithm uses the strategy to make use of the available slack times of periodic and sporadic jobs to complete aperiodic jobs. The slack stealing algorithm suffers from none of the above disadvantages. It is optimal in the sense that it minimizes the response times of soft aperiodic tasks amongst all algorithms that meet all hard periodic task deadlines. The slack stealer services aperiodic

Global Journal of Computer Science and Technology (A) Volume XVII Issue I Version I Year 2017

requests by making any spare processing time available as soon as possible. In doing so, it effectively steals slack from the hard deadline periodic tasks.

In [22], Davis et al. presents new analysis that allows the slack available on hard deadline periodic and hard deadline sporadic tasks to be calculated. The analysis caters for tasks that have release time jitter, synchronization, stochastic execution times and arbitrary deadlines. Further extension to the basic slack stealing work can be found in [21,25].

vii. *Dynamic Priority Scheduling Algorithms: EDF, LST*

Now the turn comes to the study of dynamic scheduling algorithms that we call the deadline driven scheduling algorithm. As said earlier, processor utilization increases by use of the dynamic scheduling schemes. In this section, the dynamic priority assignment scheduling schemes used in the literature is studied.

a. *Earlier- Deadline- First (EDF) Scheduling Algorithm*

Liu and Layland [9], proposed an Earlier-Deadline-First EDF scheduling scheme. Using this algorithm, priorities are assigned to tasks according to the deadlines of their current requests. Specifically, a task will be assigned the highest priority if the deadline of its current request is the nearest, and will be assigned the lowest priority if the deadline of its current request is the furthest. Such a method of assigning priorities to the tasks is a dynamic one, in contrast to a static assignment in which priorities of tasks do not change with time. Schedulability analysis to determine whether a given task set can be scheduled by EDF is given in [9]. An EDF algorithm is optimal for scheduling preemptive jobs on one processor. However, it is non- optimal when jobs are non-preemptive or when there is more than one processor [96].

b. *Least- Slack- Time- First (LST) Scheduling Algorithm*

Another well-known dynamic-priority algorithm is the Least-Slack-Time-First (LST) [48] algorithm. At time t, slack of a job whose remaining execution time is x and whose deadline is d is equal to d - t - x. The LST scheduling algorithm checks the slacks of all the ready jobs each time a new job is released and orders the new job and the existing jobs on the basis of their slacks: the smaller the slack, the higher the priority. Like EDF, LST algorithm is also optimal for scheduling preemptive periodic jobs [95] on one processor but non-optimal for scheduling non-preemptive jobs or multiprocessor scheduling.

c. *Scheduling Non-Periodic Tasks in Dynamic Priority Systems*

As dynamic priority-driven scheduling schemes makes a better processor utilization, many approaches have been reported in the literature that cover the problem of scheduling the soft / hard aperiodic jobs in the dynamic priority-driven framework. Chetto and Chetto [66] studied the localization and duration of idle times and proposed an algorithm for scheduling hard aperiodic tasks. Chetto's algorithm requires that the periodic task deadlines be equal to their periods, and assumes that when any hard aperiodic task arrives and is required to run, all the aperiodic tasks previously accepted have completed their execution. Schwan and Zhou [70] relax the above assumptions and propose a joint algorithm in which every task, whether periodic or aperiodic, is subject to an acceptance test upon arrival.

Work has been carried out for dynamic priority versions of deferrable server, sporadic servers and other bandwidth preserving algorithms, as is found in the fixed priority schemes. Three server mechanisms under EDF have been proposed by Ghazalie and Baker [68]. The authors describe a dynamic version of the known Deferrable and Sporadic servers [61], called Deadline Deferrable server and Deadline Sporadic Server respectively. Then, the later is extended to obtain a simpler algorithm called Deadline Exchange Server. Later, Spuri and Buttazzo [72,73], presented five new online algorithms for servicing soft aperiodic tasks scheduled using EDF. They presented following algorithms:

1. Dynamic Priority Exchange, an extension of previous work under RM.
2. A new bandwidth-preserving algorithm called as Total Bandwidth Server.
3. Earliest-Deadline-Last (EDL) Server.
4. Improved Priority Exchange with less runtime overhead and
5. Dynamic Sporadic Server (DSS) Algorithm.

Spuri et al in [29], extended the Total Bandwidth Sever algorithm to handle hard aperiodic tasks and to deal with overload situations. Total Bandwidth approach was further expanded toward optimality by Buttazzo and Sensini [51,74]. They provided a general method for assigning deadlines to soft aperiodic requests.

Homayoun et al [56] combine the EDF algorithm for scheduling periodic tasks with the deferrable server for servicing aperiodic tasks. An online algorithm for scheduling sporadic tasks with shared resources in hard real-time systems has been presented in [75]. Jeffay [75] describes a method, the Dynamic Deadline Modification (DDM) protocol, for scheduling sporadic tasks with shared resources under the Earliest Deadline First (EDF) scheduling algorithm. Baker [15] proposed a general resource access protocol, the Stack Resource Policy (SRP), which can be used under fixed as well as dynamic priority assignments. Group Priority Earliest Deadline First (GPEDF) performs schedulability test prior to grouping a particular job. In the GPEDF, jobs with short execution time are executed first in the group, which leaves more time for other jobs to execute. This allows more jobs to be completed, the response is reduced. [96].

In [71], Caccomo et al extended the analysis to deal with dynamic deadline modifications, in order to use the tunable Total Bandwidth server [51,74], for improving aperiodic responsiveness in the presence of resource constraints.

Kim et al [76-78], discuss two scheduling algorithms known as Alternative Priority Scheduling (APS) and Critical Task Indication (CTI) algorithms.

Buttazzo [50] proposes a variant of earliest deadline first scheduling algorithm which exploits skips to minimize the response time of aperiodic requests in a firm real-time system.

viii. *Scheduling in Multiprocessor Systems*

a. *Introduction*

Thus far we have seen about the scheduling algorithms without considering the case where the real-time system has more than one processor. A multiprocessor system is classified into the shared-memory and distributed-memory systems. A shared-memory multiprocessor model is a centralized system as the processors are located at a single point in the system and the inter-processor communication cost is negligible compared to the processor execution cost. The distributed-memory multiprocessor model, also known as distributed system, is one in which the processors are distributed at different points in the system and the inter-processor communication cost is not negligible compared to the processor execution cost. A local area network is an example of such system.

Scheduling scheme for multiprocessor systems has to provide solutions for the problems that arise in the multiprocessor environments. Firstly, task assignment is an important problem in multiprocessor systems. Most hard real-time systems built to date are static, that is jobs or tasks are partitioned and statically bound to processors. The task assignment problem is concerned with how to partition the system of tasks and passive resources into modules and how to assign the modules to processors. Second problem is the inter-processor synchronization. Some kind of synchronization protocol is needed to ensure that precedence constraints of jobs on different processors are always satisfied. Finally, in a distributed real-time system, tasks may arrive unevenly at the nodes (processors) in the system and / or processing power may vary from node to node, thus getting some nodes temporarily overloaded while leaving others idle or under-loaded. Many load sharing (LS) algorithms have been proposed in the literature to counter this problem.

Scheduling schemes for multiprocessor system has to take into account the following important factors: memory and resource utilization, deadlock avoidance, precedence constraints, and communication delay. Because of all these complicating factors, the development of appropriate scheduling schemes for multiprocessor real-time systems is problematic, it is known that optimal scheduling for multiprocessor systems is NP hard. It is therefore necessary to look for ways of simplifying the problem and algorithms that give adequate sub-optimal results.

b. *Scheduling Problem Definition for Multiprocessor Systems*

The problem of multiprocessor scheduling is to determine when and on which processor a given task executes. This can be done either statically or dynamically. In static algorithms, the assignment of tasks to processors and the time at which the tasks start execution are determined a priori. Static algorithms [19], [37] are often used to schedule periodic tasks with hard deadlines. The main advantage is that, if a solution is found, then one can be sure that all deadlines will be guaranteed. However, this approach is not applicable to aperiodic tasks whose characteristics are not known a priori. Scheduling such tasks in a multiprocessor real-time system requires dynamic scheduling algorithms. In dynamic scheduling [4], [53], when new tasks arrive, the scheduler dynamically determines the feasibility of scheduling these new tasks without jeopardizing the guarantees that have been provided for the previously scheduled tasks. Thus, for predictable executions, schedulability analysis must be done before a task's execution is begun.

Dynamic scheduling algorithms can be either distributed or centralized. In a distributed dynamic scheduling scheme, tasks arrive independently at each processor. When a task arrives at a processor, the local scheduler at the processor determines whether or not it can satisfy the constraints of the incoming task. The task is accepted if they can be satisfied, otherwise, the local scheduler tries to find another processor which can accept the task. In a centralized scheme, all the tasks arrive at a central processor called the *scheduler*, from where they are distributed to other processors in the system for execution.

Global Journal of Computer Science and Technology (A) Volume XVII Issue I Version I Year 2017

c. *Inter-Processor Synchronization Protocols*

Synchronization protocol is a protocol that governs when the schedulers on different processors release the jobs of sibling subtasks. A synchronization protocol is said to be correct if it (1) never releases jobs in any first subtask before the end-to-end release times of the jobs and (2) never allows the violation of any precedence constraint among sibling subtasks. Four types of synchronization protocols are reported in the literature. Those are Greedy Synchronization Protocol, Phase Modification (PM) Protocol, Modified Phase-Modification (MPM) Protocol and the Release-Guard (RG) Protocol [8,80]. Rajkumar et al [12] extend the priority inheritance protocol for uniprocessors [31] to multiprocessors.

d. *Load Sharing Algorithms*

In load sharing scheme, if a node cannot guarantee a task or some of its existing guarantees are to be violated as a result of inserting a task into its schedule, it has to determine candidate receiving processor(s) for the task(s) to be transferred. Two issues need to be considered when choosing a receiving processor(s).

1. Minimization of the probability of transferring a task to an incapable node.
2. Avoidance of task collisions and / or excessive task transfers, and minimization of the possibility of a task's guarantee being violated due to future tighter-laxity task arrivals.

Most of the work concentrates on *1* and chooses the most desirable receiving processor based on the state information collected from periodic/aperiodic state broadcasts [87,88, 98] or state probing/bidding [89]. Moreover, implied in this work is the assumption of homogeneous workload distribution among nodes. This assumption does not always hold, because the distribution that governs task arrivals at different nodes may vary greatly over time and thus the workload distribution is not homogeneous among the nodes. Therefore both 1 and 2 above should be considered in guaranteeing tasks on a heterogeneous system.

Hou and Shin [81] propose a load-sharing algorithm for real-time applications, which takes into account the future task arrivals.

e. *Fault Tolerant Scheduling*

In many real-time systems, a fault tolerance is an important issue. A system is fault tolerant if it produces correct results even in the presence of faults. When a fault occurs, extra time is required during task execution to handle fault detection and recovery. For real-time systems in particular, it is essential that the extra time be considered and accounted for prior to execution. Methods explicitly developed for fault tolerance in real-time systems must take into consideration the number and type of faults, and ensure that the timing constraints are not violated.

In a multiprocessor system fault tolerance can be provided by scheduling multiple copies of tasks on different processors [81,82] and the high-performance computation power from multiple cores on the platforms [99]. A primary / backup (PB) approach and triple modular redundancy (TMR) approach are two basic approaches that allow multiple copies of task to be scheduled on different processors [83]. One or more of these copies can be run to ensure that the task completes before its deadline. In TMR, multiple copies are usually run to achieve error checking by comparing results after completion. In PB approach, if correct results are generated from the primary task, the backup task is activated. Ghost et al [84] study techniques for providing fault tolerance for non-preemptive, aperiodic, dynamic real-time tasks using the PB approach. Maode et al [85] proposed a strategy called as task reassignment fault tolerance (TRFT) scheduling scheme. The basic idea in [85] is that when a fault appears in the system, it means that a node has no capability to handle tasks and it can not accept other tasks any more. The tasks that have been assigned to it not successfully done should be reassigned to other node which is ready to accept new batch of tasks. Liberto et al [86], focus on global scheduling where tasks can migrate across processors. Two varieties of global multiprocessor scheduling schemes, frame- based scheduling and periodic scheduling, are discussed.

In the frame-based scheduling model, an aperiodic task set is scheduled to create a template (frame), and that schedule may be executed periodically. In the periodic model, each task in the set has a separate period, and is executed with no explicitly predetermined schedule.

f. *Related Work*

Tasks can be statically bounded to a processor i.e. once tasks are allocated to processors; each processor runs the same set of tasks. Each task thus runs on its host processor. Dhall and Liu [79] have shown that the rate monotonic algorithm, which performs well on uniprocessors, behaves poorly for multiprocessor with dynamic binding. They considered the problem of assigning a set of independent periodic tasks to a minimal number of processors. They proposed two heuristic algorithms, called the Rate-monotonic-First-Fit (RMFF) and Rate-Monotonic-Next-Fit (RMNF) algorithms respectively. They showed that in the worst-case, the assignment produced by the RMFF algorithm uses no more than 2.33 times the optimal number of processors, while RMNF uses no more than 2.67

times. Davari and Dhall [90] considered another variation of the heuristic, called First-Fit-Decreasing-Utilization-Factor (FFDUF) algorithm, which improves the worst-case performance to 2 times the optimal number of processors. Davari and Dhall then devised an on-line algorithm, called Next-Fit-M algorithm [91] which has a worst-case performance ratio of 2.2838.

Baruah et al [92,93] devised new dynamic-priority schemes that result in optimal multiprocessor schedulers for hard real-time periodic tasks. Authors [92] proved that any task set whose combined weights is at most m can be scheduled in a pfair manner on m processors, and presented a scheduling algorithm that would achieve this. In [93], they provided a more efficient algorithm.

Kwon et al. proposed an optimal algorithm for parallelizing and scheduling a task set with multiple parallelization options on multiple processor systems [10]. The algorithm presented in [10] is a global strategy while our proposed algorithm is a partitioning strategy.

IV. Summary and Conclusion

Different goals and algorithms characterize process scheduling in real-time operating system. Schedules may or may not exist that satisfy the given timing constraints. In general, the primary goal is to schedule the tasks such that all deadlines are met: in case of success (failure) a secondary goal is maximizing earliness (minimizing tardiness) of task completion. An important issue is predictability of the scheduler, i.e., the level of confidence that the scheduler meets the constraints.

In this section, various scheduling schemes and their schedulability tests have been given. Recent work in process scheduling for multiprocessor and distributed systems is also covered.

The scheduling problem for the design of hardware/software systems is explained in this report. Here it has defined the scheduling in the scenario of embedded systems. Generally speaking, hardware and software scheduling problems differ not just in the formulation but in their overall goals. Nevertheless, some hardware scheduling algorithms are based on techniques used in the software domain, and some recent system-level process scheduling methods have leveraged ideas in hardware sequencing. Scheduling algorithms as applied to design of hardware, compilers, and operating systems were explained in chapters 2, 3 and 4 respectively.

Various process scheduling algorithms have been described. Process Scheduling has to take into account the real-time constraints. Processes are characterized by their timing constraints, periodicity, precedence and data dependency, pre-emptivity, priority etc. The way in which these characteristics affect scheduling decisions has been described.

Broadly, the approaches taken to real-time task scheduling are classified into three categories: clock-driven scheduling, round-robin scheduling and priority-driven scheduling. Priority driven scheduling can be further classified into fixed and dynamic priority scheduling. Also, scheduling schemes are differentiated as preemptive and non-preemptive scheduling scheme. The scheduling algorithms found in the literature target the topic of scheduling the hybrid of real-time periodic and non- periodic (aperiodic and sporadic) tasks with hard or soft deadlines respectively. In literature the work of scheduling covers specific cases of uniprocessor, multiprocessor and distributed systems (with identical or heterogeneous processors).

Clock-driven scheduler schedules the jobs at specific and pre-defined time instants. So, clock-driven scheduling is possible for a system that is by and large deterministic. In round robin scheduling, every process gets its share of the processor (depending on its weight or priority) when there are *n* jobs ready for execution. Round robin scheduling is very simple to implement but is not suitable for the jobs with precedence constraints. Moreover, it may require a very fast processing unit to satisfy timing constraints. Priority-driven scheduling algorithms are mostly used because they never leave any processor idle intentionally and therefore often results into better processor utilization. Priorities to the tasks can be assigned statically or dynamically. Rate Monotonic (RM) and Deadline Monotonic (DM) scheduling schemes are static priority scheduling schemes and Earlier-Deadline-First (EDF) and Least-Slack-Time- First (LST) are the examples of dynamic priority scheduling schemes.

Scheduling scheme for multiprocessor systems has to provide solutions for the problems that arise in multiprocessor environments. The problems that need to be tackled by the multiprocessor scheduling schemes are: task assignment to a processor, Synchronization protocol, load-balancing etc. Also, scheduling scheme for multiprocessor system has to take into account the following important factors: memory and resource utilization, deadlock avoidance, precedence constraints, and communication delay. Because of these conflicting requirements, development of scheduling scheme for multiprocessor system is difficult.

References Références Referencias

1. G.D. Micheli and R.K. Gupta, Hardware/Software Codesign, Proceedings of the IEEE, vol.85, no.3, pp. 349-365, March, 1997
2. D.D. Gajski and F. Vahid, Specification and Design of Embedded Hardware/Software Systems, IEEE

Design and Test of Computers, vol.11, no.3, pp.44-54, 1994
3. F. Balarin, L. Lavango, P. Murthy, and A.S.-Vincentelli, Scheduling for Embedded Real-Time Systems, IEEE Design and Test of Computers, vol.12, no.1, Jan.-March, 1998
4. K. Ramamritham, J. A. Stankovic, P. Shiah, "Efficient scheduling algorithms for real-time multiprocessor systems", COINS Technical Report 89-37, April 13, 1989.
5. O. Plata, F. F. Rivera, "Dynamic Scheduling on Distributed- Memory Multiprocessors", University of Malaga, Technical Report No: UMA-DAC-95/12, June 1995.
6. K. Ramamritham, J. A. Stankovic, "Scheduling algorithms and operating systems support for Real-Time Systems", University of Massachusetts.
7. N. C. Audsley A. Burns M. F. Richardson A. J. Wellings, "Hard Real-Time Scheduling: The Deadline-Monotonic Approach". Proceedings of the 8th IEEE Workshop on Real-time Operating Systems and Software, pp. 127 – 132, 1991.
8. Bettati, R., "End-to-end scheduling to meet deadlines in distributed systems," Ph.D. thesis, Department of Computer Science, University of Illinois at Urbana- Champaign, 1994.
9. Liu and Layland, "Scheduling Algorithms for Multiprogramming in a Hard-Real- Time Environment", 1973.
10. Philip J. Christopher, Apostolos Dollas, "Knowledge Based Process Scheduling on Symmetric Multiprocessors", Proceedings of the IEEE, Nov. 1991.
11. Babak Hamidzadeh, Lau Ying Kit, David J. Lilja, "Dynamic Task Scheduling Using Online Optimization", IEEE Transactions on parallel and distributed systems, vol. 11, no. 11, Nov. 2000.
12. Ragunathan Rajkumar, Lui Sha, John P. Lehoczky, "Real-Time Synchronization Protocols for Multiprocessors", Proceedings of the 1988 Real-Time Systems Symposium, 1988.
13. Kwang S. Hong, Joseph Y-T Leung, "On-line Scheduling of Real-Time Tasks", IEEE Transactions on Computers 41, 1998.
14. John P. Lehoczky, "Fixed Priority Scheduling of Periodic Task Sets with Arbitrary Deadlines", Proceedings of the Real-Time Systems Symposium, pp. 201-209, 1990.
15. T. P. Baker, "A Stack-Based Resource Allocation Policy for Real-Time Processes", Proceedings of IEEE Real-Time Systems Symposium, 1990.
16. Chao-Ju Hou, Kang G. Shin, "Load Sharing with Consideration of Future Task Arrivals in Heterogeneous Distributed Real-Time Systems", IEEE Trans. Computers, 43(9): 1076-90, 1991.
17. Kevin Jeffay, Donald F. Stanat, Charles U. Martel, "On Non-Preemptive Scheduling of Periodic and Sporadic Tasks", Proceedings of the 12th IEEE Symposium on Real-Time Systems, pp. 129-139,1991.
18. John P. Lehoczky, Sandra Ramos-Thuel, "An Optimal Algorithm for Scheduling soft-Aperiodic Tasks in Fixed-Priority Preemptive Systems", Proceedings 13th Real- Time Systems Symposium, pp. 110-123, 1992.
19. K. Ramamritham, "Allocation and Scheduling of Precedence-Related Periodic Tasks," IEEE Trans. Parallel and Distributed Systems, vol. 6, no. 4, pp. 412-420, Apr. 1995.
20. N. Audsley, A. Burns, M. Richardson, K. Tindell, A.J. Wellings, "Applying new scheduling theory to static priority pre-emptive scheduling", Software Engineering Journal, 1993.
21. Sandra Ramos-Thuel, John P. Lehoczky, "On-line Scheduling of Hard Deadline Aperiodic Tasks in Fixed-Priority Systems", Proceedings of 14th Real-Time Systems Symposium, pp. 160-171, 1993.
22. R. I. Davis, K. W. Tindell, A. Burns, "Scheduling Slack Time in Fixed Priority Pre-emptive Systems", Proceedings of Real-Time Systems Symposium, 1993.
23. A. Burns, A. J. Wellings, "Dual Priority Assignment: A Practical Method for Increasing Processor Utilization", Real-Time Systems Symposium, 1993.
24. Jun Sun, Riccardo Bettati, Jane W. S. Liu, "An End-to-End Approach to Schedule Tasks with Shared Resources in Multiprocessor Systems", Proceedings of the 11th IEEE Workshop on Real-Time Operating Systems and Software, 1994.
25. Sandra R. Thuel, John P. Lehoczky, "Algorithm for Scheduling Hard Aperiodic Tasks in Fixed-Priority Systems using Slack Stealing", IEEE Real-Time Systems Symposium, pp. 22-33, IEEE Computer Society Press, 1994.
26. Too-Seng Tia, Jane W. S. Liu, "Task and Resource Assignment in Distributed Real-Time Systems", Parallel and Distributed Real-Time Systems, 1994.
27. Robert Davis, Andy Wellings, "Dual Priority Scheduling", IEEE Real-Time Systems Symposium, 1995.
28. Sanjay K. Baruah, "Fairness in periodic real-time scheduling", Proceedings of 16th Real-Time Systems Symposium, 1995.
29. Marco Spuri, Fiorgio Buttazzo, Fabrizio Sensini, "Robust Aperiodic Scheduling under Dynamic Priority Systems", IEEE Real-Time Systems Symposium, 1995.

30. Haken Aydin, Rami Melhem, Daniel Mosse, Pedro Mejia-Alvarez, “Optimal Reward-Based Scheduling of Periodic Real-Time Tasks”, IEEE Transactions on Computers, Vol. 50. No. 2, Feb. 2001.
31. Sha L., R. Rajkumar, J. P. Lehoczky, “Priority Inheritance Protocols: An Approach to Real-Time Synchronization”, IEEE Transactions on Computer, Vol. 39, No. 9, Sep. 1999.
32. Satoshi Fujita, Hui Zhou, “Multiprocessor Scheduling Problem with Probabilistic Execution Costs”, IEEE 2000.
33. J.M. Lopez, M. Garcia, J.L. Diaz, D.F. Garcia, “Worst-Case Utilization Bound for EDF Scheduling on Real-Time Multiprocessor Systems”, Proceedings of the 12th Euromicro Conference on Real-Time Systems (EUROMICRO-RTS 2000), 2000.
34. Sanjay K. Baruah, “Scheduling Periodic Tasks on Uniform Multiprocessors”, Proceedings of the 12th Euromicro Conference on Real-Time Systems (EUROMICRO- RTS 2000), 2000.
35. Shu-Ling Lee, Chao-Tung Yang, Shian-Shyong Tseng, Chang-Jiun Tsai, “A Cost Effective Scheduling with Load Balancing for Multiprocessor Systems”, IEEE 2000.
36. Babak Hamidzadeh, Yacine Atif, “Dynamic Scheduling of Real-Time Tasks, by Assignment”, IEEE Concurrency 1998.
37. J. Xu and L. Parnas, “Scheduling Processes with Release Times, Deadlines, Precedence, and Exclusion Relations,” IEEE Trans. Software Eng., vol. 16, no. 3, pp. 360-369, Mar. 1990.
38. G. Bernat and A. Burns, ™Combining (n, m) Hard Deadlines and Dual Priority Scheduling, Proc. 18th IEEE Real-Time Systems Symp. pp. 46-57, Dec. 1997.
39. A. Bertossi and L.V. Mancini, ™Scheduling Algorithms for Fault-Tolerance in Hard-Real-Time Systems, Real-Time Systems, vol. 7, no. 3, pp. 229-245, 1994.
40. J. -Y. Chung, J.W.-S. Liu, and K. -J. Lin, ™Scheduling Periodic Jobs that Allow Imprecise Results, IEEE Trans. Computers, vol. 19, no. 9, pp. 1156-1173, Sept. 1990.
41. W. Feng and J.W.-S. Liu, ™Algorithms for Scheduling Real-Time Tasks with Input Error and End-to-End Deadlines, IEEE Trans. Software Eng., vol. 23, no. 2, pp. 93-106, Feb. 1997.
42. M. Hamdaoui and P. Ramanathan, ™A Dynamic Priority Assignment Technique for Streams with (m, k)-Firm Deadlines, IEEE Trans. Computers, vol. 44, no. 12, pp. 1443-1451, Dec. 1995.
43. J.K. Dey, J. Kurose, D. Towsley, C.M. Krishna, and M. Girkar, ™Efficient on- line Processor Scheduling for a Class of IRIS Increasing Reward with Increasing Service) Real-Time Tasks, Proc. ACM SIGMETRICS Conf. Measurement and Modeling of Computer Systems, pp. 217-228, May 1993.
44. K. -J. Lin, S. Natarajan, and J.W.-S. Liu, ™Imprecise Results: Utilizing Partial Computations in Real-Time Systems, Proc. Eighth IEEE Real-Time Systems Symp. pp. 210-217, Dec. 1987.
45. J.W.-S. Liu, K. -J. Lin, W. -K. Shih, A.C.-S. Yu, C. Chung, J. Yao, and W. Zhao, ™Algorithms for Scheduling Imprecise Computations, Computer, vol. 24, no. 5, pp. 58-68, May 1991.
46. W. -K. Shih, J.W.-S. Liu, and J. -Y. Chung, ™Algorithms for Scheduling Imprecise Computations with Timing Constraints, SIAM J. Computing, vol. 20, no. 3, pp. 537-552, July 1991.
47. Sha L., J. B. Goodenough, “Real-Time Scheduling Theory and Ada”, IEEE Computer, 1990.
48. Mok, A. K., “Fundamental Design Problems of Distributed Systems for the Hard Real-Time Environment”, Ph.D. Thesis, MIT, 1983.
49. Chen, M.I., and K. J. Lin, “Dynamic priority ceiling: A concurrency control protocol for real-time systems”, Real-Time System Journal, vol 2, no. 4, pp. 325-346, Dec. 1990.
50. Giorgio C. Buttazzo “Minimizing Aperiodic Response Times in a Firm Real-Time Environment”, IEEE Transactions On Software Engineering, Vol. 25, No. 1, January/February 1999
51. Giorgio C. Buttazzo, F. Sensini, “Optimal Deadline Assignment for Scheduling Soft Aperiodic Tasks in Hard Real-Time Environment”, Proceedings of 3rd IEEE Conference on Engineering of Complex Computer Systems (ICECCS'97), pp. 39-48, 1997.
52. M.L. Dertouzos and A.K. Mok, “Multiprocessor On-Line Scheduling of Hard Real-Time Tasks,” IEEE Trans. Software Eng., vol. 15, no. 12, pp. 1,497-1,506, Dec. 1989.
53. M. Silly-Chetto, “Dynamic Acceptance of Aperiodic Tasks with Periodic Tasks Under Resource Sharing Constraints”, IEEE Proc. On Software Engg. , Vol 146, No. 2, Apr. 1999.
54. Dey, J. K., J. Kurose, and D. Towsley, “On-line scheduling policies for a class of IRIS (Increasing Reward with Increasing Service) real-time tasks,” IEEE Transactions on Computers, vol. 45, no.7, July 1996.
55. Gutierrez, J. C. P., J. J. G. Garcia, and M. G. Harbour, “On the schedulability analysis for distributed hard real-time systems,” Proceedings of Euromicro Workshop on Real-Time Systems, pp. 136–143, June 1997.
56. Homayoun, N., and P. Ramanathan, “Dynamic priority scheduling of periodic and aperiodic tasks

in hard real-time systems," Real-Time Systems Journal, vol 6, no. 2, pp. 207–232, 1994.
57. Audsley N. C., "Optimal priority assignment and feasibility of static priority tasks with arbitrary start times", Report YCS 164, Dept. of Comp. Sci., University of York, Dec. 91.
58. Rajkumar R, "Real-Time Synchronization Protocols for Shared Memory Multiprocessors", IEEE Proc. on Dist. Computing systems, Jun 1990.
59. Joseph M. and Pandya P., "Finding response times in a real-time systems", Computing Journal, 1986.
60. Lehoczky J. P., Sha L., stronides J. K., "Enhancing aperiodic responsiveness in hard real-time environment", IEEE Proc. Real-Time systems Symp. Dec 1987.
61. Sprunt, B, L. Sha, and J. P. Lehoczky, "Aperiodic task scheduling for hard real- time systems," Real-Time Systems Journal, vol 1, no. 1, pp. 27–60, 1989.
62. Leung, J. Y. T., and J. Whitehead, 'On the complexity of fixed-priority scheduling of periodic real-time tasks," Performance Evaluation, vol. 2, pp. 37–250, 1982.
63. Lehoczky J. P., Sha L., Ding Y., "The Rate Monotonic Scheduling Algorithm: Exact Characterization and Average Case Behavior", Proceedings of the 10th IEEE Symposium on Real-Time Systems, pp. 166-171, 1989.
64. Singh H., "Scheduling Techniques for Real-Time Application Consisting of Periodic Task Sets", IEEE 1994.
65. Shih W. K., Liu J. W. S., Liu C. L., "Modified Rate-Monotonic Algorithm for Scheduling Periodic Jobs with Deferred Deadlines", IEEE Transactions on Software Engineering, Vol 19, No. 12, Dec 1993.
66. Chetto, H., and M. Chetto, "Some results of the earliest deadline scheduling algorithm," IEEE Transactions on Software Engineering, vol. 15, no. 10, pp. 1261–1269, October 1989.
67. Strosnider, Lehoczky, and L.Sha, "The deferrable server algorithm for enhanced aperiodic responsiveness in hard real-time environments," IEEE Transactions on Computers, vol 44, issue 1, Jan 1995.
68. Ghazalie, T. M., and T. P. Baker, "Aperiodic servers in deadline scheduling environment," Real-Time Systems Journal, vol. 9, no. 1, pp. 31–68, 1995.
69. Sprunt B, Lehoczky J. P. and Sha L., "Exploiting Unused Periodic Time for Aperiodic Service Using the Extended Priority Exchange Algorithm", Proceedings IEEE Real-Time Systems Symposium, Dec 1988.
70. K. Schawan and H. Zhou, "Dynamic Scheduling of Hard Real-Time Tasks and Real-Time Threads," IEEE Trans. Software Eng., vol. 18, pp. 736-747, Aug. 1992.
71. Caccamo M., Lipari G., Buttazzo G., "Sharing Resources among Periodic and Aperiodic Tasks with Dynamic Deadlines", Proceedings of the 20th IEEE Real-Time Systems Symposium.
72. M. Spuri, and G.C. Buttazzo, "Efficient Aperiodic Service under Earliest Deadline Scheduling", Proc. IEEE Real-Time Systems Symp. 1994.
73. M. Spuri, and G.C. Buttazzo, "Scheduling Aperiodic Tasks in Dynamic Priority Systems", Journal on Real-Time Systems, vol 10, no. 2, 1996.
74. Buttazzo, G.C.; Sensini, F., "Optimal deadline assignment for scheduling soft aperiodic tasks in hard real-time environments", IEEE Transactions on, Volume: 48 Issue: 10 , Oct. 1999, Page(s): 1035 –1052
75. Jeffay K., "Scheduling sporadic tasks with shared resources in hard real-time systems", Proceedings of the 13th IEEE Real-Time Systems Symposium, Phoenix, AZ, December 1992, pp. 89-99.
76. Kim H. I., Lee S. Y., Lee J.W., "A soft Aperiodic Task Scheduling Algorithm in Dynamic Priority Systems", Proceedings of the 2nd International Workshop on Real- Time Computing Systems and Applications, 1995.
77. Kim H. I., Lee S. Y., Lee J. W., "Scheduling of hard Aperiodic Requests in Dynamic Priority Systems", IEEE 1995.
78. Kim H. I., Lee S. Y., Lee J. W., "Alternative Priority Scheduling in Dynamic Priority Systems", Proceedings of the 2nd IEEE International Conference on Engineering of Complex Computer Systems (ICECCS'96), 1996.
79. Dhall S. K., Liu C. L., "On a Real-Time Scheduling Problem", Operations Research, vol 26. no. 1, 1978.
80. Sun J, Liu J., "Synchronization Protocols in Distributed Real-Time Systems", 16th International Conference on Distributed Computing Systems, 1996.
81. Liestman A. L., Campbell R. H. 'A Fault-Tolerant Scheduling Problem", IEEE Trans. Software Engg. vol 12, no 11, 1988.
82. Oh Y., Son S., "Multiprocessor Support for Real-Time Fault Tolerant Scheduling", Proc. IEEE 1991 Workshop Architectural Aspects of Real-Time Systems, 1991.
83. Pradhan D. K., "Fault-Tolerant Computing: Theory and Techniques", Englewood Cliffs, N.J: Prentice Hall, 1986.
84. Ghosh S., Melhem R., Mosse D., "Fault-Tolerance Through Scheduling of Aperiodic

Tasks on Hard Real-Time Multiprocessor Systems", IEEE Trans. On Parallel and Distributed Systems, vol. 8, no. 3, 1997.

85. Maode M., Babak H., "A Fault-tolerant Strategy for Real-Time Task Scheduling on Multiprocessor System", Proceedings of the 1996 International Symposium on Parallel Architectures, Algorithms and Networks (ISPAN '96), 1996.
86. Liberto F., Lauzac S., Melhem R., Mosse D., "Fault Tolerant Real-Time Global Scheduling on Multiprocessors", IEEE Proceedings of the 11th Euromicro Conference on Real-Time Systems, 1999.
87. Shin K. G., Hou C. -J., "Design and evaluation of effective load sharing in distributed real-time systems", Proc. IEEE Symp. On Parallel and Distributed Processing, 1991.
88. Shin K. G., Chang Y. -C., "Load Sharing in distributed real-time systems with state change broadcasts", IEEE Trans. On Computers, vol C-38, no. 8, 1989.
89. Eager D. L., Lazowska E. D., Zahorjan J., "Adaptive load sharing in homogeneous distributed systems", IEEE Trans. On Software Engineering, vol. SE-12, no. 5, 1986.
90. Davari S., Dhall S., "On a Real-Time Task Allocation Problem", Proc. of 19th Annual International Conference on System Sciences, 1986
91. S. Davari and S.K. Dhall, An On Line Algorithm for Real-Time Tasks Allocation, IEEE Real-Time Systems Symposium, 1986
92. S.K. Baruah, N.K. Cohen, C.G. Plaxton, D.A. Varvel, "Proportionate Progress: A Notion of Fairness in Resource Allocation", ACM Symposium on Theory of Computing, 1994.
93. S. Baruah, J. Gehrke, and C. G. Plaxton. "Fast scheduling of periodic tasks on multiple resources", Proceedings of the 9th International Parallel Processing Symposium, pages 280-288, April 1995.
94. Ghosh S., Melhem R., Mosse D., "Fault-Tolerant Scheduling on a Hard Real- Time Multiprocessor System", International Parallel Processing Symp., 1994.
95. W. Li, K. Kavi, and R. Akl, "A non-preemptive scheduling algorithm for soft real-time systems", Computers and Electrical Engineering, vol.33, no. 1, pp. 12–29, 2007.
96. Li, Q. & Ba, W, "A group priority earliest deadline first scheduling algorithm", Frontiers of Computer Science October 2012, Volume 6, Issue 5, pp 560–567
97. Arshjot Kaur, Supriya Kinger, International Journal of Computer Science and Information Technologies, Vol. 5 (4) , 2014, 4886-4890
98. J. Kwon, K.-W. Kim, S. Paik, J. Lee, and C.-G. Lee. Multicore scheduling of parallel real-time tasks with multiple parallelization options. In IEEE 21st Real-Time and Embedded Technology and Applications Symposium (RTAS), pages 232–244, April 2015.
99. L. Zeng, P. Huang, and L. Thiele. Towards the design of fault-tolerant mixed-criticality systems on multicores. In Proceedings of the International Conference on Compilers, Architectures and Synthesis for Embedded Systems, CASES '16, ACM. pages 6:1–6:10, New York, NY, USA, 2016.
100. G. Dhiman, K. K. Pusukuri and T. Rosing, "Analysis of Dynamic voltage scaling for system level energy management," in Proc. UNISEX Workshop Power Aware Comput. Syst, 2008.
101. S. Yue, D. Zhu, Y. Wang and M. Pedram, "Reinforcement Learning Based Dynamic Power Management with a Hybrid Power Supply," Computer Design (ICCD), 2012 IEEE 30th International Conference, pp. 81-86, 2012.
102. U. khan and B. Rinner, "A reinforcement learning framework for dynamic power management of a portable, multi-camera traffic monitoring system," in Green Computing and Communications (GreenCom), IEEE, 2012, pp. 557-564.
103. M. Trikil, A. C. Ammari, Y. Wang and M. Pedram, "Reinforcement Learning-Based Dynamic Power Management of a Battery-Powered System Supplying Multiple Active Modes.," European Modelling Symposium (EMS),, pp. 437-442, 2013.
104. M. Triki, Y. Wang, A. Ammari and M. Pedram, "Hierarchical power management of a system with autonomously power-managed components using reinforcement learning.," Elsevier, 2015.

Global Journal of Computer Science and Technology: A
Hardware & Computation
Volume 17 Issue 1 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Encrypted Color Image Transmission in LDPC Encoded MIMO Wireless Communication System with implementation of MP-WFRFT based Physical Layer Security Scheme

By Laila Naznin, Mohammad Reaz Hossain & Shaikh Enayet Ullah

Rajshahi University

Abstract- This paper emphasizes on comprehensive study for the performance evaluation of LDPC encoded MIMO wireless communication system under implementation of MP-WFRFT based physical layer security scheme. The 4 ×4 multi antenna configured simulated system under investigation incorporates LDPC channel coding scheme and various types of modulation (QPSK, DQPSK, and 4-QAM) and signal detection (ZF, MMSE, ZF-SIC and MMSE-SIC) techniques. On considering transmission of encrypted color image in a hostile fading channel, it is noticeable from MATLAB based simulation study that the LDPC channel encoded system is very much robust and effective in retrieving color image under utilization of MMSE-SIC signal detection and 4-QAM digital modulation techniques.

Keywords: 4-weighted fractional fourier transform, MIMO, LDPC, SNR.

GJCST-A Classification: *C.2.1, E.3*

ENCRYPTEDCOLORIMAGETRANSMISSIONINLDPCENCODEDMIMOWIRELESSCOMMUNICATIONSYSTEMWITHIMPLEMENTATIONOFMPWFRFTBASED

Strictly as per the compliance and regulations of:

Encrypted Color Image Transmission in LDPC Encoded MIMO Wireless Communication System with implementation of MP-WFRFT based Physical Layer Security Scheme

Laila Naznin[α], Mohammad Reaz Hossain[σ] & Shaikh Enayet Ullah[ρ]

Abstract- This paper emphasizes on comprehensive study for the performance evaluation of LDPC encoded MIMO wireless communication system under implementation of MP-WFRFT based physical layer security scheme. The 4 ×4 multi antenna configured simulated system under investigation incorporates LDPC channel coding scheme and various types of modulation (QPSK, DQPSK, and 4-QAM) and signal detection (ZF, MMSE, ZF-SIC and MMSE-SIC) techniques. On considering transmission of encrypted color image in a hostile fading channel, it is noticeable from MATLAB based simulation study that the LDPC channel encoded system is very much robust and effective in retrieving color image under utilization of MMSE-SIC signal detection and 4-QAM digital modulation techniques.

Keywords: 4-weighted fractional fourier transform, MIMO, LDPC, SNR.

I. Introduction

In perspective of fulfillment of ever-increasing demand for authenticated, confidential and secret data transmission in presence of malicious eavesdroppers over existing and future generation wireless networks, a considerable amount of research is being going on physical layer security which offers an information-theoretic level of secrecy with implementation of various improved cryptographic algorithms under exploitation of important characteristics of wireless channel such as fading, interference and noise. During the past two decades, Multiple-input multiple-output (MIMO) wireless systems have been studied extensively with quantification of their potential gains in throughput, diversity and range. In MIMO linked based 4G wireless networks, cryptographic algorithms are used to maintain physical layer security. With proper designed of powerful error-correction codes called low-density parity-check (LDPC) codes, a high level of data security can be provided at the physical layer[1].The WWWW(Wireless World Wide Web) supportable 5G network has not yet been deployed commercially and its physical layer radio interface technology (RAT) has not been standardized. The Mobile Internet and IoT (Internet of Things) have been considered as two main market drivers for 5G and will be used massively in augmented reality, virtual reality, remote computing, eHealth services, automotive driving etc. In 5G/future generation wireless network, massive MIMO antenna arrays with beamforming techniques would hopefully be implemented with consideration of physical layer security[2,3]. In 2010, Mei and et.al., proposed an approach to carrier scheme convergence based on 4-WFRFT. With utilization of such proposed technique, the authors demanded that communication facilities was capable of switching between multi-carrier (MC) ,OFDM and single-carrier (SC) system with simple parameters controlling and improving the distortion resistance capability of the communication system[4]. In 2016, Xiaojie and et.al., proposed a multiple parameters weighted fractional Fourier transform (MPWFRFT) and constellation scrambling (CS) method based physical layer (PHY) security system executed in two steps. In the first step of such proposed scheme, MPWFRFT was implemented as the constellation beguiling (CB) method to change signal's identity. In the second step, the additional pseudo random phase information regarded as the encryption key was attached to the original signal to enhance the security. The authors mentioned that their proposed physical layer (PHY) security scheme was capable of preventing the exchanging signals from eavesdropper's classification and inception.[5]. In 2017, Chen and et.al. proposed a novel user cooperation scheme based on weighted fractional Fourier transform (WFRFT), to enhance the physical (PHY) layer security of wireless transmissions against eavesdropping. The authors mentioned that the proposed security scheme was capable of creating an identical artificial noise to eavesdroppers and providing information bearing signal to the legitimate receiver. They also demanded that their proposed WFRFT-based user cooperation scheme could achieve significant performance advantage in terms of secrecy ergodic capacity, compared with conventional PHY-layer security oriented user

Author α σ: Assistant Professor, Department of Information and Communication Engineering, University of Rajshahi, Rajshahi-6205, Bangladesh. e-mails: lipy.naznin.ice.ru@gmail.com, mrh.ice.ru@gmail.com
Author ρ: Professor, Department of Information and Communication Engineering, University of Rajshahi, Rajshahi-6205, Bangladesh. e-mail: enayet_apee@ru.ac.bd

cooperation schemes such as relay-jamming and cluster-beamforming[6]. In this paper, we have presented information on suitability of signal detection scheme in performance evaluation of 4-WFRFT based physical layer security scheme implemented channel encoded system under consideration of color image transmission.

II. Signal Processing Techniques

In our present study various signal processing schemes have been used. A brief overview of these schemes is given below with special emphasis on Four - Weighted Fractional Fourier Transform (4-WFRFT) physical layer security scheme:

a) Four -Weighted Fractional Fourier Transform (4-WFRFT)

We assume that the binary data extracted from color image are channel coded and interleaved and subsequently digitally modulated using 4-QAM, QPSK and DQPSK mapping constellation. The complex digitally modulated symbols are rearranged block wise with each block containing 1024(L=1024) symbols. Under scenario of block wise signal processing, the 4-Weighted Fractional Fourier Transform (4-WFRFT) of a digitally modulated complex sequence

$X_0(n)$ (n=0,1,2,3……………L-1) is defined as:

$$\begin{aligned} S_0(n) &= F^{\alpha, m_k, n_k}[X_0(n)] \\ &= w_0(\alpha, m_k, n_k)X_0(n) + w_1.(\alpha, m_k, n_k)X_1(n) \\ &+ w_2(\alpha, m_k, n_k)X_2(n) + w_3.(\alpha, m_k, n_k)X_3(n) \\ &= w_0 X_0(n) + w_1.\frac{1}{\sqrt{L}}\sum_{l=0}^{l=L-1} X_0(l)e^{-j\frac{2\pi}{L}ln} \\ &+ w_2 X_0(-n) + w_3.\frac{1}{\sqrt{L}}\sum_{l=0}^{l=L-1} X_0(l)e^{-j\frac{2\pi}{L}ln} \end{aligned} \tag{1}$$

where, k= 0, 1, 2, 3 ; {$X_0(n)$, $X_1(n)$, $X_2(n)$, $X_3(n)$} are the 0~3 times normalized DFT of $X_0(n)$ separately and the weighting coefficients w_p(p =0, 1, 2, 3) are defined by[7]

$$w_p = \frac{1}{4}\sum_{k=0}^{k=3} \exp\{\pm\frac{2\pi j}{4}[(4m_k+1)\alpha(k+4n_k)-pk]\} \quad (p=0,1,2,3) \tag{2}$$

b) LDPC Channel Coding

The low-density parity-check (LDPC) code has been considered as one of the useful modern channel codes. It was invented as early as 1962 by Gallager. It is a linear block code whose parity-check matrix H_{parity} contains only a few 1's in comparison to 0's (i.e., sparse matrix). In our study, we have used linear block code with coding rate ½ defined by 64× 128 sized parity-check matrix H_{parity}. The LDPC code can be represented by the bilateral Tanner graph containing two kinds of nodes(bit nodes or variable nodes are associated with a column and check nodes or parity nodes are associated with a row of the parity-check matrix H_{parity}. In case of merely any elemental value of the H_{parity} matrix is of 1, a parity node will be connected to a bit node[8].In each LDPC channel encoded 1×128 matrix sized codeword c, the first 64 bits of the codeword matrix are the parity bits and the last 64 bits are the information bits. The LDPC decoding adopts an iterative approach and operates alternatively on the bit nodes and the check nodes to find the most likely codeword c that satisfies the condition cH^T_{parity}=0. In iterative Log Domain Sum-Product LDPC decoding, various steps are followed with estimation of various parameters. Primarily, the 128×1 sized received bit sequence $rx_{i,\ i=1,2,3………………128}$ are converted from (0/1) format into (-1/1) format and passed through AWGN channel of noise variance of N0. The log-likelihood ratio (LLR) of transmitted codeward c=[$c_1c_2c_3c_4$…….c_{128}] is given by

$$Lc_i = -4rx_i/N0 \tag{3}$$

Taking transposed form of Equation (3) and considering all its sampled values and inserting in each of 64 rows, a 64× 128 sized [LCI] matrix is formed. As the Lqij are considered to be the messages sent from bit nodes i to check nodes j, initially, 64× 128 sized [LQIJ] matrix is formed from the element wise product of two matrices [H_{parity}] and[LCI] as:

$$[LQIJ] = [H_{parity}] \odot [LCI] \tag{4}$$

From matrix [LQIJ], α_{ij} and β_{ij} are estimated using the following relation:

$$\alpha_{ij} \triangleq \text{sign}[LQIJ] \quad \beta_{ij} \triangleq |LQIJ|$$

Initially, a 64× 128 sized [LRJI] matrix is considered as null matrix. In horizontal stepping for finding non zero in the column of H_{parity} matrix, the Pibetaij parameter values at the position(r,l) are estimated using the relation:

$$\text{Pibetaij}(r,l) = \ln[(\exp(\beta_{ij}(r,l)+1)/[(\exp(\beta_{ij}(r,l)-1)] \tag{5}$$

At each position of non zero element, new values Pibetaij(i,c1) are estimated from the summation of all column wise Pibetaij values- previous Pibetaij value at that position where, i=1,2, …….64, c1 is the non zero elemental position in the column for a row identified by i. With estimated values of Pibetaij(i,c1), PiSum(i,c1) are estimated as:

$$\text{PiSum}(i,c1) = \ln[(\exp(\text{Pibetaij}(i,c1)+1)/[(\exp(\text{Pibetaij}(i,c1)-1)] \tag{6}$$

Similarly, another parameter prodOf(i,c1) values are estimated from the product of all column wise multiplied α_{ij} values with α_{ij} value at that position. The previously considered [LRJI] matrix is upgraded through inserting the parameter Lrji(i,c1) values as:

$$\text{Lrji}(i,c1) = \text{prodOf}(i,c1) * \text{PiSum}(i,c1) \tag{7}$$

In vertical stepping for finding non zero in the row of H_{parity} matrix, the Lqij parameter values at the position (r1,j) are updated using the relation:

$$\text{Lqij(r1,j)} = Lc_i + \text{sum(Lrji(r1,j))} - \text{Lrji(r1,j)} \tag{8}$$

where, i=1,2………128, j=1,2………128

Finally, a new parameter value is estimated as:

$$LQi = Lc_i + \text{sum(Lrji(r1, j))} \tag{9}$$

If LQi is less than zero, the transmitted bit is 1, otherwise the transmitted bit is 0. The above mentioned steps in iterative Log Domain Sum-Product LDPC decoding algorithm have been executed in MATLAB source codes available in the website at[9]. Generation of different sized parity-check matrix and estimation of parity bits corresponding to information bits have also been presented in the cited website.

c) Signal detection scheme

In our 4 x 4 simulated LDPC encoded MIMO wireless communication system, the transmitted and received signals are represented by $x=[x_1, x_2, x_3, x_4]^T$ and $y=[y_1, y_2, y_3, y_4]^T$ respectively. If $n= [n_1, n_2, n_3, n_4]^T$ denotes the white Gaussian noise with a variance $\boldsymbol{\sigma_n}^2$ and the channel matrix is represented by H=[h_1 h_2 h_3 h_4], we can write

$$\mathbf{y} = \mathbf{H}\mathbf{x} + n = \mathbf{h}_1 x_1 + \mathbf{h}_2 x_2 + \mathbf{h}_3 x_3 + \mathbf{h}_4 x_4 \tag{10}$$

As the interference signals from other transmitting antennas are minimized to detect the desired signal, the detected desired signal from the transmitting antenna with inverting channel effect by a weight matrix W is given by

$$\tilde{x} = [\tilde{x}_1, \tilde{x}_2, \tilde{x}_3, \tilde{x}_4]^T = Wy \tag{11}$$

In Minimum mean square error (MMSE) scheme, the MMSE weight matrix is given by

$$W_{MMSE} = (H^H H + \sigma_n{}^2 I)^{-1} H^H \tag{12}$$

and the detected desired signal from the transmitting antenna is given by

$$\tilde{x}_{MMSE} = W_{MMSE}\, y \tag{13}$$

In Zero-Forcing (ZF) scheme, the ZF weight matrix is given by

$$W_{ZF} = (H^H H)^{-1} H^H \tag{14}$$

and the detected desired signal from the transmitting antenna is given by

$$\tilde{x}_{ZF} = W_{ZF}\, y \tag{15}$$

In MMSE-SIC based signal detection scheme, the received signal, channel matrix and noise are extended as

$$\overleftrightarrow{\mathbf{H}}_{ex} = \left[\overleftrightarrow{\mathbf{H}}^T \sqrt{\frac{\boldsymbol{\sigma}^2{}_n}{\boldsymbol{\sigma}^2{}_s}}\mathbf{I} \right]^T, \; \mathbf{Y}_{ex} = \left[\mathbf{Y}^T \quad \mathbf{0}^T \right] \text{ and}$$

$$\mathbf{N}_{ex} = \left[\mathbf{N}^T - \sqrt{\frac{\boldsymbol{\sigma}^2{}_n}{\boldsymbol{\sigma}^2{}_s}}\mathbf{X}^T \right]^T \tag{16}$$

Where, $\frac{\sigma^2{}_n}{\sigma^2{}_s}$ is the ratio of average receive noise power to average receive signal power.

The signal model in terms of transmitted and received signals, noise and channel coefficients can be written as

$$Y_{ex} = \overleftrightarrow{H}_{ex} X + N_{ex} \tag{17}$$

On QR factorization of 8 × 4 sized extended channel matrix $\overleftrightarrow{\mathrm{H}}_{ex}$, we get

$$\overleftrightarrow{H}_{ex} = \overleftrightarrow{Q}_{ex} . \overleftrightarrow{R}_{ex} \tag{18}$$

where, $\overleftrightarrow{\mathrm{Q}}_{ex}$. and $\overleftrightarrow{\mathrm{R}}_{ex}$ represent 8 × 8 sized unitary matrix and 8 × 4 sized upper triangular matrix respectively. Substituting the values of $\overleftrightarrow{\mathrm{H}}_{ex}$ in Equation (17) and multiplying with $\overleftrightarrow{\mathrm{Q}}^H_{ex}$, we get

$$\overleftrightarrow{Y}_{ex} = \overleftrightarrow{R}_{ex} . X + \overleftrightarrow{Q}^H_{ex} . N_{ex} \tag{19}$$

Equation(19) can be rewritten with neglecting $\mathrm{Q}^H_{ex} . \mathrm{N}_{ex}$ term as:

$$\overleftrightarrow{Y}_{ex} = \begin{bmatrix} \overleftrightarrow{\mathbf{Y}}_{ex1} \\ \overleftrightarrow{\mathbf{Y}}_{ex2} \\ \overleftrightarrow{\mathbf{Y}}_{ex3} \\ \overleftrightarrow{\mathbf{Y}}_{ex4} \\ \overleftrightarrow{\mathbf{Y}}_{ex5} \\ \overleftrightarrow{\mathbf{Y}}_{ex6} \\ \overleftrightarrow{\mathbf{Y}}_{ex7} \\ \overleftrightarrow{\mathbf{Y}}_{ex8} \end{bmatrix} = \begin{bmatrix} \overleftrightarrow{\mathbf{R}}_{ex}(1,1) & \overleftrightarrow{\mathbf{R}}_{ex}(1,2) & \overleftrightarrow{\mathbf{R}}_{ex}(1,3) & \overleftrightarrow{\mathbf{R}}_{ex}(1,4) \\ 0 & \overleftrightarrow{\mathbf{R}}_{ex}(2,2) & \overleftrightarrow{\mathbf{R}}_{ex}(2,3) & \overleftrightarrow{\mathbf{R}}_{ex}(2,4) \\ 0 & 0 & \overleftrightarrow{\mathbf{R}}_{ex}(3,3) & \overleftrightarrow{\mathbf{R}}_{ex}(3,4)) \\ 0 & 0 & 0 & \overleftrightarrow{\mathbf{R}}_{ex}(4,4) \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \overleftrightarrow{\mathbf{X}}_1 \\ \overleftrightarrow{\mathbf{X}}_2 \\ \overleftrightarrow{\mathbf{X}}_3 \\ \overleftrightarrow{\mathbf{X}}_4 \end{bmatrix} \tag{20}$$

From Equation (20), the primarily estimated detected signal $\overleftrightarrow{X}$ from the four transmitting antennas can written as:

Global Journal of Computer Science and Technology (A) Volume XVII Issue I Version I Year 2017

$$\ddot{X}_4 = \frac{\ddot{Y}_{ex4}}{\ddot{R}_{ex}(4,4)}$$
$$\ddot{X}_3 = \frac{(\ddot{Y}_{ex3} - \ddot{R}_{ex}(3,4)\ddot{X}_4)}{\ddot{R}_{ex}(3,3)}$$
$$\ddot{X}_2 = \frac{(\ddot{Y}_{ex2} - \ddot{R}_{ex}(2,3)\ddot{X}_3 - \ddot{R}_{ex}(2,4)\ddot{X}_4)}{\ddot{R}_{ex}(2,2)} \tag{21}$$
$$\ddot{X}_1 = \frac{(\ddot{Y}_{ex1} - \ddot{R}_{ex}(1,2)\ddot{X}_2 - \ddot{R}_{ex}(1,3)\ddot{X}_3 - \ddot{R}_{ex}(1,4)\ddot{X}_4)}{\ddot{R}_{ex}(1,1)}$$

With ML decoding, the digitally modulated detected signals can be written using the following relation,:

$$\ddot{\vec{x}}_m = \arg\min_{\hat{x}^{(k)} \in \vec{x}} \left|\hat{x}^{(k)} - \ddot{x}_m\right|^2 \tag{22}$$

where, $\vec{X}$ is the digitally modulated complex symbols.

In ZF-SIC channel equalization scheme, the channel matrix H undergoes QR factorization as

$$H = QR = Q\begin{bmatrix} R_{1,1} & R_{1,2} & R_{1,3} & R_{1,4} \\ 0 & R_{2,2} & R_{2,3} & R_{2,4} \\ 0 & 0 & R_{3,3} & R_{3,4} \\ 0 & 0 & 0 & R_{3,4} \end{bmatrix} \tag{23}$$

where, Q and R are the unitary and upper triangular matrix respectively. Equation (10) can be rewritten on multiplying by Q^H as

$$\bar{y} = Q^H y = Rx + Q^H n \tag{24}$$

where, $Q^H N$ is a zero-mean complex Gaussian random vector. Since $Q^H n$ and n have the same statistical properties, $Q^H n$ can be used to denote **n**. We get Equation (24) as

$$\bar{y} = Rx + n$$

$$\Downarrow$$

$$\begin{bmatrix} \bar{\mathbf{y}}_1 \\ \bar{\mathbf{y}}_2 \\ \bar{\mathbf{y}}_3 \\ \bar{\mathbf{y}}_4 \end{bmatrix} = \begin{bmatrix} \mathbf{r}_{1,1} & \mathbf{r}_{1,2} & \mathbf{r}_{1,3} & \mathbf{r}_{1,4} \\ \mathbf{0} & \mathbf{r}_{2,2} & \mathbf{r}_{2,3} & \mathbf{r}_{2,4} \\ \mathbf{0} & \mathbf{0} & \mathbf{r}_{3,3} & \mathbf{r}_{3,4} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{r}_{4,4} \end{bmatrix} \begin{bmatrix} \tilde{\mathbf{x}}_1 \\ \tilde{\mathbf{x}}_2 \\ \tilde{\mathbf{x}}_3 \\ \tilde{\mathbf{x}}_4 \end{bmatrix} + \begin{bmatrix} \mathbf{n}_1 \\ \mathbf{n}_2 \\ \mathbf{n}_3 \\ \mathbf{n}_4 \end{bmatrix} \tag{25}$$

the primarily estimated detected signal $\tilde{X}$ from the four transmitting antennas can written on neglecting noise term from Equation (25) as

$$\tilde{\mathbf{x}}_4 = \frac{\bar{\mathbf{y}}_4}{\mathbf{r}_{4,4}}$$
$$\tilde{\mathbf{x}}_3 = \frac{(\bar{\mathbf{y}}_3 - \mathbf{r}_{3,4}\tilde{\mathbf{x}}_4)}{\mathbf{r}_{3,3}}$$
$$\tilde{\mathbf{x}}_2 = \frac{(\bar{\mathbf{y}}_2 - \mathbf{r}_{2,3}\tilde{\mathbf{x}}_3 - \mathbf{r}_{2,4}\tilde{\mathbf{x}}_4)}{\mathbf{r}_{2,2}} \tag{26}$$
$$\tilde{\mathbf{x}}_1 = \frac{(\bar{\mathbf{y}}_1 - \mathbf{r}_{1,2}\tilde{\mathbf{x}}_2 - \mathbf{r}_{1,3}\tilde{\mathbf{x}}_3 - \mathbf{r}_{1,4}\tilde{\mathbf{x}}_4)}{\mathbf{r}_{1,1}}$$

With ML decoding, the digitally modulated detected signals can be written using the following relation,:

$$\tilde{\tilde{x}}_m = \arg\min_{\hat{x}^{(k)} \in \vec{x}} \left|\hat{x}^{(k)} - \tilde{x}_m\right|^2 \tag{27}$$

where, $\vec{X}$ is the digitally modulated complex symbols[10,11].

d) 2D Median Filtering

2D median filtering is widely used as an effective technique for removing various types of noises (salt and pepper and Gaussian) from noise contaminated image. In such filtering operation, the pixel values in the neighborhood window are generally ranked according to intensity and the middle value (the median) becomes the output value for the pixel under evaluation. In this paper, 2D Median Filtering scheme with a 3×3 neighborhood windowing mask is preferably used to make sorting of all the pixel values within the window and finding the median value and replacing the original pixel value with the median value [12].

III. System Description

The simulated LDPC encoded MIMO Wireless Communication System with Implementation of MP-WFRFT based physical layer security scheme is depicted in Figure 1.A RGB color image with 96 pixels width and 96 pixels height has been considered. The color image is converted into its respective three Red, Green and Blue components with each component is of 96 $\times$ 96 pixels in size. The pixel integer values are converted into 8 bits binary form and channel encoded using LDPC and interleaved and subsequently digitally modulated using QPSK, DQPSK and 4-QAM[13]. The digitally modulated complex data sequence are transformed using 4-Weighted Fractional Fourier Transform (4-WFRFT) for encryption. The encrypted data symbols are fed into spatial multiplexing encoder section for production of four data series to be transmitted simultaneously from four antennas. In receiving section, the transmitted signals are detected using various signal detection techniques. The detected signals are decrypted and fed into spatial multiplexing decoder, digitally demodulated, deinterleaved and channel decoded. The estimated binary data are now converted into integer form and processed for 2-D image filtering. The filtered data are entered into R,G and B components and eventually, color image is retrieved.

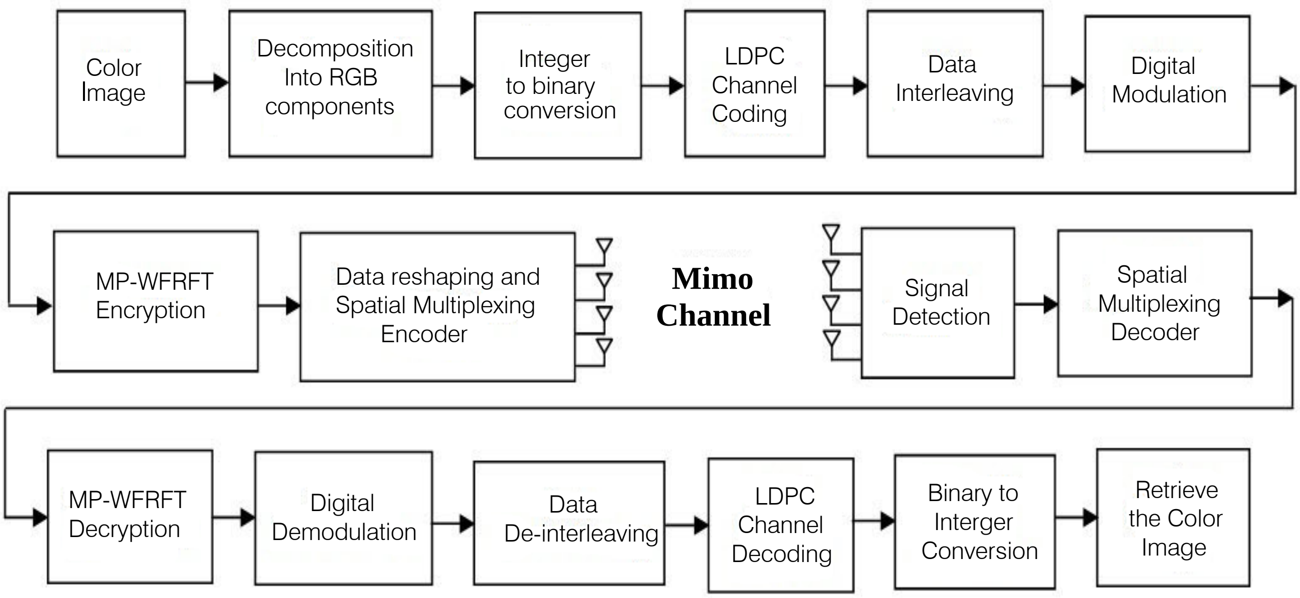


Figure 1: Block Diagram Of Physical Layer Security Scheme Implemented LDPC Encoded MIMO Wireless Communication System

IV. Result and Discussion

In this section, we present a series of simulation results using MATLAB R2014a to illustrate the significant impact of various types of signal detection and modulation techniques on performance of LDPC encoded and MP-WFRFT based physical layer security scheme implemented .MIMO wireless communication system in terms of bit error rate (BER). It is assumed that the channel state information (CSI) of the MIMO fading channel is available at the receiver and the fading channel coefficients are constant during simulation. The proposed model is simulated to evaluate the quality of the system performance with considering the following parameters presented in the Table 1.

Table 1: Summary of the simulated model parameters

Parameters	Types
Data Type	Color image
Image Size	(96 x 96 x 3) pixels
Physical Layer Security scheme	Multiple parameters weighted fractional Fourier transform (MPWFRFT) with constellation scrambling (CS)
WFRFT modulation order	0.2
Arbitrary real parameters [m] and [n] considered in estimation of weighting coefficients	[1,3,7,0] and [8,3,1,5]
Noise reduction image filter	2D-Median filter
Antenna configuration	4 x 4 MIMO Channel

Channel Coding	LDPC
LDPC Channel decoding	Log-domain sum product
Digital Modulation	QPSK, DQPSK and 4-QAM
Signal Detection Scheme	ZF,MMSE,ZF-SIC and MMSE-SIC
SNR	0 to 15 dB
Channel	AWGN and Rayleigh

Graphical illustrations presented in Figure 2 through Figure 5 are clearly indicative that our considered LDPC channel encoded simulated system shows comparatively better performance in QAM digital modulation as compared to QPSK and DQPSK. The system performance in terms of bit error rate (BER) is very much well defined in all cases.

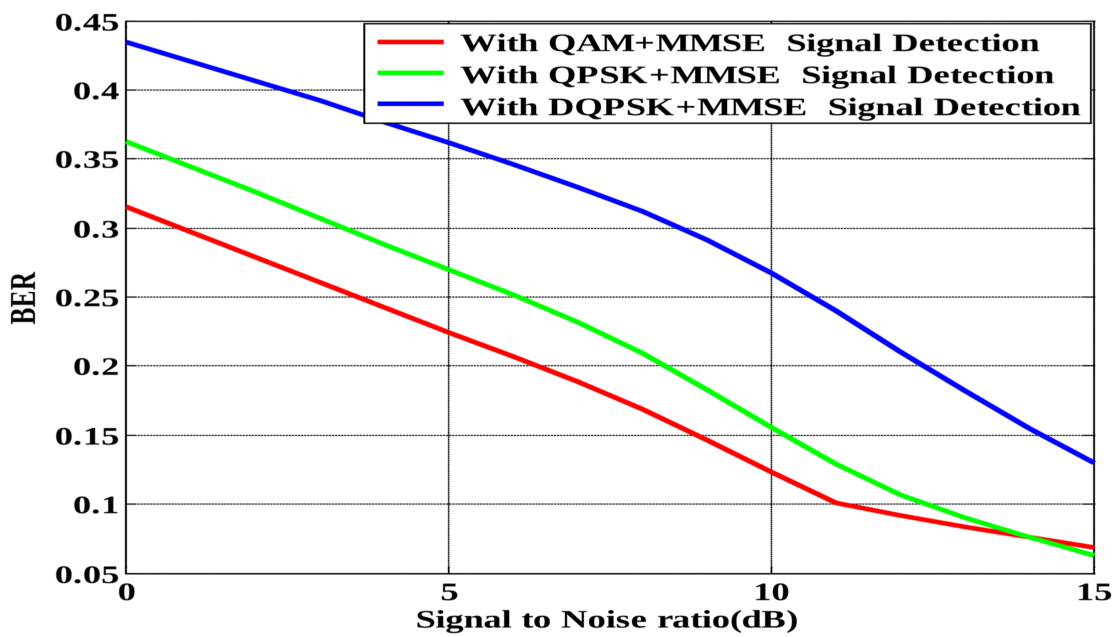


Figure 2: BER performance of LDPC channel encoded MP-WFRFT based Physical Layer Security Scheme implemented MIMO wireless communication under utilization of various digital modulation and MMSE signal detection technique

It is seen from Figure 2 that the estimated BER values at a typically assumed SNR value of 5dB are 0.2247 and 0.3616 in case of QAM and DQPSK which is indicative of system performance improvement of 2.07 dB in QAM as compared to DQPSK. At 15% BER, SNR gain of 1.41dB and 5.39dB are achieved in QAM as compared to QPSK and DQPSK .

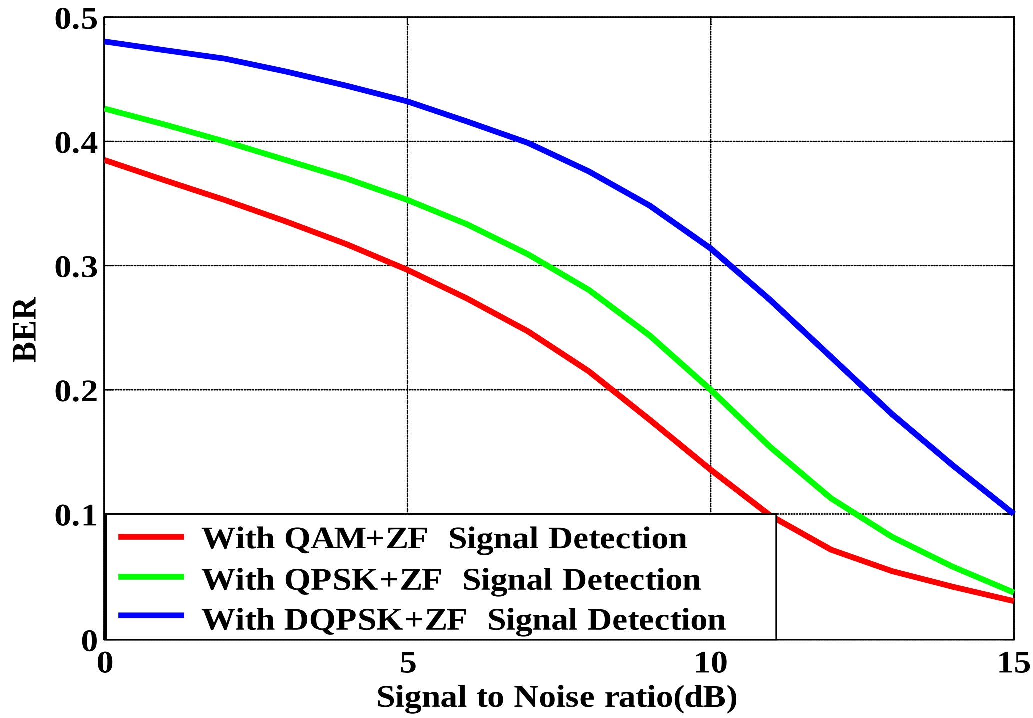


Figure 3: BER performance of LDPC channel encoded MP-WFRFT based Physical Layer Security Scheme implemented MIMO wireless communication under utilization of QAM and ZF signal detection technique

At 5dB SNR value, the estimated BER values are 0.2968 and 0.4315 in case of QAM and DQPSK (Figure 3) which is indicative of system performance improvement of 1.63 dB in QAM as compared to DQPSK. It is noticeable from Figure 3 that at 15% BER, SNR gain of 1.48dB and 3.98dB are achieved in QAM as compared to QPSK and DQPSK.

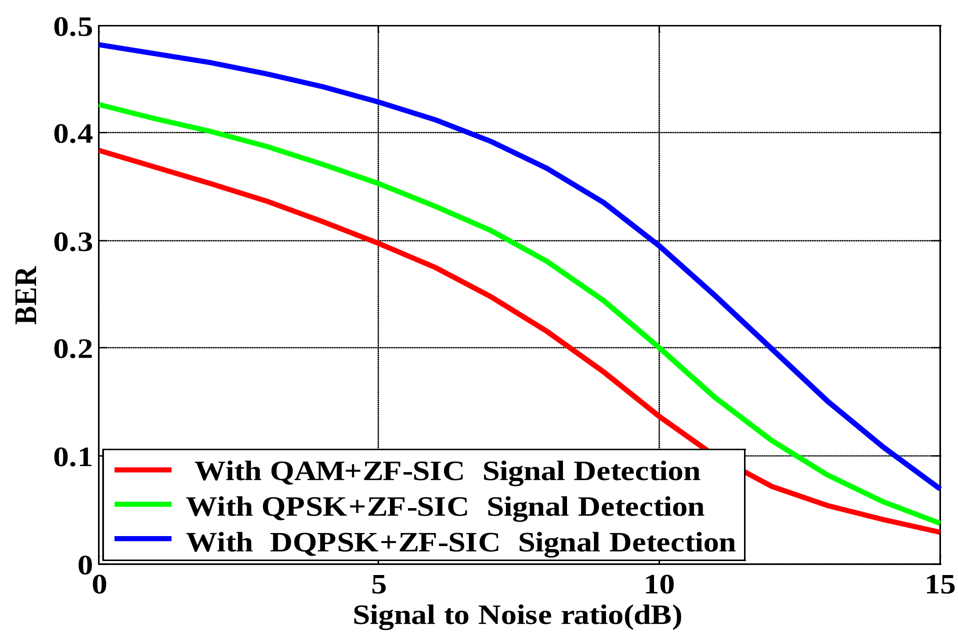


Figure 4: BER performance of LDPC channel encoded MP-WFRFT based Physical Layer Security Scheme implemented MIMO wireless communication under utilization of QAM and ZF-SIC signal detection technique

In Figure 4, the estimated BER values are found to have values 0.2978 and 0.4284 in case of QAM and DQPSK for a typically assumed SNR value of 5dB which implies a system performance improvement of 1.58 dB in QAM as compared to DQPSK. At 15% BER, SNR gain of 1.56dB and 1.95dB are achieved in QAM as compared to QPSK and DQPSK.

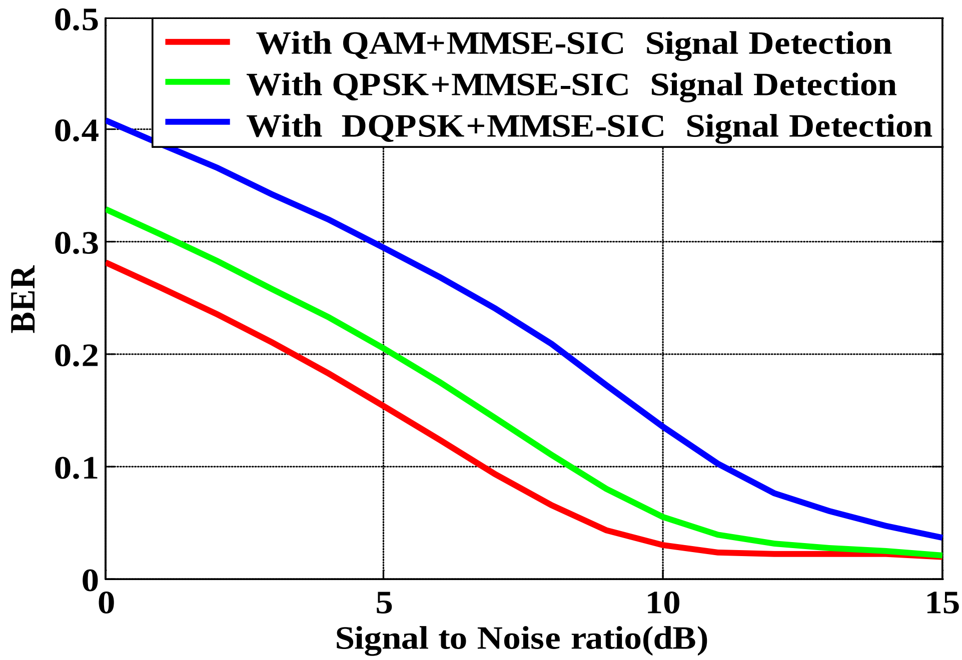


Figure 5: BER performance of LDPC channel encoded MP-WFRFT and CS based Physical Layer Security Scheme implemented MIMO wireless communication under utilization of QAM and MMSE-SIC signal detection technique

It is quite observable from Figure 5 that at a SNR value of 5dB, the estimated BER values are 0.1541 and 0.2947 in case of QAM and DQPSK which ratifies a system performance improvement of 2.82 dB in QAM as compared to DQPSK. It is also quite obvious from Figure 5 that at 15% BER, SNR gain of 1.60dB and 4.53dB are achieved in QAM as compared to QPSK and DQPSK.

Our critical observation at various images presented in Figure 6, it is justified that the encrypted image is not understandable. The quality of the retrieved images improves with the increase in SNR values. The impact of 2-D filtering technique on improvement of retrieved image is reasonably acceptable.

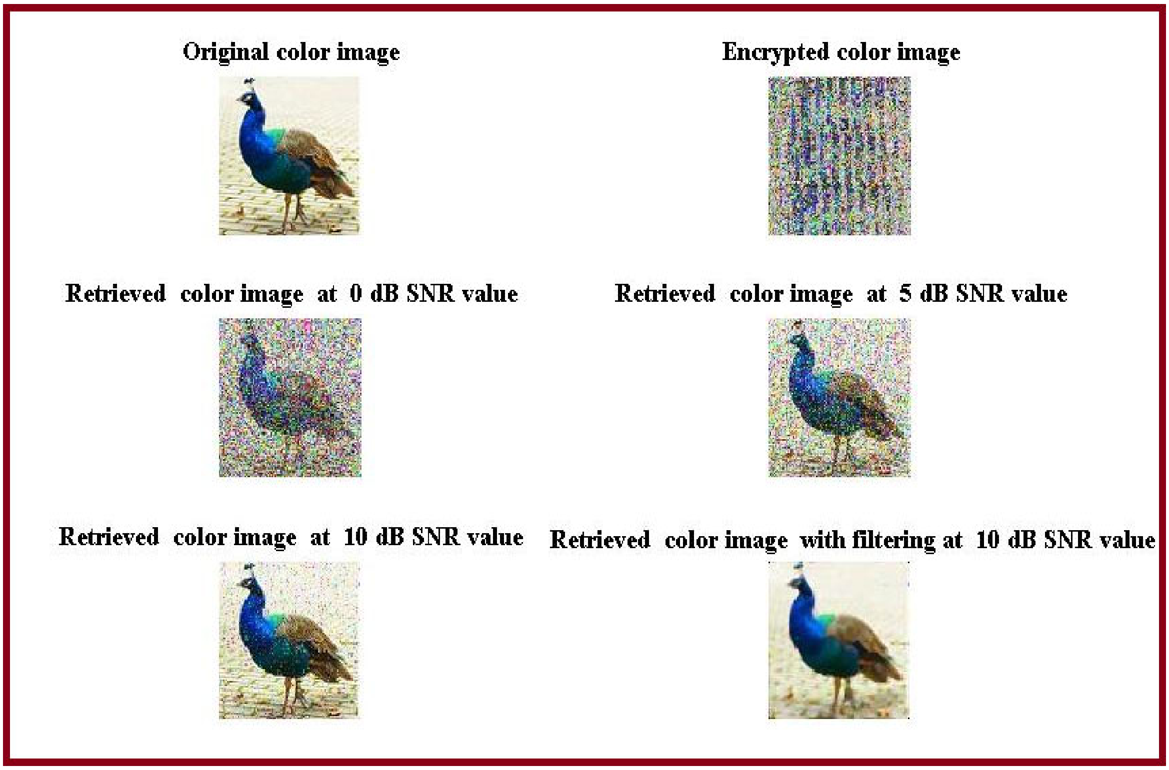


Figure 6: Transmitted, Encrypted and Retrieved color images in LDPC channel encoded MP-WFRFT and CS based physical layer security scheme implemented MIMO wireless communication

In Figure 7, it is quite obvious that the pixel values of the original color image have comparatively higher values at the lower and upper regions. Over significant part of the histogram, the original color image contains low pixel values. In case of 0dB SNR and encrypted image, distribution of pixel values are totally changed. In case of higher SNR value preferably 10dB and filtered image, the presented histograms get resemblance as to original image.

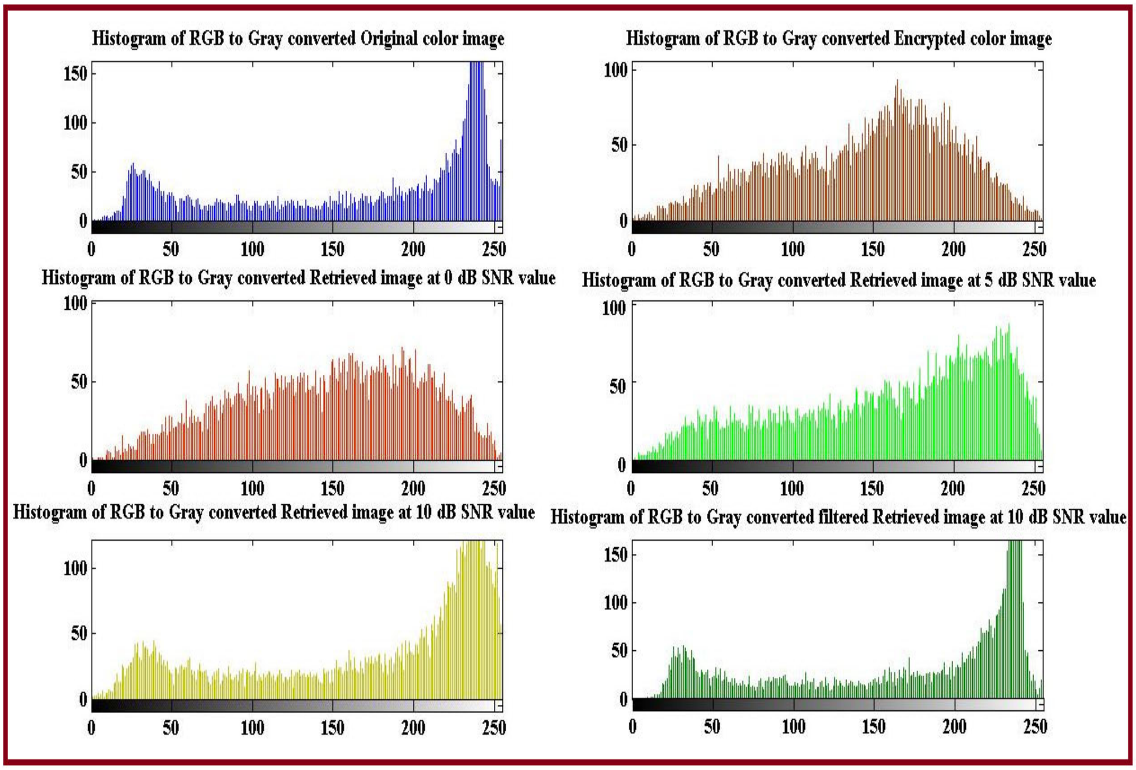


Figure 7: Histogram of RGB to Gray converted Transmitted, Encrypted and Retrieved color images in LDPC channel encoded MP-WFRFT based physical layer security Scheme implemented MIMO wireless communication

In Figure 8, 3 dimensional graphical illustration showing transmitted, encrypted and retrieved color images with and without filtering have been presented to justify the suitability of our proposed physical layer security scheme implemented wireless communication system.

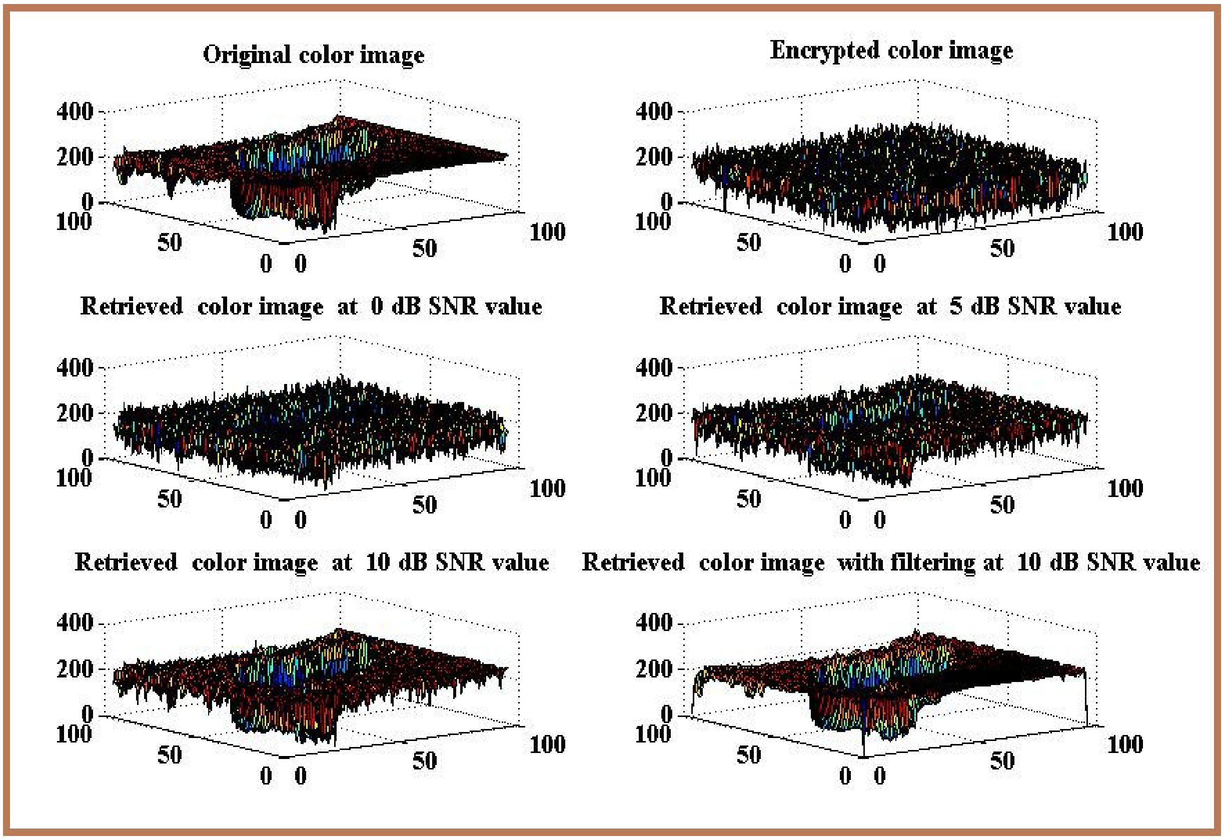


Figure 8: 3-Dimensional Graphical illustration showing transmitted, Encrypted and retrieved color images with and without filtering in LDPC channel encoded MP-WFRFT based physical layer security scheme implemented MIMO wireless communication

V. Conclusions

In this paper, the performance of MP-WFRFT based physical layer security scheme implemented LDPC encoded MIMO wireless communication system has been investigated on secured color image transmission with .utilization of various channel equalization/signal detection techniques. In all cases, the system out performs in 4-QAM and shows worst performance in DQPSK digital modulations. The simulation results show that the implementation of MMSE-SIC signal detection scheme with utilization of 4-QAM digital modulation schemes ratifies the robustness of LDPC encoded and MP-WFRFT based physical layer security scheme implemented MIMO wireless communication system in retrieving color image transmitted over noisy and Rayleigh fading channels.

References Références Referencias

1. Xiangyun Zhou, Lingyang Song and Yan Zhang, “Physical Layer Security in Wireless Communications”, CRC Press, Taylor and Francis Group, Florida, USA, 2014.
2. Xiang, Kan Zheng, Xuemin (Sherman) Shen, “5G Mobile Communications”, Springer International Publishing company, Switzerland, 2017.
3. Elias Yaacoub and Mohammed Al-Husseini, “Achieving Physical Layer Security with Massive MIMO Beamforming”, European Conference on Antennas and Propagation (EUCAP), pp.1753-1757, 2017.
4. Lin Mei, Xue-junSha, and Nai-tong Zhang, “The Approach to Carrier Scheme Convergence Based on 4-Weighted Fractional Fourier Transform”, IEEE COMMUNICATIONS LETTERS, vol. 14, no. 6, pp.503-505, 2010.
5. FANG Xiaojie, SHA Xuejun, LI Yue, “MP-WFRFT and Constellation Scrambling Based Physical Layer Security System”, China communications, pp.138-145, 2016.
6. Dajiang Chen, Xuejun Sha, and Xuemin (Sherman) Shen, Xiaojie Fang, Ning Zhang, Shan Zhang, “On Physical Layer Security: Weighted Fractional Fourier Transform based User Cooperation”, 2017.
7. Lin Mei, Xue-jun Sha, and Nai-tong Zhang, “The Approach to Carrier Scheme Convergence Based on4-Weighted Fractional Fourier Transform”, IEEE Communications Letters, vol. 14, no.6, pp. 503-505, 2010.
8. Yuan Jiang, “A Practical Guide to Error-ControlCoding Using MATLAB”, Artech House, Norwood, MA, USA, 2010.

9. Bagawan Sewu Nugroho, https://sites.google.com/site/bsnugroho/ldpc.
10. Yong Soo Cho, Jackson Kim, Won Young Yang, Chung G. Kang, "MIMO-OFDM Wireless Communications with MATLAB", John Wiley and Sons (Asia) PTE Limited, Singapore, 2010.
11. Lin Baiand Jinho Choi, "Low Complexity MIMO Detection", Springer Science and Business Media, LLC, New York, USA, 2012.
12. Oge Marques, "Practical Image and Video Processing Using MATLAB", John Wiley and Sons, New Jersey, USA, 2011.
13. T. S. Rappaport, "Wireless communications", Upper Saddle River, New Jersey, USA: Prentice Hall, 1st ed.1996.

Global Journal of Computer Science and Technology: A
Hardware & Computation
Volume 17 Issue 1 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Reduction of Power Consumption using Different Coding Schemes using FPGA in NoC

By Dr. S. S. Chorage & Miss. Mitkari Sneha U

Bharati vidyapeeth's college

Abstract- Network-On-Chip (NoC) is used as a main part of a system. NoC overcomes traditional System-On-Chip (SoC) problems. Because, SoC has problems like cost, design risk, more complexity and more power consumption. In software part, Xilinx ISE Design suite 14.5 with VHDL programming is used. It is simple programming language. In hardware part, FPGA of Spartan 3E family is used. It is advanced 90nm technology. It is world's the cheapest FPGA family. It has 500K gates and 40 LUTs. It has lowest cost per logic. Its better advantage is that it is designed for more volume-to-market. Power consumption of given system is compared with previous system. From output power analysis chart, it is concluded that given system has lower power consumption than previous system. Power consumption of gray to binary conversion block of previous system is nearly equal to power consumption of present (given) whole system. This proves that there is a great reduction in power consumption in the system.

Keywords: FPGA, LUTs, Network-on-Chip (NoC), System-on-Chip (SoC), Spartan 3E, VHDL.

GJCST-A Classification: E.4, I.4.2

REDUCTIONOFPOWERCONSUMPTIONUSINGDIFFERENTCODINGSCHEMESUSINGFPGAINNOC

Strictly as per the compliance and regulations of:

Reduction of Power Consumption using Different Coding Schemes using FPGA in NoC

Dr. S. S. Chorage [α] & Miss. Mitkari Sneha U [σ]

Abstract- Network-On-Chip (NoC) is used as a main part of a system. NoC overcomes traditional System-On-Chip (SoC) problems. Because, SoC has problems like cost, design risk, more complexity and more power consumption. In software part, Xilinx ISE Design suite 14.5 with VHDL programming is used. It is simple programming language. In hardware part, FPGA of Spartan 3E family is used. It is advanced 90nm technology. It is world's the cheapest FPGA family. It has 500K gates and 40 LUTs. It has lowest cost per logic. Its better advantage is that it is designed for more volume-to-market. Power consumption of given system is compared with previous system. From output power analysis chart, it is concluded that given system has lower power consumption than previous system. Power consumption of gray to binary conversion block of previous system is nearly equal to power consumption of present (given) whole system. This proves that there is a great reduction in power consumption in the system.

Keywords: FPGA, LUTs, Network-on-Chip (NoC), System-on-Chip (SoC), Spartan 3E, VHDL.

I. Introduction

As process technology scaling continues number of transistor increases and hence power consumption also increases. Chip-multiprocessor can reach higher efficiency due to synchronized parallel execution of multiple programs or threads. Network-on-Chip is a scalable alternative to conventional when core count is more in Chip-multiprocessor. For mainly in current VLSI design, power efficiency is very important constraint in NoC design.

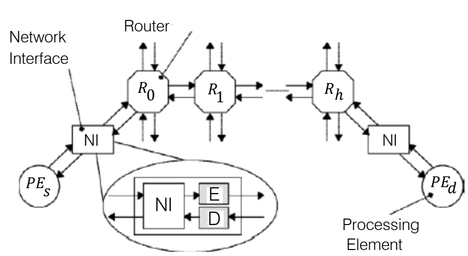


Fig. 1: Network-on-Chip power dissipation sources (links)[1]

Design density and total length of interconnection wires are directly proportional with each other. This affects on long distant transmission delay and higher power consumption.

II. Related Work

Giuseppe Ascia, et al. [1],

In this paper, we propose the data encoding techniques are used to reduce both power dissipation and energy consumption of NoC links

Working on the basis of end-to-end, the proposed encoding scheme exploits the wormhole switching techniques.

That is, encoding and decoding of flits by NIs at source and destination.

Shivaraj MN, et al. [2],

In this paper, encoding techniques are used to reduce dynamic power reduction than previous system. Coupling switching activities are reduced. Detailed process of inversion is explained with the help of flowchart.

Jeeva Anusha,et al.[3],

In the proposed system, different encoding schemes are given. Also, hardware design properties are presented. Output details and power details are given.

III. Proposed System

In method 1, Encoding is done by reducing number of type-I, II transitions and converting them to type-III and / or Type IV transition.

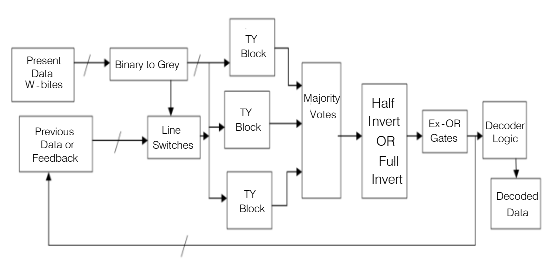


Fig. 2: Block Diagram of Encoding Scheme-I

In method-2, Full and odd inversions are done to convert type-II to type-IV transitions.

Author α σ: Electronics and telecommunication, Department Bharati Vidyapeeth's College of Engineering for Women Pune, 43, Savitribai Phule Pune University, Maharashtra, India.
e-mails: suvarna.chorage@bharatividyapeeth.edu, snehamitkari@gmail.com

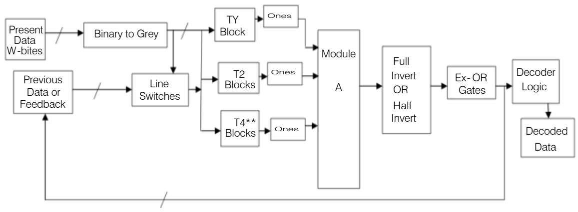


Fig. 3: Block Diagram of Encoding Scheme-II

In this method-3, Even inversion is added with odd inversion. Because, Type-II transitions are formed in even inversion.

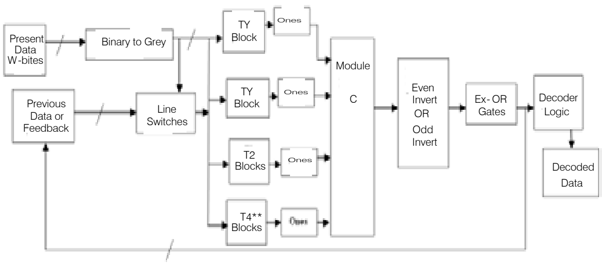


Fig. 4: Block Diagram of Encoding Scheme-III

IV. Hardware Part

Xilinx SPARTAN 3E FPGA kit:

Fig. 4: Xilinx Spartan3E board [7]

- World's lowest cost FPGA is of Spartan 3E FPGA.
- Designed for the High-Volume Market
- Designed for the Low-Cost Market
- Optimized for Gate-Centric Designs
- 100K to 1.6 million gates
- 4000 LuTs.
- Lowest cost per logic
- Advanced 90nm technology.

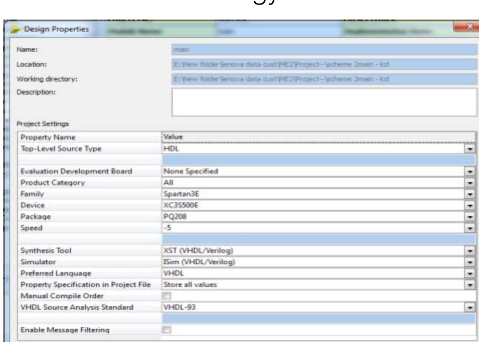


Fig. 5: Design properties in Xilinx simulator

V. Mathematical Calculations for Power Analysis

We know energy formula with respect to voltage and capacitance.

$$W = (1/2)(CV^2) \tag{1}$$

Here, capacitance is in μF. So, it is very negligible.

$$P = W/t \tag{2}$$

$$W = VIt \tag{3}$$

These two formulae are the basic formulae for energy and power.

$$W/t = VIt/t = VI \tag{4}$$

From (2) and (4),

$$P = VI \tag{5}$$

$$W/t = (1/2)(CV^2)/t \tag{6}$$

$$1/2\ (CV^2)f = P \tag{7}$$

From (2) and (7),

$$P = (1/2)(CfV^2) \tag{8}$$

From Eq.8, power is directly proportional to capacitance value, frequency and square of voltage. Here, capacitance value is very less i.e. in μF. As switching between i/p and o/p increases, frequency also increases and hence, power consumption increases. Power consumption is more affected by voltage value.

```
---------------------------------------------------------------------------------
|         On-Chip          | Power (mW) |  Used  | Available | Utilization (%) |
---------------------------------------------------------------------------------
| Clocks                   |       0.46 |      1 |    ---    |       ---       |
| Logic                    |       0.00 |    144 |      5720 |               3 |
| Signals                  |       0.00 |    175 |    ---    |       ---       |
| IOs                      |       0.00 |     20 |       102 |              20 |
| Static Power             |      13.69 |        |           |                 |
| Total                    |      14.15 |        |           |                 |
---------------------------------------------------------------------------------

2.2.  Thermal Summary
------------------------------
|      Thermal Summary       |
------------------------------
| Effective TJA (C/W) | 38.4 |
| Max Ambient (C)     | 84.5 |
| Junction Temp (C)   | 25.5 |
------------------------------

2.3.  Power Supply Summary
---------------------------------------------------------
|                 Power Supply Summary                  |
---------------------------------------------------------
|                       | Total | Dynamic | Static Power |
---------------------------------------------------------
| Supply Power (mW)     | 14.15 | 0.46    | 13.69        |
---------------------------------------------------------
```

Fig. 6: Power analysis for scheme-III

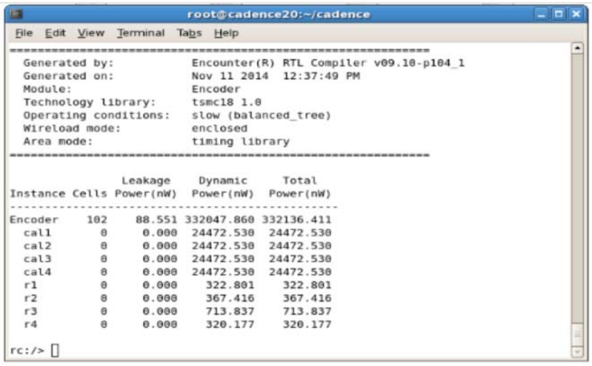


Fig. 7: Power analysis for scheme III for gray Encoding [4]

Table 2: Comparison different parameters of three Schemes

Parameter	Scheme-1	Scheme-2	Scheme-3
Family	Spartan-3E	Spartan-3E	Spartan-3E
Device	XC3S500E	XC3S500E	XC3S500E
Package	PQ208	PQ208	PQ208
Speed	5	5	5
Clock	1	1	1
Logics	148	163	144
Signals	197	177	175
IOs	20	11	20
Dynamic Power	0.46mW	0.46mW	0.46mW
Static Power	13.69mW	13.69mW	13.69mW

- As shown in Table.2, number of logics increases efficiency. As number of signals decreases power consumption also decreases from scheme-1to scheme-3.
- In previous system, for only one stage, i.e. Gray Encoding block, dynamic power consumption was 0.3mW.And now, in the present system after summing for all stages, dynamic power consumption is 0.46mW.From this comparison is done. We can conclude that power consumption is minimized in more amounts.

VI. Results and Discussion

a) Scheme-I

In scheme-I, half invert and full invert is performed. In full invert, 00 is converted into 11. When any one of the two is performed then inversion bit is set to 1, otherwise it is set to 0.

b) Scheme-II

Simulation is done on Xilinx 14.5 ISE simulator. It is backend design tool. In scheme-II odd inversion is added. Type-II transitions are converted into type-IV transitions. Data coming at Network interface is from Encoder block. Then it is converted into desired encoded data which is passed through number of routers. This type of encoding is of scheme-II.

c) Scheme-III

In scheme-III, there is additional inversion is performed that is Even inversion. For that Te block is added in second stage. Here, power consumption will be less than Scheme-II because; link power consumption is minimized in more amounts.

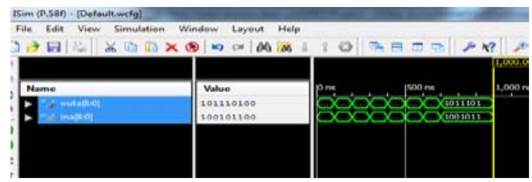


Fig. 8: Result of Binary to gray conversion Block

Binary bit has some switching problem. So, they are converted into gray bits.

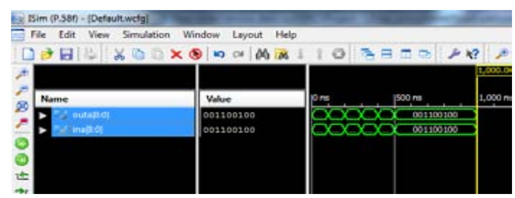


Fig. 9: Result of Previous data Block

In scheme3, apart from Ty, T2, and T4** blocks, Te block is added which will further help in determining type of Inversion.

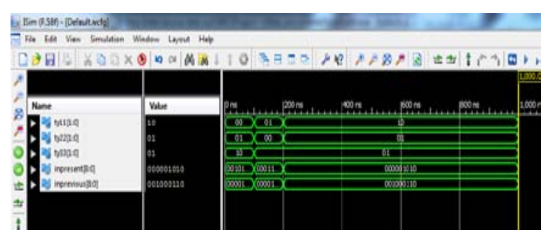


Fig. 10: Result of 2nd stage

Detection of number of 1's is taken placed from Ones module. Next is, majority block. It can detect major number of 1's present in inputs to it. Data bits are passed through Module-C, checks type of inversion. Data is preceded with odd invert, even invert.

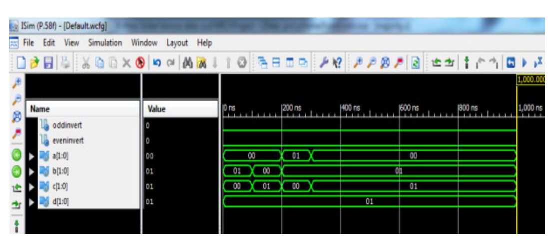


Fig. 11: Result of Majority Block

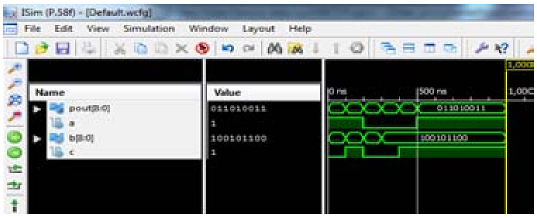


Fig. 12: Result of Last Stage

Last output is gained by making Ex-or operations.

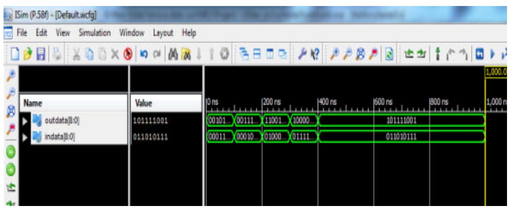


Fig. 13: Result of All connected Blocks

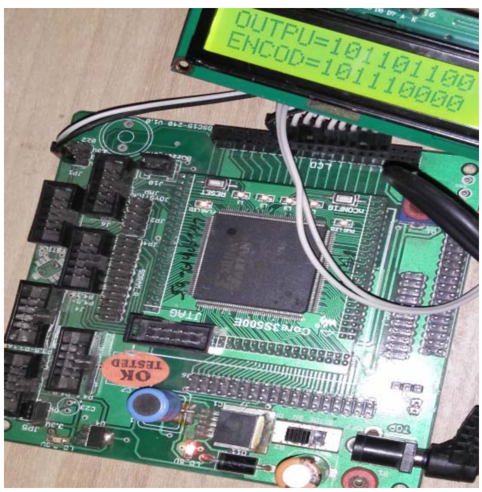


Fig. 14: Xilinx FPGA Spartan-3E kit with Encoded and Decoded data as o/p.

d) Results obtained by LCD Interfacing

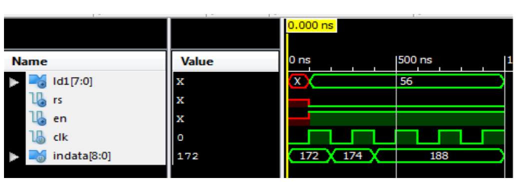


Fig. 15: Result for Scheme-1 LCD interfacing

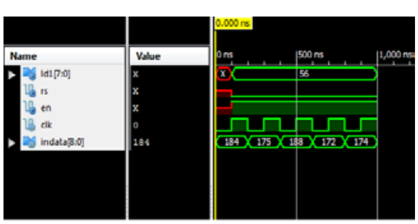


Fig. 16: Result for Scheme-2 LCD interfacing

To calculate report for power consumption, first, we have to interface encoder and decoder with LCD. On this LCD, we can see desired output for both stages, encoding and decoding.

Here, 'en' is for enable, 'clk' is for clock and 'rs' is for register select. When there is initialization of lcd rs=0. When rs=1, data is as it is written on lcd. When en=1, module is enabled or is started.

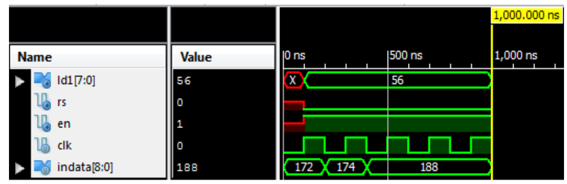


Fig. 17: Result for Scheme-3 LCD interfacing

VII. Conclusion

- Encoding and decoding operation is used for security purpose. But here, main aim is to reduce power consumption in a effective way.
- Hardware part is used in such a way that cost of Spartan 3E (for Xilinx) is the lowest among different FPGA families.
- Dynamic power consumption without interfacing is calculated and compared with previous systems.
- In scheme-I, II, III, on the basis of parameters, power analysis is done.

References Références Referencias

1. Data Encoding Schemes in Networks on Chip by Maurizio Palesi, Giuseppe Ascia, Fabrizio Fazzino and Vincenzo Catania, *IEEE transactions on Computer-aided design of integrated circuits and systems*, vol. 30, no. 5, may 2016.
2. Shivaraj MN, Ravi H Talawar, "Dynamic Power Reduction in NOC by Encoding Techniques", *IJIRST (International Journal for Innovative Research in Science & Technology)* Volume 2, Issue 04, September 2015.
3. JEEVA ANUSHA, V.THRIMURTHULU, "VLSI DESIGN OF LOW ENERGY MODELING FOR NETWORK ON CHIP (NoC) APPLICATIONS", *International Journal of VLSI and Embedded Systems (IJVES)*, Vol 06, Article 06596; June 2015.
4. Maurizio Ascia, Fabrizio Fazzinoand Vincenzo Catania, "Data Encoding Schemes in Networks on Chip", *IEEE transaction on computer aided design of integrated circuits and systems*, vol. 30, no. 5, may 2016.
5. Nima Jafarzadeh, Maurizio Palesi, Ahmed Khademzadeh and Ali Afzali-Kusha, "Data Encoding Schemes for Reducing Energy Consumption in NoC", *IEEE transaction on VLSI system*, vol. 22, no. 3, march 2014.

6. Suresh Dannana, Govinda Rao Tamminaina and A.R.V. Sathish Kumar, "Data Driven Data Encoding for Low Power Application*", International Journal of Signal Processing (IJSP), Image Processing and Pattern Recognition(IPPR)*, Vol.8, No.10 (2015), pp.375-388.
7. Akula Soujanya, Mrs. P. Vinitha, Mr. K. Gopi, "Data Encoding Techniques for Reducing Energy Consumption in Network-on-Chip", *International Journal of Eminent Engineering Technologies (IJOEET)* ,Volume 4, Issue 2 NOV 2015.
8. A.V. Manoj, S. Bhavya Sree, K. Yuva Kumar, V. Purandhar Reddy," Power Consumption in Network-on-Chip by Encoding Scheme", *International Journal of Innovative Research & Development (IJIRD),* January, 2014 Vol 3 Issue 1.
9. D. Anisha, R. Sarathbabu, "Data Encoding Techniques for Lower Power Dissipation in *NoC*", *International Journal of Engineering Research & Technology(IJERT)*, Vol. 3 Issue 2, February – 2014.
10. Chetan. S. Behere and Somulu. Gugulothu, "ENCODING SCHEMES FOR POWER REDUCTION IN NETWORK ON CHIP LINKS", *International Journal of Research in Engineering and Applied Sciences* (*IJREAS),* Vol. 02, Issue 02, July 2014.

This page is intentionally left blank

Global Journal of Computer Science and Technology: A
Hardware & Computation
Volume 17 Issue 1 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

Tool Support of Developing Systems Simulation with Active Elements

By Igor N. Skopin

Abstract- In this paper we propose and discuss a new approach to the simulation of developing systems is proposed and discussed. The base of the approach is idea of independent development of the so-called aspect models, whose interconnections are provided by computational environment toolkit. The main feature of the approach is the abandonment of postulate of the deterministic behavior of systems if they develop due the activity of event-driven elements behavior. We discuss their initial requirements for the tool support of the proposed approach.

Keywords: developing systems, active element, attributive representation, the aspect model, simulation, multi-aspect, multidimensional nature, multiple structures, tool support.

GJCST-A Classification: I.6.1, I.6.6, I.6.7

Tool Support of Developing Systems Simulation with Active Elements

Igor N. Skopin

Abstract- In this paper we propose and discuss a new approach to the simulation of developing systems is proposed and discussed. The base of the approach is idea of independent development of the so-called aspect models, whose interconnections are provided by computational environment toolkit. The main feature of the approach is the abandonment of postulate of the deterministic behavior of systems if they develop due the activity of event-driven elements behavior. We discuss their initial requirements for the tool support of the proposed approach.

Keywords: developing systems, active element, attributive representation, the aspect model, simulation, multi-aspect, multidimensional nature, multiple structures, tool support.

I. Introduction

The study of developing systems, whose behavior depends on the individual activity of their elements, is urgent for a wide range of research. From a practical point of view, it is important to have such control over the behavior of the system, which allows you to direct development to the right conditions for development and to limit undesirable ones. However, in most approaches to the study and design of systems, it is difficult to take into account the individual activity of the elements. This is due to the fact that the main focus of the developers is to search for a common deterministic development principle, whereas such principles are not reflected in the individual activities of the elements.

A problem in research into developing systems with active elements is the accounting for the behavior of elements not only in this system but also in other important aspects. This multi-aspect activity may contradict the object model of a system, and developers usually regard it as external non-controllable impact. Objectives of the behavior of an element rarely correspond to the system development objectives, and so it is difficult to reflect the involvement of the element in other activities in the model of the system. But this changes the activity of the element. Trying to avoid the complexity of multi-aspect properties one can build different models for different aspects. However, this way brings about no less complicated problem of adjoining models.

Author: Institute of Computational Mathematics and Mathematical Geophysics of SB RAS. e-mail: iskopin@gmail.com

The proposed approach is intended to overcome both a postulate of determinism and difficulties of multidimensional nature. One can consider it as a version of the discrete-event simulation proposed in the 1960s by J. Gordon [1]. In the most developed form it is presented in the programming methodology in Simula [2] and Simula 67 [3] languages. Unlike a traditional to use the global (linear) ordering of events in controlling a computation, we refuse from this determination that mostly admitted to optimize computer cost. We consider the support of autonomous modeling of aspects as another feature of our approach thus making it associated with the so-called aspect-oriented programming [4]. In this case, the difference is that following our proposals, one should provide the support of aspect features by a specialized design and computation environment as well as the pre-fixed representation of model elements.

Conceptually close to our approach is the development of the so-called multi-agent systems (MAS) [5]. One of the Russian researchers and developers in this area P.O. Sobolev says: "The key element of these systems is a program agent that can perceive the situation, to make decisions, and to communicate with other agents. These capabilities dramatically distinguish MAS from existing rigidly organized systems providing them with such an important new feature as self-organization. In this case, separate parts of the program can agree on how a problem should be solved. The parts acquire their activity and can initiate a dialogue with the user in advance at not prescribed times. They can work in conditions of uncertainty and offer clarification and reformulation of tasks, etc." [6]. The abandonment to find a deterministic principle, which allows identification of the best solution, the agent's activity with their purposeful behavior, the focus on operations with developing systems are a common concept for both approaches.

However, outside the multi-agent approach, there remains a problem of supporting the mutual influence aspects. The information affecting the behavior of an agent came from its environment and transferred for the use by other agents. But this is not an independent construction of mutually depended aspect models supported by tools. We declare this position in our approach as one of the main requirements. At the same time, methods of constructing multi-agent systems are applicable in our case, especially in defining the behavior of agents. For our approach, there is a very valuable information about organizing the functioning of the agent computing environment and support toolkit (an example of this kind of a system is REPAST [7]).

In the first part of this paper, we present characteristic features of the approach and show how one can attain the declared capacities. The second part discusses the requirements for the toolkit support of the approach. The desired tool should be appropriate to develop and to perform simulations of models, data collection, storage, and processing of information in the course of studying a system.

II. Characteristic Features of the Approach

a) Model System, Simulation, and Events

We are speaking about a *model of the system* as an abstract notion, without being tied to any meaningful interpretation. The system consists of elements whose actions change some characteristics of the elements themselves and the system as a whole. This is the behavior of the real system. In the model system, we represent these characteristics as *attributes of elements*. Their change in the course of calculation one can interpret as the *model simulation of the system behavior* or *functioning of the system*.

A value of element attribute is modified only as a result of program action execution if the operational context of a program includes a mutable attribute. We postulate that all actions are methods of elements (in the sense of object-oriented programming [8]), and operational contexts form from all available elements and their attributes. The action-method which carries out an element is the manifestation of its activity in the simulation system through the model calculations. We do not impose restrictions on how described the programs of element actions, and the only thing that we require is a single *unified attributive representation of all elements* as common basis of description of action.

Elements can be *linked*, which is understood as the presence of *binary relationship* (of any nature), reflecting the relations in the real system. Due to the links a set of all elements of the model system receives the network structure. The links are a kind of attributes: they allow the element methods to access to the attributes associated with this element. This provides the opportunity to use and modify the attribute values (including links) and to influence the actions of the elements available by the links. An element can *give rise* to other ones, associated with the parent element, *add relationship ties*, or *remove* them according to requirements of modeling. It may deny all links of an element, that one can interpret as destruction of the latter. All these activities develop a network of the model system.

It is convenient to assume that there is allotted element for indicating the system as a whole. It has the especial attributive representation which allows one to distinguish between the external impacts and changes of attributes of the system. The allotted element receives ties with all other elements of the system. It is not necessary that allotted element had its prototype in a real system.

Any action of the model system runs as a response to some event that occurs during the simulation. The event-driven mechanism, used in the approach proposed, reflects Hoare's conception [9], according to which any change in the model system is an event if there are elements that *recognize* it. If this is true for such an element, one of its actions executes. Execution of this action is called the *reaction* to the event.

The types of all events are determined in advance, but a set of event types to which the element can react is formed in the dynamics of calculations (while carrying out this or other element action). A current set of the types of recognizable events is called *status* of the element. We consider that the status of the element is set as a particular attribute that coding the set of the types of events. Knowing the value of this attribute, one can always find all types of the events that the element can recognize. In the correctly constructed attributive representation opposite is truth too. If this condition fails, then it is deemed to have violated the integrity of the attributive representation of the element. Response to a joint event that is recognized by several elements is executed *jointly* and *asynchronously*. This allows demarcating parallel execution of actions. They execute as usual parallel processes in own threads. Processes management of threads uses conventional means. They coordinate several reactions of elements. Following Hoare [9], we consider that the recognition of an event is an instant action, but in the reaction execution, it is possible that other events may occur to which the element should respond.

In the event-driven mechanism we can define a *protocol of element behavior* as a sequence of triples: (<element status>, <event to which it responds>, <element reaction>). In such a notion, we define the *behavior of the model system* as a collection of all protocols of elements glued on the joint recognized events. This set determines a partial order on all the events occurred, where each included protocol is a linear chain. It is natural to consider a protocol of an element (more precisely, a sequence of its events) as element local time. In this case, we offer the mentioned partial order on all events to consider as a correctly determined *global time of the model system*. Here, by correctness we mean the most accurate information about relations for events *earlier*, *later*, *unknown when*. In the concept of model time there is no inaccuracy, which is typical for the commonly used time. Instead of the desired accuracy, the temporal relations are usually determined arbitrarily. We do not exclude the possibility of such a refinement, but we always insist that simulation of developing systems requires an accurate definition of the concept of time. Details on the local and global time one can found in [10]. Note that our understanding of time differs from that used in discrete events and multi-agent systems.

b) Multi-aspects, Structure of a System, and Attribute Representation of Elements

The behavior of elements in a real system involves the activities in various aspects of functioning. On the model level describe this, one can build models of all important aspects. They are the so-called *aspect models*. However, because of the problems of harmonizing the aspect models, developers are often limited to building a common model of the system. In our approach, we offer the support for independent aspect modeling and dynamics of mutual influence of aspect models in the simulation calculations that are common to all or several of these models.

The aspect model defines the structure of a set of elements, and their relations called the *aspect structure*. It is a part of the model system network. The model system We consider the modeling system as the union of all its aspect structures. When constructing aspect models is provided a joint and equitable co-existence of aspect structures (we call this feature *multiplicity of system structures* [11]), it is possible to co-operate all or selected aspect models (including one model). To ensure such an operation with aspect structures, we consider it necessary to use a standardized format for attributive representation of elements. This format provides for splitting the representation into blocks related to each of the aspect structures. These blocks are called the *aggregate of aspect attributes*. Each aggregate contains the data assigned to this structure, current status, as well as methods of aspect actions. The combination of all aggregates contains all information about any of the aspect models.

The necessity to distinguish between the aggregate of attributes related to different aspects follows from requirements to the standardized attribute representation of elements. These requirements also mean that the activity of an element is an aspect property: ability to affect the system as a whole through the actions related to an aspect. In our approach, the construction of aspect models takes into account the fact that a user operating on some element has access to others only through references to them, and access to attributes of other aspects is allowed for the type of this element. This limitation leads to independence of constructing each aspect model from its environment.

The event generation is global in the sense that a created event is accessible for the response of elements in any aspect models. The recognition of an event and the response of an element to it are local, i.e. they are represented in a certain aspect model. It is possible that the element response to one event in several models, but this means only the occurrence of several independent reactions.

c) Horizontal and Vertical Modeling of a System

As a model of a system, we consider a set of all aspect models whose joint simulation forms the characteristics of a system represented among the attributes of an indicating element. To test various hypotheses concerning the control of the simulated system, one can use the truncated joint simulation. In this case, he chooses for calculations not all possible models and establishes the lack of influence on their behavior through external actions. This use of aspect models is called *horizontal modeling of the system*.

From the standpoint of horizontal modeling, implementing the behavior of all aspect models is not necessary. For all unrealized aspect models, you need to present elements that replace missing implementations. Each such element must ensure the generation of events adequate to the required behavior of the aspect model. Thus, the replacement element will create conditions for the functioning of other aspect models. It would be naive to expect that the model of the system, constructed using replacement elements for aspects, will be adequate to the real simulated processes. But due to the addition of the replacement elements with programs reflecting real aspect behavior, the quality of modeling will grow. Note that in this way it is possible to build various versions of aspect programs, and, as a consequence, to test different versions of modeling the real system for selecting the best of them. In particular, when modeling aspects, the developer can use concepts that are different from the agreements of our approach. In this case, she/he must ensure that the proposed development of the model system is coordinated only at the interface level. Otherwise, it will be necessary to ascertain the conceptual incompatibility of approaches. In fulfilling this condition, one can pose the problem of replacement of aspectual models with real data from external sources. This brings our concept to the level of real-time systems for making management decisions. Leaving out details, let us note that the widespread use of a similar approach in practical applications of multi-agent systems (see, for instance, [6]) indicates to its effectiveness in our case as well.

The element representing the model of the system as a whole differs from the other elements only in that it alone interacts with the external environment of the model. The environment affects the system, generating corresponding events, to which only it responds, and receives information about the model behavior only from it. We can consider the environment of our model as a some supersystem in which our system is an integral part. And for this additional modeling, the element representing our system, is a usual an active element in its horizontal model, i.e., in the new *model of a higher level*. To meet different needs, one can build different supersystems, which in turn, one can use as active elements of models of even higher levels. Thus, the multilevel modeling can be a source of aggregated data for the hierarchical control in various areas. Such a kind of modeling is called *vertical*. As in the case of the horizontal modeling, this approach allows for the replacement of models with real data.

d) Groups of Elements, Subsystems, and Operation with Groups

One can distinguish *meaningfully related groups of elements* in the model system, which sometimes it is convenient to consider as independent ones. Sometimes one can consider a set of attribute descriptions of the elements of the group as the model of a subsystem, but it is not quite accurate: a system (and a subsystem) is not reduced to a sum of its parts. So, it is needed to speak about own attributes of a subsystem, i.e., the subsystem receives the status of the element affecting the behavior of the system as a whole. This formal status we may regrade as a definition: an element indicating a group (i.e., it is linked with all the group elements by a specifically prescribed relation, called *grouping*) and all elements of the group are called *subsystem*. The grouping relation is dynamic because the element belonging to a group, as well as its connection with the element indicating the subsystem can vary.

Attributes of a subsystem are formed both by their behavior (actions of its elements) and under the influence of the behavior of other elements that provide an external information for the subsystem. In particular, the links occurring in a subsystem as relations with external elements are set for the subsystem as a whole, and it can re-direct them to their elements. At the same time, this does not exclude the possibility of independent recognition of events using its elements. On a set, consisting of groups, including also the groups composed of all the elements of each aspect structure we define *set-theoretic operators*: intersection, union and supplement. Their results can be considered as groups. They are sometimes interpreted in terms of their behavior.

We formally introduce the operator called *convolution of subsystem*. Its performance is the replacement of the interaction of the subsystem elements with the environment by the interaction of element indicating the group (subsystem). In this case generation of events to them are transferred from the subsystem elements to the element indicating the subsystem. A convolution subsystem can be considered as a *black box*, whose *inputs* provide information produced by the subsystem reactions to events and *outputs* are presented by generation of events from the subsystem, providing information for the environment. But such a consideration is not quite correct: every subsystem, being formed in some aspect, cannot screen from its elements belonging to other aspect models.

Convolution can be used in the top down construction of models, starting with the upper level, gradually refining the models by revealing the subsystem-elements structure. It fits for localization of models that are beyond our approach developed, but adequate for certain processes and can be coordinated with events of the system. However, it is should be noted that convolution is applicable only in the cases when there is not information about the individual behavior of the subsystem elements.

III. Initial Requirements of Tools

The approach proposed to studying or developing systems is aimed at designing the supporting toolkit. We present it as a software package, whose facilities are referred to the three categories:

- Ensuring the dynamic simulation;
- Control of simulation, collection and processing of simulation results;
- Facilities for models development.

The simulation of every aspect model can be implemented with the use of a variety of algorithm, including external ones for our toolkit. Therefore, it is necessary that our toolkit be an *open software system*. Only incompatibilities of interfaces can prevent the use of external computational models. This is a common requirement for all the three categories.

a) Ensuring the Dynamic Simulation

Active elements and the autonomy of their behavior in each aspect model, as well as the mutual effect of models require that each element should be defined as a separate computational process that is running in a separate thread. Each process has a local memory, which is filled up with data of attributive representations of the element. In our approach the event-driven technique does not require the shared memory of different processes. If a shared memory is necessary, one can provide auxiliary elements, whose processes are responsible for the delivery of information to basic processes on demand. Of course, this does not exclude the possibility of optimizing the main mechanism on the system level: for statically computed cases of operations with events, it is possible to replace reactions by a direct call of the respective methods (this optimization technique is discussed in Section 3.5 of [12]).

The event-driven communication of processes (methods of elements) ensures the transfer of information between processes through the *messages* associated with events. The messages contain data formed by the elements that generate the events. Using messages, it is possible to transmit specific data as well as links to the attributive representations of various elements. Thus, there is a possibility of the direct effects of elements on each other. Such effects, generally speaking, may be incorrect if one does not take care of matching synchronization. On the attributive representations level there should be an access system enabling/disabling flags, dynamic priorities, and other well known features to support the matching of communicating processes [9].

Thus, the parallel and asynchronous execution of processes of elements of the model is realized, if necessary, they coordinate and synchronize the joint reactions controlled by a conventional technique of parallel computing. A specific feature of the simulation requires that the number of threads involved in the simulation, be sufficiently large. Therefore, our support toolkit requires of the modern high performance hardware architecture. On the other hand, at least for the first versions of the system, whose one of the main objectives should be working out the methodology of modeling, it is reasonable to choose an existing universal system with parallel computing as the technical and program environment of the simulation. So, it is sensible to develop our toolkit as a specific amplification of the chosen system. Promising in this regard is the system [13], whose users are provided with the opportunity to adapt algorithms to specific features.

b) Control of Simulation, Collection and Processing of Simulation Results

The control of simulations is used to give the user feature to influence the calculations in order understanding the significance of model factors. Such control is considered as a part of an event-driven technique. We establish that all elements recognize a special event of simulation named as *pause* and may response to it, maintaining their status for re-starting the activity in the future. A pause allows one to receive the current information about calculation, to change some parameters of models, to add or to delete elements and to specify their relationships. At the time of pause, to all elements is assigned a special state in which they respond to a single event named as *resumption of modeling*.

Through a series of pauses, *monitoring of system behavior* can be arranged, i.e. user can obtain information about changes in the structure, build of element protocols, and collect integral characteristics. This information may be used for the results processing. For comparison of the simulation versions options for saving the suspended configurations of the simulated system in the repository are provided. Standard facilities of version control (see, for example, [14]) are supplemented with options selection according to integral characteristics.

There is no need to develop special means for the simulation results processing, because today the software market offers a variety of advanced products for this purpose (see, for example, [15]). A good solution is to focus on the features associated with potentiality of the above mentioned support system of parallel programming [13].

c) Facilities for Models Development

The proposed toolkit should provide *tools for building and editing models*. First, there are editors for adding and deleting elements of the model, modifying their attributes, etc. Editing should be followed by validation. In preparing the initial configuration of a model system or its modification during a pause, as well as in the course of the simulation calculation, we need *integrity control of models*, which prohibits an incorrect configuration of simulation. In particular, the initial configuration should be realistic. If an algorithmic verification of the tolerance of simulation is not possible, we provide the user control of configurations.

Modeling and support of simulation are based on appropriate *means to visualize structures*. Different structures of a set of elements should be coordinated. In the model design and monitoring of simulations, an element should be shown jointly in all the structures. The choice between the removal and preservation of elements in different structures should be known for the correct decision-making. Structures of different aspect models should be highlighted in different colors. Visualization of a modeling process must support the correctness of constructions.

A set of development tools to support different strategies for modeling should support different strategies of design. In particular, we offer the support of *bottom-up* and *top-down modeling strategies*.

In the bottom-up strategy, building of each aspect model is started from construction of a primary set of basic elements. Each type of elements is provided with a certain attribute representation. At first, methods of element actions are given as dummy routines. Later on should be refined in developing the aspect model. Specifying the links is needed to determine their properties as relations and permissions of an access of element to other ones. In this case it may be required to add new types of elements, for instance, in forming subsystems.

In the top-down strategy, development of an aspect model begins with subsystems and their elements indicating the subsystems. The subsystems are supplemented with new basic elements or a set of already-prepared elements. The new or refined existing elements are described in the same manner as just as in the bottom-up strategy.

In both cases, the development of models should be supported by tools of tracing the life cycles of elements, reflecting the degree of readiness of their attribute representation. The life cycle of an element class is considered complete when the path from the original class to its readiness to use to generate the elements is traversed, and all conditions for the correctness of the descriptions of each aspect model are provided.

After the aspect models are constructed, are coordinated the influences of the aspect actions on the behavior of other models. This process can result to the identification of classes, refinement of the behaviors of aspect models, and other modifications of the descriptions of classes, that aimed at ensuring the correctness of the horizontal model of the system.

The process of designing and using model systems should be provided by system-wide means of supporting development, as well as managing model calculations. Discussion of this aspect of the proposed toolkit is beyond the scope of this paper. Nevertheless, it should be noted the main requirement for a set of developer tools, without which the expectation of the advantages of using the concept presented above will not justify itself. This is the fullness and integrity of support for user activity. The requirement concerns both the functionality of the software system and its interface: it should be ensured adequate reflection in the interface of all the features associated with the creation and using of models. The problems associated with the requirement of interface completeness and the possibilities for their solution were discussed in [16]. In [17] we proposed a technique that can be used to create interfaces that meet the requirement of fullness and integrity.

IV. Conclusion

The proposed approach for studying developing systems is aimed at supporting the development of models and fulfillment of a series of simulations for obtaining information useful in study the real systems. The work related with this processes is very laborious. It requires analysis of input data and different variants of system behavior, the identification of significant aspects and the construction of aspect models. So we propose the approach to creation of a tool support to ensure the development of models, carrying out calculations, performance control, management of simulations, collecting and processing of results. Depending on the purpose of such tools, its architecture and modeling support capabilities can be very different. Therefore, we confine ourselves to discussing only key concepts. Nevertheless, it is appropriate to note a number of aspects of developing the toolkit to support the development of models, as a software system, the quality of implementation of which essentially affects its usefulness. These issues are discussed in detail in [18], where, in particular, we point out the need for instrumental support for the development and use at all stages of setting and solving the problem of mathematical modeling.

In this paper, we did not dwell on issues of the input and output of information, and only in passing discussed outlined the mechanism for monitoring the simulation pauses. These are important points for the real use of model complexes and they should be solved at the next stage of design. In principle, these problems are solvable, but it seems reasonable to give concrete proposals for these issues based on a detailed analysis of subsequent further requirements.

We should mention the issues of computational complexity of simulation, which are associated with our approach as applied to practical tasks. Multithread execution of the elements actions, event-driven technique, etc. require high performance computing. In this regard, our project should incorporate the use of existing general means as well as development of special facilities of the architecture-dependent optimization. To improve the performance of the simulation, the adaptive software platform should be used. Although this task is beyond the scope of our discussion, we note that it must be solved in a more general context, implying the organization of parallel computations. In this connection, the use of the above-mentioned system [13] seems a reasonable solution.

Acknowledgment

The article presents the work that is supported by the grant RF RSF № 14 11 00485 "High-performance methods and technologies of electro physical processes and devices modeling".

References Références Referencias

1. T. J. Schriber. *Simulation using GPSS*. — New York, Wiley. 1974.
2. O.J. Dahl and K. Nygaard. *SIMULA – A language for programming and description of discrete event systems. Introduction and user's manual*. NCC, Sept. 1967.
3. O.J. Dahl, B. Myhrhaug and K. Nygaard. *SIMULA 67 Common Base Language*. NCC, May 1968.
4. G. Kiczales, O. Lamping, A. Mendhekar and other. *Aspect-oriented programming* http://citeseerx.ist.psu.edu/viewdoc/similar?doi=10.1.1.115.8660&type=ab
5. M. Wooldridge, *An Introduction to Multi-Agent Systems*. — John Wiley & Sons Ltd, 2002, paperback, 366 pages, ISBN 0-471-49691-X.

6. P.O. Skobelev. *Holistic approach to the creation of open multi-agent systems* — Proceedings of the 3rd International Conference on control and modeling of complex systems, Samara: SSN RAS, 2001, p. 147 – 160 (in Russian).
7. REPAST: *Recursive Porous Agent Simulation Toolkit*. http://repast.sourceforge.net/.
8. G. Booch. *Object-Oriented Analysis and Design with Applications*. Addison-Wesley. 2007. ISBN 0-201-89551-X
9. C. A. R. Hoare. *Communicating Sequential Processes*. — Prentice-Hall International. Englewood Cliffs, New Jersey, 1985.
10. I.N. Skopin. *Local and global time in modeling developing systems*. — In Proceedings of the 7th Ershov International Conference "Perspectives of System Informatics", Workshop on Science Intensive Applied Software. Novosibirsk, 2009, p. 254–259 (in Russian).
11. I.N. Skopin. *Hierarchy and developing simulation systems*. In Problems of System Informatics. Novosibirsk: Ltd. "Siberian Scientific Publishers", 2010. — p. 188-214 (in Russian).
12. N.N. Nepeivoda, I.N. Skopin. *The Foundation of Programming*. — Moscow, Izhevsk: Institute of Computer Sciences Reseaching, 2003 (in Russian).
13. V.Malyshkin. *Assembling of Parallel Programs for Large Scale Numerical Modeling*. – In the Handbook of Research on Scalable Computing Technologies. IGI Global, USA, 2010, 1021 pp, Chapter 13, pp. 295 – 311. ISBN 978-1-60566-661-7
14. Ben Collins-Sussman, Brian W. Fitzpatrick, C. Michael Pilato *Version Control with Subversion.Next Generation Open Source Version Control*. — O'Reilly Media, 2004, 320 p.
15. S.V. Maklakov C.B. *BPwin and ERwin CASE-tools of developing information systems*. — Moscow: Dialog-MIPR, 2001. — 340 с.
16. I.N. Skopin. *Development of software systems interfaces*. — In System Informatics, issue 6 "The problems of architecture, analysis and software development". Novosibirsk: Nauka, 1997, p. 34-96 (in Russian).
17. I.N. Skopin. *An approach to the design of application interfaces*. — In joint issue of the book "Computing technology" v. 20 and "Bulletin of Al-Farabi KazNU. Series Mathematics, Mechanics, Computer Science" № 3 (86), 2015. — Novosibirsk, Almaty. — p. 332 – 345. ISSN 1560-7534, 1563-0285 (in Russian).
18. V.P. Il'in, I.N. Skopin. *About Performance and Intellectuality of Supercomputer Modeling*. - Programming and Computer Software, 2016, Vol. 42, No. 1, pp. 5–16.

Global Journals Inc. (US) Guidelines Handbook 2017

www.GlobalJournals.org

FELLOW OF ASSOCIATION OF RESEARCH SOCIETY IN COMPUTING (FARSC)

Global Journals Incorporate (USA) is accredited by Open Association of Research Society (OARS), U.S.A and in turn, awards "FARSC" title to individuals. The 'FARSC' title is accorded to a selected professional after the approval of the Editor-in-Chief/Editorial Board Members/Dean.

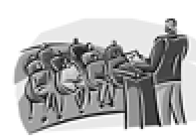
- The "FARSC" is a dignified title which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., FARSC or William Walldroff, M.S., FARSC.

FARSC accrediting is an honor. It authenticates your research activities. After recognition as FARSC, you can add 'FARSC' title with your name as you use this recognition as additional suffix to your status. This will definitely enhance and add more value and repute to your name. You may use it on your professional Counseling Materials such as CV, Resume, and Visiting Card etc.

The following benefits can be availed by you only for next three years from the date of certification:

FARSC designated members are entitled to avail a 40% discount while publishing their research papers (of a single author) with Global Journals Incorporation (USA), if the same is accepted by Editorial Board/Peer Reviewers. If you are a main author or co-author in case of multiple authors, you will be entitled to avail discount of 10%.

Once FARSC title is accorded, the Fellow is authorized to organize a symposium/seminar/conference on behalf of Global Journal Incorporation (USA).The Fellow can also participate in conference/seminar/symposium organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent.

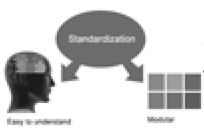


You may join as member of the Editorial Board of Global Journals Incorporation (USA) after successful completion of three years as Fellow and as Peer Reviewer. In addition, it is also desirable that you should organize seminar/symposium/conference at least once.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The FARSC can go through standards of OARS. You can also play vital role if you have any suggestions so that proper amendment can take place to improve the same for the benefit of entire research community.

As FARSC, you will be given a renowned, secure and free professional email address with 100 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders, Auto-Responders, Email Delivery Route tracing, etc.



The FARSC will be eligible for a free application of standardization of their researches. Standardization of research will be subject to acceptability within stipulated norms as the next step after publishing in a journal. We shall depute a team of specialized research professionals who will render their services for elevating your researches to next higher level, which is worldwide open standardization.

The FARSC member can apply for grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A. Once you are designated as FARSC, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria. After certification of all your credentials by OARS, they will be published on your Fellow Profile link on website https://associationofresearch.org which will be helpful to upgrade the dignity.

The FARSC members can avail the benefits of free research podcasting in Global Research Radio with their research documents. After publishing the work, (including published elsewhere worldwide with proper authorization) you can upload your research paper with your recorded voice or you can utilize chargeable services of our professional RJs to record your paper in their voice on request.

The FARSC member also entitled to get the benefits of free research podcasting of their research documents through video clips. We can also streamline your conference videos and display your slides/ online slides and online research video clips at reasonable charges, on request.

The FARSC is eligible to earn from sales proceeds of his/her researches/reference/review Books or literature, while publishing with Global Journals. The FARSC can decide whether he/she would like to publish his/her research in a closed manner. In this case, whenever readers purchase that individual research paper for reading, maximum 60% of its profit earned as royalty by Global Journals, will be credited to his/her bank account. The entire entitled amount will be credited to his/her bank account exceeding limit of minimum fixed balance. There is no minimum time limit for collection. The FARSC member can decide its price and we can help in making the right decision.

The FARSC member is eligible to join as a paid peer reviewer at Global Journals Incorporation (USA) and can get remuneration of 15% of author fees, taken from the author of a respective paper. After reviewing 5 or more papers you can request to transfer the amount to your bank account.

MEMBER OF ASSOCIATION OF RESEARCH SOCIETY IN COMPUTING (MARSC)

The ' MARSC ' title is accorded to a selected professional after the approval of the Editor-in-Chief / Editorial Board Members/Dean.
The “MARSC” is a dignified ornament which is accorded to a person’s name viz. Dr. John E. Hall, Ph.D., MARSC or William Walldroff, M.S., MARSC.

MARSC accrediting is an honor. It authenticates your research activities. After becoming MARSC, you can add 'MARSC' title with your name as you use this recognition as additional suffix to your status. This will definitely enhance and add more value and repute to your name. You may use it on your professional Counseling Materials such as CV, Resume, Visiting Card and Name Plate etc.

The following benefitscan be availed by you only for next three years from the date of certification.

MARSC designated members are entitled to avail a 25% discount while publishing their research papers (of a single author) in Global Journals Inc., if the same is accepted by our Editorial Board and Peer Reviewers. If you are a main author or co-author of a group of authors, you will get discount of 10%.

As MARSC, you will be given a renowned, secure and free professional email address with 30 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders, Auto-Responders, Email Delivery Route tracing, etc.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The MARSC member can apply for approval, grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A.

Once you are designated as MARSC, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria.

It is mandatory to read all terms and conditions carefully.

Auxiliary Memberships

Institutional Fellow of Open Association of Research Society (USA)-OARS (USA)

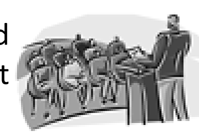
Global Journals Incorporation (USA) is accredited by Open Association of Research Society, U.S.A (OARS) and in turn, affiliates research institutions as “Institutional Fellow of Open Association of Research Society” (IFOARS).

The “FARSC” is a dignified title which is accorded to a person’s name viz. Dr. John E. Hall, Ph.D., FARSC or William Walldroff, M.S., FARSC.

The IFOARS institution is entitled to form a Board comprised of one Chairperson and three to five board members preferably from different streams. The Board will be recognized as “Institutional Board of Open Association of Research Society”-(IBOARS).

The Institute will be entitled to following benefits:

The IBOARS can initially review research papers of their institute and recommend them to publish with respective journal of Global Journals. It can also review the papers of other institutions after obtaining our consent. The second review will be done by peer reviewer of Global Journals Incorporation (USA) The Board is at liberty to appoint a peer reviewer with the approval of chairperson after consulting us.
The author fees of such paper may be waived off up to 40%.



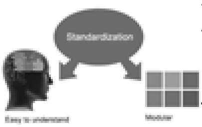
The Global Journals Incorporation (USA) at its discretion can also refer double blind peer reviewed paper at their end to the board for the verification and to get recommendation for final stage of acceptance of publication.

The IBOARS can organize symposium/seminar/conference in their country on behalf of Global Journals Incorporation (USA)-OARS (USA). The terms and conditions can be discussed separately.

The Board can also play vital role by exploring and giving valuable suggestions regarding the Standards of “Open Association of Research Society, U.S.A (OARS)” so that proper amendment can take place for the benefit of entire research community. We shall provide details of particular standard only on receipt of request from the Board.

The board members can also join us as Individual Fellow with 40% discount on total fees applicable to Individual Fellow. They will be entitled to avail all the benefits as declared. Please visit Individual Fellow-sub menu of GlobalJournals.org to have more relevant details.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.



After nomination of your institution as “Institutional Fellow” and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf.
The board can also take up the additional allied activities for betterment after our consultation.

The following entitlements are applicable to individual Fellows:

Open Association of Research Society, U.S.A (OARS) By-laws states that an individual Fellow may use the designations as applicable, or the corresponding initials. The Credentials of individual Fellow and Associate designations signify that the individual has gained knowledge of the fundamental concepts. One is magnanimous and proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice.

Global RESEARCH RADIO

Open Association of Research Society (US)/ Global Journals Incorporation (USA), as described in Corporate Statements, are educational, research publishing and professional membership organizations. Achieving our individual Fellow or Associate status is based mainly on meeting stated educational research requirements.

Disbursement of 40% Royalty earned through Global Journals : Researcher = 50%, Peer Reviewer = 37.50%, Institution = 12.50% E.g. Out of 40%, the 20% benefit should be passed on to researcher, 15 % benefit towards remuneration should be given to a reviewer and remaining 5% is to be retained by the institution.

We shall provide print version of 12 issues of any three journals [as per your requirement] out of our 38 journals worth $ 2376 USD.

Other:

The individual Fellow and Associate designations accredited by Open Association of Research Society (US) credentials signify guarantees following achievements:

- The professional accredited with Fellow honor, is entitled to various benefits viz. name, fame, honor, regular flow of income, secured bright future, social status etc.

- In addition to above, if one is single author, then entitled to 40% discount on publishing research paper and can get 10%discount if one is co-author or main author among group of authors.
- The Fellow can organize symposium/seminar/conference on behalf of Global Journals Incorporation (USA) and he/she can also attend the same organized by other institutes on behalf of Global Journals.
- The Fellow can become member of Editorial Board Member after completing 3yrs.
- The Fellow can earn 60% of sales proceeds from the sale of reference/review books/literature/publishing of research paper.
- Fellow can also join as paid peer reviewer and earn 15% remuneration of author charges and can also get an opportunity to join as member of the Editorial Board of Global Journals Incorporation (USA)
- • This individual has learned the basic methods of applying those concepts and techniques to common challenging situations. This individual has further demonstrated an in–depth understanding of the application of suitable techniques to a particular area of research practice.

Note :

"

- In future, if the board feels the necessity to change any board member, the same can be done with the consent of the chairperson along with anyone board member without our approval.
- In case, the chairperson needs to be replaced then consent of 2/3rd board members are required and they are also required to jointly pass the resolution copy of which should be sent to us. In such case, it will be compulsory to obtain our approval before replacement.
- In case of "Difference of Opinion [if any]" among the Board members, our decision will be final and binding to everyone.

"

Process of submission of Research Paper

The Area or field of specialization may or may not be of any category as mentioned in 'Scope of Journal' menu of the GlobalJournals.org website. There are 37 Research Journal categorized with Six parental Journals GJCST, GJMR, GJRE, GJMBR, GJSFR, GJHSS. For Authors should prefer the mentioned categories. There are three widely used systems UDC, DDC and LCC. The details are available as 'Knowledge Abstract' at Home page. The major advantage of this coding is that, the research work will be exposed to and shared with all over the world as we are being abstracted and indexed worldwide.

The paper should be in proper format. The format can be downloaded from first page of 'Author Guideline' Menu. The Author is expected to follow the general rules as mentioned in this menu. The paper should be written in MS-Word Format (*.DOC,*.DOCX).

The Author can submit the paper either online or offline. The authors should prefer online submission.Online Submission: There are three ways to submit your paper:

(A) (I) First, register yourself using top right corner of Home page then Login. If you are already registered, then login using your username and password.

(II) Choose corresponding Journal.

(III) Click 'Submit Manuscript'. Fill required information and Upload the paper.

(B) If you are using Internet Explorer, then Direct Submission through Homepage is also available.

(C) If these two are not convenient, and then email the paper directly to dean@globaljournals.org.

Offline Submission: Author can send the typed form of paper by Post. However, online submission should be preferred.

Preferred Author Guidelines

MANUSCRIPT STYLE INSTRUCTION <u>(Must be strictly followed)</u>

Page Size: 8.27" X 11'"

- Left Margin: 0.65
- Right Margin: 0.65
- Top Margin: 0.75
- Bottom Margin: 0.75
- Font type of all text should be Swis 721 Lt BT.
- Paper Title should be of Font Size 24 with one Column section.
- Author Name in Font Size of 11 with one column as of Title.
- Abstract Font size of 9 Bold, “Abstract” word in Italic Bold.
- Main Text: Font size 10 with justified two columns section
- Two Column with Equal Column with of 3.38 and Gaping of .2
- First Character must be three lines Drop capped.
- Paragraph before Spacing of 1 pt and After of 0 pt.
- Line Spacing of 1 pt
- Large Images must be in One Column
- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
- Numbering of Second Main Headings (Heading 2) must be in Alphabets, Italic, and Font Size of 10.

You can use your own standard format also.
Author Guidelines:

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript’s Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

1. GENERAL

Before submitting your research paper, one is advised to go through the details as mentioned in following heads. It will be beneficial, while peer reviewer justify your paper for publication.

Scope

The Global Journals Inc. (US) welcome the submission of original paper, review paper, survey article relevant to the all the streams of Philosophy and knowledge. The Global Journals Inc. (US) is parental platform for Global Journal of Computer Science and Technology, Researches in Engineering, Medical Research, Science Frontier Research, Human Social Science, Management, and Business organization. The choice of specific field can be done otherwise as following in Abstracting and Indexing Page on this Website. As the all Global

Journals Inc. (US) are being abstracted and indexed (in process) by most of the reputed organizations. Topics of only narrow interest will not be accepted unless they have wider potential or consequences.

2. ETHICAL GUIDELINES

Authors should follow the ethical guidelines as mentioned below for publication of research paper and research activities.

Papers are accepted on strict understanding that the material in whole or in part has not been, nor is being, considered for publication elsewhere. If the paper once accepted by Global Journals Inc. (US) and Editorial Board, will become the copyright of the Global Journals Inc. (US).

Authorship: The authors and coauthors should have active contribution to conception design, analysis and interpretation of findings. They should critically review the contents and drafting of the paper. All should approve the final version of the paper before submission

The Global Journals Inc. (US) follows the definition of authorship set up by the Global Academy of Research and Development. According to the Global Academy of R&D authorship, criteria must be based on:

1) Substantial contributions to conception and acquisition of data, analysis and interpretation of the findings.

2) Drafting the paper and revising it critically regarding important academic content.

3) Final approval of the version of the paper to be published.

All authors should have been credited according to their appropriate contribution in research activity and preparing paper. Contributors who do not match the criteria as authors may be mentioned under Acknowledgement.

Acknowledgements: Contributors to the research other than authors credited should be mentioned under acknowledgement. The specifications of the source of funding for the research if appropriate can be included. Suppliers of resources may be mentioned along with address.

Appeal of Decision: The Editorial Board's decision on publication of the paper is final and cannot be appealed elsewhere.

Permissions: It is the author's responsibility to have prior permission if all or parts of earlier published illustrations are used in this paper.

Please mention proper reference and appropriate acknowledgements wherever expected.

If all or parts of previously published illustrations are used, permission must be taken from the copyright holder concerned. It is the author's responsibility to take these in writing.

Approval for reproduction/modification of any information (including figures and tables) published elsewhere must be obtained by the authors/copyright holders before submission of the manuscript. Contributors (Authors) are responsible for any copyright fee involved.

3. SUBMISSION OF MANUSCRIPTS

Manuscripts should be uploaded via this online submission page. The online submission is most efficient method for submission of papers, as it enables rapid distribution of manuscripts and consequently speeds up the review procedure. It also enables authors to know the status of their own manuscripts by emailing us. Complete instructions for submitting a paper is available below.

Manuscript submission is a systematic procedure and little preparation is required beyond having all parts of your manuscript in a given format and a computer with an Internet connection and a Web browser. Full help and instructions are provided on-screen. As an author, you will be prompted for login and manuscript details as Field of Paper and then to upload your manuscript file(s) according to the instructions.

To avoid postal delays, all transaction is preferred by e-mail. A finished manuscript submission is confirmed by e-mail immediately and your paper enters the editorial process with no postal delays. When a conclusion is made about the publication of your paper by our Editorial Board, revisions can be submitted online with the same procedure, with an occasion to view and respond to all comments.

Complete support for both authors and co-author is provided.

4. MANUSCRIPT'S CATEGORY

Based on potential and nature, the manuscript can be categorized under the following heads:

Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

Research articles: These are handled with small investigation and applications.

Research letters: The letters are small and concise comments on previously published matters.

5. STRUCTURE AND FORMAT OF MANUSCRIPT

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and to make suggestions to improve briefness.

It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

Format

Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.

Standard Usage, Abbreviations, and Units: Spelling and hyphenation should be conventional to The Concise Oxford English Dictionary. Statistics and measurements should at all times be given in figures, e.g. 16 min, except for when the number begins a sentence. When the number does not refer to a unit of measurement it should be spelt in full unless, it is 160 or greater.

Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

Structure

All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

Color Charges: It is the rule of the Global Journals Inc. (US) for authors to pay the full cost for the reproduction of their color artwork. Hence, please note that, if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a color work agreement form before your paper can be published.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

6.1 Proof Corrections

The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

As changes to proofs are costly, we inquire that you only correct typesetting errors. All illustrations are retained by the publisher. Please note that the authors are responsible for all statements made in their work, including changes made by the copy editor.

6.2 Early View of Global Journals Inc. (US) (Publication Prior to Print)

The Global Journals Inc. (US) are enclosed by our publishing's Early View service. Early View articles are complete full-text articles sent in advance of their publication. Early View articles are absolute and final. They have been completely reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after sending them. The nature of Early View articles means that they do not yet have volume, issue or page numbers, so Early View articles cannot be cited in the conventional way.

6.3 Author Services

Online production tracking is available for your article through Author Services. Author Services enables authors to track their article - once it has been accepted - through the production process to publication online and in print. Authors can check the status of their articles online and choose to receive automated e-mails at key stages of production. The authors will receive an e-mail with a unique link that enables them to register and have their article automatically added to the system. Please ensure that a complete e-mail address is provided when submitting the manuscript.

6.4 Author Material Archive Policy

Please note that if not specifically requested, publisher will dispose off hardcopy & electronic information submitted, after the two months of publication. If you require the return of any information submitted, please inform the Editorial Board or dean as soon as possible.

6.5 Offprint and Extra Copies

A PDF offprint of the online-published article will be provided free of charge to the related author, and may be distributed according to the Publisher's terms and conditions. Additional paper offprint may be ordered by emailing us at: editor@globaljournals.org .

You must strictly follow above Author Guidelines before submitting your paper or else we will not at all be responsible for any corrections in future in any of the way.

Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including <u>definite statistics</u> - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.
- Do not give permission to anyone else to "PROOFREAD" your manuscript.
- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals Inc. (US).

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

Index

C

Catastrophic · 15
Coarser · 12

D

Deadlock • 25, 27
Deferrable • 23, 24, 32
Deterministic • 14, 19, 20, 27, 56, 57
Dissipation • 50

E

Ergodic · 35

I

Implantable · 12
Imprecise · 30
Intellectuality · 63

L

Laborious · 62

P

Pedagogy · 3, 8, 9
Preemptive · 13, 15, 17, 19, 21, 22, 24, 26, 27, 34

R

Rayleigh · 48
Reiterates · 3

S

Sporadic · 14, 15, 17, 19, 20, 21, 22, 23, 24, 27, 32
Stochastic · 21, 24

save our planet

Global Journal of Computer Science and Technology

Visit us on the Web at www.GlobalJournals.org | www.ComputerResearch.org
or email us at helpdesk@globaljournals.org

ISSN 9754350