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Highlights

- Letter Generator System
- Software with C Language
- Analytical Process Data
- Agent Reusability Mechanism

Discovering Thoughts, Inventing Future

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Automatic Cover Letter Generator System from CVs (ACLGS)

By Hasan Al Shalabi, Rafeeq Al-Hashemi & Tahseen A. Al-Ramadin
Al-Hussein Bin Talal University

Abstract - The proposed system comes to overcome the problem of writing a C.V. Cover letter which requires some linguistic skills and a lot of experience in this domain in addition to its cost in term of time and money. The ACLGS solved the problem by developing an auto generated cover letter based on the user C.V. regardless its format. The ACLGS takes the user C.V. and the carrier announcement that contains the job requirements and the skills needed as input. The system solved the problem by building a template as a frame of slots each slot contains a required skill for the job; the system extracted the required information from the user CV and fills the slots in an automatic fashion. The ACLGS applies the Information retrieval methodologies to extract information with intelligence trends to mine the user C.V. in terms of part of speech tags and some of indicator words that the system used to recognize the proper data and required information. In addition, the system specifies a set of features for each slot in the form. The user C.V. clustered into a number of categories (e.g. Personal information, Qualifications, Experience, Skill, Rewords, and Publications). These categories are used as additional features for the extracted information and data. The system took into account the problem of sentence coherence and improves the output document through using pre-specified sentences that inserted into the output document based on the extracted information discovered from the user C.V.

Keywords : *cover letter, curriculum vitae, information retrieval, information extraction.*

GJCST-C Classification : *H.3.3*

AUTOMATIC COVER LETTER GENERATOR SYSTEM FROM CVS ACLGS

Strictly as per the compliance and regulations of:

Automatic Cover Letter Generator System from CVs (ACLGS)

Hasan Al Shalabi [α], Rafeeq Al-Hashemi [σ] & Tahseen A. Al-Ramadin [ρ]

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Keywords : cover letter, curriculum vitae, information retrieval, information extraction.

I. Introduction

The cover letter is a letter usually attached to the applicant's CV to summarize the information related to that particular job. It reflects the applicant's personality in a positive way and includes basic information about his/her expertise and qualifications. It should reflect his/her enthusiasm and competency for the job. The content of the letter should be complementary to the CV, translation and adaptation-oriented information, biography realism in addition to the personal touch. A well-constructed letter often motivates the reader to go through the entire content of the CV. Yet, such a well-organized letter requires significant time and effort to have it in an acceptable shape.

A typical CV does not allow for prolonged and detailed sentences or paragraphs. While, on the other hand, a cover letter could be employed to deliver detailed and specific information signifying the applicant's capability and interest about the issue for which the letter has been written.

Rule-based information extraction is a two-stage process: learning rules and application rules for target information. Information extraction rules are mainly used to indicate the target information and the context constrained environment, such as CIRCUS [7.] extraction rules of the system concept nodes, each concept node specified rules trigger words, activation conditions, hard constraints, soft constraints and the position of the target information. The trigger word is used to indicate that the target information context must contain keywords, language patterns of activation conditions specified must meet rigid constraint is mandatory semantic constraints, soft constraints is a semantic restrictions, but this restriction is violated. Concept node later AutoSlog [1], CRYSTAL [3].

LIEP [5], PALKA [2], RAPIER [6] and other extraction rules of the system have a similar end. Shows that as long as the text to meet the rules specify constraints, namely to achieve the purpose of information extraction. Therefore, the learning of the rule itself and extracting key information, information extraction is relegated to a secondary process. Rules epitomize the fusion of domain knowledge and linguistic knowledge; build process of the knowledge acquisition process. According to the manual involvement of the different, the building is divided into three types: the manual preparation of knowledge, knowledge of the semi-automatic acquisition and knowledge rules automatically obtain.

The proposed system takes into consideration many parameters to improve the results in additional to the applicant C.V. the system based its results on the institutes announcement and the job position. The new system gave different results with different sentences which make the output dynamic and not limited to a single template as other research papers. The ACLGS follows the Information retrieval methodologies to extract information with intelligence trends to mine the user C.V. in terms of part of speech tags and some of indicator words that the system used to recognize the proper data and required information

II. Proposed System

The ACLGS is a new approach of creating cover letter based on processing two documents: the user

Author : College of Information Technology Al-Hussein Bin Talal University.

C.V. and the job announcement. This research paper uses different methods to get best results; it uses mainly information extraction and text mining techniques. Figure (2) illustrates the proposed system.

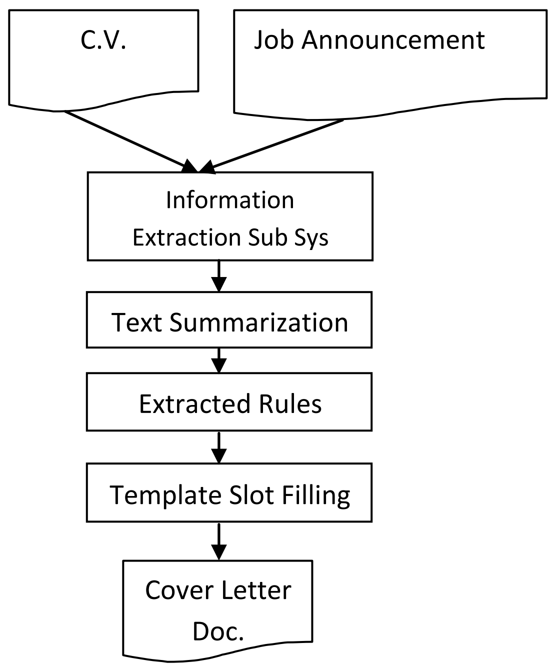

Figure 2 : The proposed system diagram

Two types of cover letters the system serves, one for a faculty position and the other for post-doctorate degree.

A classifier used to identify the job title using the announcement and assign a class for it. Based on that class, the system selects the best template for the cover letter. The classifier builds its decision based on a set of keywords that identifies the appropriate class.

We use the CTS Tagger [8] subsystem to identify the part of speech tag (P.O.S). The P.O.S is a significant feature that the system used for information extraction in additional to other features.

The algorithm starts by pre-processing the input documents as a required step in order to get good results. This step partitions the C.V. into many segments as in the algorithm (1) below.

Input: *User C.V. Doc. and Job Announcement Doc.*
Output: *Cover Letter*
1. *Announcement and C.V. analysation and classification and identifying the job Title*
2. *Preprocessing*
   - *2.1. C.V. Document Segmentation*
   - *2.2. Tokenization*
   - *2.3. Word Tagging*
3. *Processing*
   - *3.1. Template Selection*
   - *3.2. Information extraction based on the pre-extracted rules to find the required information.*
   - *3.3. Template Slots filling according to the predefined features.*
4. *Post Processing*
   - *4.1. Add additional sentences base on the user skills and experiments.*
5. ***End.***

Proposed System Algorithm (1):

The segments of the C.V. are (Personal information, Qualifications, Experience, Membership, Publications, Supervision, Awards and Patents). We know that there is no unified C.V. template but the system identifies these parts based on a set of features .Table (1) lists all the subjects that will be searched in the C.V. and the synonyms that may be written.

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No	Keywords	Synonyms
1.	Contact	Contact information Personal information - Name and Date & email etc.
2.	Qualification	Academic qualification - Ph.D., MS.C. , BSc Education
3.	Experience	Academic Experience, Teaching Experience Work History, Employment Part time, Fields of interest
4.	Publications	Research, Scholarship Patent, Journal Articles
5.	Awards	Honors, Professional memberships/affiliations. Conferences & courses Honors/awards/fellowships/grants: Professional qualifications

Table 1 : Synonyms

Two more steps implemented in the preprocessing step are the tokenization and word tagging. Based on the classifier the right template will be selected. The template contains many slots with identified features that will be filled by the system as in figure (3) for Post-Doctorate.

Date: << **Date** >>

Location: << **location** >>

I am writing to apply for the postdoctoral position at your department beginning in <<**Var1**>> . I am currently in a doctoral program in the department of << **Var2**>> at the <<**Var 3**>> , and fully I expect to complete my PhD degree by << **Var4**>>**.** I am extremely interested in obtaining this position.

As a PhD student at << **Var 3**>> , I taught for several years a variety << **list 1**>> courses and I made progress in my researches, and I believe my background would be useful in your department. My doctoral dissertation was conducted under the direction of Prof. <<**Var 5**>> in the area of << **Var 6**>>

I would appreciate the opportunity to interview and look forward to hearing from you in the near future. I have enclosed **the C.V** . If you require any additional materials or information, I would be happy to supply it. Thank you very much for your time and your consideration.

Sincerely yours,

<< **name**>>

Figure 3 : Post-Doctorate Template Example

The following table (2) displays the rules and the features used to extract the required information in order to place it in the blanks (Slots). A set of P.O.S patterns was extracted by examining the C.V. These patterns used to be one of the features that help in extracting the required items from the C.V. Where the number of the C.Vs used in the dataset is about 100 document form the field of Academic Faculty members especially in the domain of Information technology.

Variable name	Description	Taken from	INDICATION WORDS In C.V.	P.O.S Tag
Date	Date	Computer date	-	-
Location	Address	Careers	-	-
<< Var 1>>	Semester	Careers	Beginning	/NN /IN /NNP /CD
<< Var 2>>	Dep. Name	C.v // contact information	Department of	/IN /DT /NN /IN /NNP
<< Var 3>>	Univ. Name	C.v// contact information	At the ____ University	/IN /DT /NNP /IN /NNP /NNP
<< Var 4>>	Semester	C.v //academic qualification	Semester/ Course/ *follow by one of the semeste name(first, second,….etc.)*	/PRP /VBP /TO /VB /PRP$ /NNP /NN /IN /NNP /CD
<< Var 5>>	Prof name	C.v//academic qualification	Supervisor / Supervised by/ / Under the direction of	/PRP$ /JJ /NN /VBD /VBN /IN /DT /NN /IN /NNP /NNP
<< Var 6>>	Dissertation area	C.v// academic qualification	Domain/ Area / Field / Specialization	/IN /DT /NN /IN /DT /NN /IN /JJ /NN /VBZ ./.
<< list 1>>	Courses name	CV// Experience	Taught courses/ interesting courses/	/NN [/NN]*
<< name>>	Applicant's Name	CV // Contact information	Name/ Applicant/	/NNP [/NNP]*

Table 2 : Slots features and rules

One more feature adapted to extract the required information which defines the set of keywords that are the indicator of the existing of important words in the C.V. these keywords called as indicator words as shown in table (2). The indicator words are frequently written before the required information that the system tries to extract.

The algorithm takes into account the calculation of the user (Faculty member) experience years. In some C.Vs the user didn't write the total experience years so the algorithm extract that value by accumulating the years of experience. The algorithm starts by calculating the period of each job especially that the users wrote the experience of each job in the C.V. So we find the period of the experiment by subtracting the second value from the first one, and finally we accumulate all these periods to give the total number experiment years.

The algorithm takes into consideration the information exists in the carrier announcement document that much the user information and used as a feature to be searched in the user C.V. One of the data that the algorithm looks for is the University or College and department name to be inserted in the beginning of the Created Cover Letter and the job title that can be extracted by the set of features that described in table (2) above.

The system provides a set of sentences for each paragraph in the cover letter. These sentences clustered into three categories for the three paragraphs that cover letter consists of. The system selected randomly by the system in order to make results vary as much as possible as in table (3).

First Paragraph Sentences
I am interested in a (type of work) position in your (company, agency). I believe that my interest, experience and education support my ability to learn and produce in this area.
I am interested in applying for a (teaching position, opportunity in your school district). I will be/am certified to teach (subject or grades).
Second Paragraph Sentences
My educational background, experience in this area, and my sincere interest in the challenges offered support my belief that I have the qualifications you seek.
During the past four years of college, I have developed through education and experience a strong desire to find an entry level opportunity in (work area). I feel that I am equipped with educational preparation and valuable experience that supports my qualification for a career in ___________ .

A position with your <institute> would provide the kind of opportunity and challenge I seek.
Third Paragraph Sentences
Enclosed is a resume describing my employment and educational background for your consideration.
Enclosed is a resume describing my education and employment background in support of my qualifications for your staff opportunity.
If you will review the enclosed resume you will see that I have had a strong education and varied experience which is compatible with (supportive of) the requirements of this position.
I would appreciate an opportunity to discuss my qualifications in an interview at your convenience. I look forward to hearing from you.
Because of my strong research and teaching background, I am confident I would contribute immediately to the strong reputation that your department already enjoys.
I look forward to hearing from you.
Because of my graduate training, my doctoral research, and my teaching [experience/interests], I am uniquely qualified for this job.

Table 3 : Sample Set of Stored sentences [9,4]

In the post-processing step we try to give better results and put the final cover letter in different formats and content, the algorithm adds some sentences that depend on the C.V. and the announcement. Each user has different skills and may have different highlights in his C.V. according to that the algorithm will select a suitable sentence from the database to fit in.

III. Results

The following is an example of a cover letter generated by the system for a faculty member applicant as in figure (4).

< Address: P.O. Box 20, Ma'an, Jordan

Mobile telephone: + 962 799889571
Email: Rafiq_alhashimy@yahoo.com

Website: ahu.edu.jo

<29.12.2012>

Application for position of Faculty member
Dear Chair of **Computer Science Department**,

I would like to be considered for the position of [Faculty member] in [computer science department] at the [University of Northern Iowa].

My educational background, experience in this area, and my sincere interest in the challenges offered support my belief that I have the qualifications you seek. My research and teaching interests fit extremely well with the requirements of this post and with existing members of staff. I have extensive teaching experience in the *<department of computer science>* *<at Al-Hussein Bin Talal University>*, most of it focused on < Artificial Intelligence, Distributed Database, Computation Theory, Computer Technology, Network Security, Image Processing, Genetic Algorithm, Software Project Management, Object Oriented Programming, Logic Design. I have taught programming languages such as C++, Java, PROLOG, and Visual Basic. Net.>. My work provides a useful link between < Artificial Intelligence, Data Mining > in the department, encouraging research and teaching collaborations. I have more than 4 years of Experience in administration (as Dean, Vice Dean, and Chairman), I am on several committees, Reviewing Activities.

I was awarded my Ph.D. by the 10- Nov- 2006 at Technology University in< department of computer science>. My thesis was entitled < Automatic Keyword Extraction Using Combined Methods >. Samples of My publication are as follows: < Data Gathering for Periodic Sensor Applications, Text Summarization Extraction System (TSES), developing a Virtual Laboratory for a Communication and Computer Networking Course >

Enclosed is a resume describing my employment and educational background for, I would appreciate an opportunity to discuss my qualifications in an interview at your convenience.
I look forward to hearing from you.

Yours sincerely,
<Rafeeq Al-Hashemi>

Figure 4 : Faculty member position cover letter Generated by the system

IV. Conclusions and Future Works

The need of cover letters, the difficulties that the applicants faced and the cost of writing the cover letter by experts motivated us to design a system to auto generate the cover letter. ACLGS takes into consideration many parameters to improve the results in additional to the applicant C.V. the system based its results on the institutes announcement and the job position. The new system gave different results with different sentences which make the output dynamic and not limited to a single template as other research papers.

For future work, to improve our proposed system in order to get more valuable and accurate outputs by adding more sentence database to generate completely different output. And implementing the research on Arabic language.

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Software Agent Reusability Mechanism at Application Level

By Deepti Aggarwal & Aarti Singh
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Abstract - The usage of already available software agents plays a vital role in the process of development of application specific software. This reuse also leads to software development cost benefits as well as may ensure the timely delivery. This paper lay down an idea that for reusing reactive multi-agents systems two factors are to be considered i.e. (i) abstract description of agent in application independent way and (ii) reuse of such systems through adoption in specific domain[25]. For such a development main requirement is the effective reusable software abstractions. In present study the role of abstraction level and dependence level is analyzed for intelligent agents.

Keywords : software reuse, software agents, software abstraction.

GJCST-C Classification : D.2.13

SOFTWARE AGENT REUSABILITY MECHANISM AT APPLICATION LEVEL

Strictly as per the compliance and regulations of:

Software Agent Reusability Mechanism at Application Level

Deepti Aggarwal [α] & Aarti Singh [σ]

Abstract - The usage of already available software agents plays a vital role in the process of development of application specific software. This reuse also leads to software development cost benefits as well as may ensure the timely delivery. This paper lay down an idea that for reusing reactive multi-agents systems two factors are to be considered i.e. (i) abstract description of agent in application independent way and (ii) reuse of such systems through adoption in specific domain[23]. For such a development main requirement is the effective reusable software abstractions. In present study the role of abstraction level and dependence level is analyzed for intelligent agents.

Keywords : software reuse, software agents, software abstraction.

I. Introduction

The reuse of software components refers to the process of using software artifacts for the development of new software. Since the evolution of computational systems, the reuse of software is in practice. Reuse of the already existing code to develop new software or developing the software that can be reused is one of the prominent areas of research. The present study mainly focuses on the intricacies involved in reuse of multi agent software systems.

A **software agent** is a computer program that symbolizes a user. It implies that an agent has the capacity to make the appropriate decisions.

Using software agents for Domain-oriented component design method is a newly proposed reuse approach in software engineering and it starts from the process of acquiring business knowledge within a common application domain. After having the knowledge of the application domain, a collection of business logic is mapped into components which can be reused in the future deign. This method increases the functional completeness of the software component and makes it reusable to a lower extent. Since the business requirements of different organizations are diverse and are changing, so a reusable knowledge base that can be adaptive and flexible are yet to be provided by current domain component design methods. In the following section the major design issues of the reusable software components are addressed.

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Author σ : Associate Professor, M.M. Institute of Computer Technology & Business Management, M.M. University, Mullana, India.

II. Design Issues

The major issues to be considered in the development of agent-based software systems include [3], [11], [12].

- Scheduling of tasks and their synchronization
- Prioritization of tasks by the agent
- Assignment of tasks by the agents
- Representation of agents in different environments, and storage of their internal state
- For heterogeneous platform what are the Behavioral changes of the agents
- How message passing can be facilitated and communication can be established
- Usage of hierarchies of agents

Apart from the above stated issues following issues are critical issues in reusability of the software agents:-

- Usage of software agents on diverse platforms
- Sharing or reconstructing ontology for software agents being reused

III. Software Abstractions

The abstraction of software artifacts has to be used in every method of software reuse. A software abstraction is high-level, in the sense that attributes corresponding to one or more realizations of facts in more detailed level are represented. Some attributes describe what and how abstraction is done [19]. For the clear understanding, comparison and selection of appropriate software artifacts, the small abstractions are needed and these abstractions can be used in reuse process. The clear understanding of user interface has to be there so that a set of software artifacts can be composed and this should be depicted in the abstraction specification. Every artifact plays an important role in application development and it may not be concluded that the final deliverable i.e. the software product satisfies the user requirements or not.

An abstraction is composed of a fixed, a variable and a hidden part. Only the fixed and variable part is visible in the abstraction specification. The fixed part represents the invariant features and the variable part symbolizes the variable features of the abstraction. The hidden part consists of the realization details.

The *cognitive distance* is the measure of the effectiveness of the reuse technique. It is the effort

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required to transfer software system from one phase to another in terms of intellect. The goal of the reuse technique should be to minimize the cognitive distance between the abstraction and the final software product. To minimize this distance the abstraction specification should more specifically represent the abstractions which are used for application domain. Finally the mapping of the specifications should be made partially or fully automated [10].

IV. Multi-Agent Application Engineering

"Multi-Agent Application Engineering" is a domain oriented research towards reducing software complexity and increasing productivity. This can be accomplished via techniques and tools that aid software reuse in Multi-Agent Software Engineering.

In Application Engineering, the software abstractions that can be reused are created. Application Development is the process of developing domain specific applications using software abstractions that can be used again and again [12].

In the following section the model for developing agent based application specific software is presented. A set of activities and various tools and libraries that can be used is also discussed for developing high level software abstractions.

a) Developing Multi-Agent Specific Applications

A multi-agent specific application is made using the constitution of a group/assortment of reusable agent frameworks available in the library of the development environment as shown in Figure 1. These frameworks are realizations of high-level software abstractions in the library.

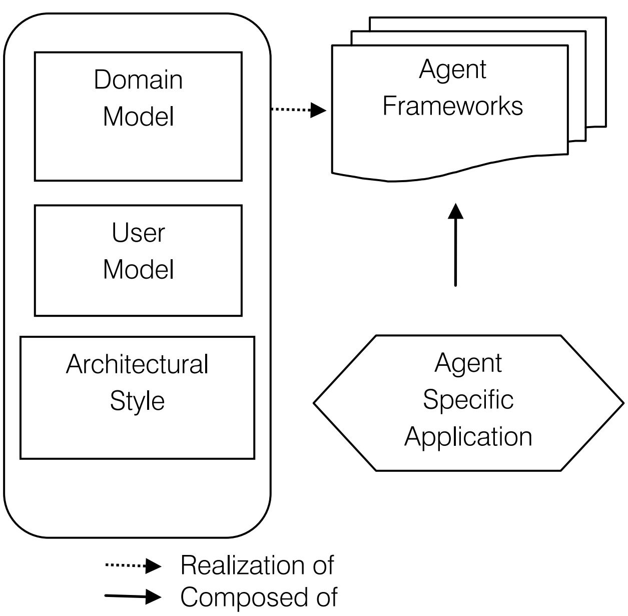

Figure 1 : A model for Agent-based Application Development [23]

Particular requirements of a multi-agent specific application are used, to map the specification level of a domain model into a realization satisfying such needs. The realization should have associated a set of frameworks, which are agent-based solutions to those requirements. Requirement analysis in Agent-based Application Development should also consider particular preferences of users of the multi-agent specific application. Therefore, these user profiles are used to map the specification level of a user model into a realization satisfying these preferences or user needs. The realization should have associated a set of frameworks, which are agent-based solutions to those needs. The choice of mapping to select best frameworks depends on the fact that which particular style of agent architecture is to be used for the design.

b) Developing High – Level Software Abstractions

The reusable agent-based software abstractions are illustrated and described considering their level of abstraction and their dependence level from the application or user domain: domain models, user models, agent-oriented architectural styles, agent-oriented design patterns, agent-oriented frameworks and software agents.

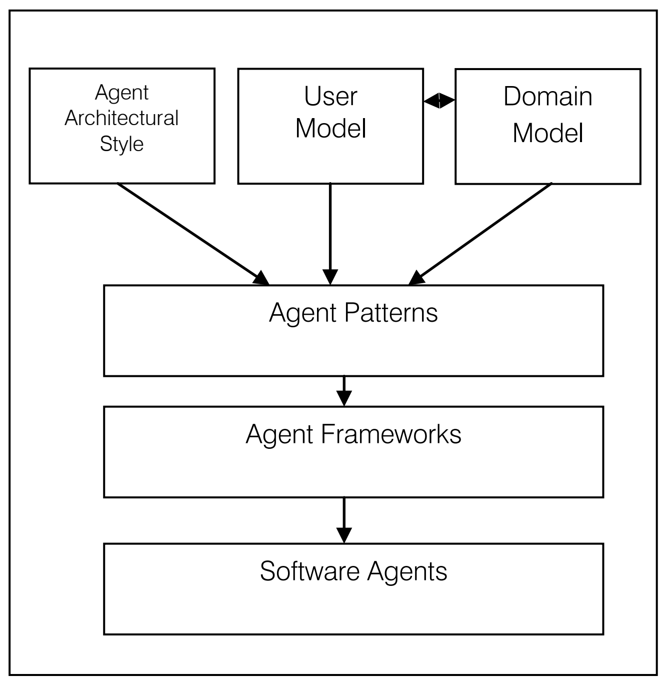

Figure 2 : Agent Based Application Development Process

c) Requirement Analysis

The next phase is to extract the requirement specifications of the domain of the application. The application domain, the user model and the interactions of domain model and the user model result in a reusable software product.

The domain model specifications are depicted at a high level of abstraction. This model represents the conception of problem. The language represents the definitions necessary for elements, processes and their relationships in the system. The user model specifies the needs and requirements of the end user.

d) Design of the Model

The outcome of the design phase is the reusable design attributes of Agent – Based Application Engineering. It consists of the agent based architectural styles, software patterns and the frameworks.

Architectural style is the set of designing rules which will specify the type of elements and coupling which can be used to constitute the system and subsystems.

The software pattern identifies and specifies the problems can commonly occur at conceptual and architectural level. These problems generally originate from architectural styles being used, domain model and the user model. A software pattern has a set format so that it can be easily propagated. This format asserts the problems that have been depicted by the pattern and forces the action to be taken to resolve the problems. For making use of such pattern there should be a framework that validates the pattern and provides a probable solution to the problem. If it was previously used in some application, that has to be mentioned in the framework. Some agent based software patterns have already been proposed that can be used at architectural level or later stages in the agent design [2, 17]. The basic design guidelines are provided by the architectural styles and the agent patterns so that agent oriented frameworks can be developed [3, 5, 20]. The participating agents are chosen from the bank of agents which facilitates domain dependent or domain independent functionality.

V. Conclusion

A new horizon of reuse based software engineering using agent paradigm has been introduced. With the introduction of one more layer of abstraction at the software level, the present study may be used for the development of reusable software components across various platforms. Thus it proposed an effective model for agent based reuse.

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Development of Material Requirements Planning (MRP) Software with C Language

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Abstract - Now a day's a number of manufacturing firms in developing countries do not practice affordable, efficient and user friendly inventory management tools which has been identified as a major cause of high inventory cost for adequate planning. This study focuses on the development of Material Requirements Planning (MRP) software with programming language C that can be used by the local industries for inventory management in a job shop manufacturing environment. An algorithm has been developed to understand the MRP processing logic. A manual method of calculation to solve MRP problem has also been shown. Evaluation tests of the software were carried out using various products ranging from those with simple structure of single product to complex structure. The software was shown to be user friendly and allow for easy data input and output to be saved and retrieved for future planning. The input process of the software has been shown step by step. The output of the program shows the time-phased requirements for assemblies, parts and raw materials as well as the missing deliveries and time required to meet the missing deliveries.

Keywords : MRP, MPS, BOM, lead time, lot-sizing, inventory, software, C language.

GJCST-C Classification : K.6.1

DEVELOPMENT OF MATERIAL REQUIREMENTS PLANNING MRP SOFTWARE WITH C LANGUAGE

Strictly as per the compliance and regulations of:

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Md. Saiful Islam [α], Md. Mahbubur Rahman [σ], Ripon Kumar Saha [ρ] & Abu Md. Saifuddoha [Ѡ]

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I. Introduction

Materials Requirements Planning (MRP) is a computer-based production planning and inventory control system which is concerned with both production scheduling and inventory control. It is a material control system that attempts to keep adequate inventory levels to assure that required materials are available when needed. The main purpose of MRP software is to facilitate the calculation of requirements of materials and timing.

Thus it is a technique for determining the quantity and timing for the acquisition of dependent demand items needed to satisfy master production schedule (MPS) requirements by converting three inputs, bill of material, inventory data and master production schedule into time-phased requirements for subassemblies, component parts and raw materials, working backward from the due date using lead times and other information to determine when and how much to order [1]. The major objectives of an MRP system are to 1) ensure the availability of materials, components, and products for planned production and for customer delivery 2) maintain the lowest possible level of inventory 3) plan manufacturing activities, delivery schedules, and purchasing activities [2].

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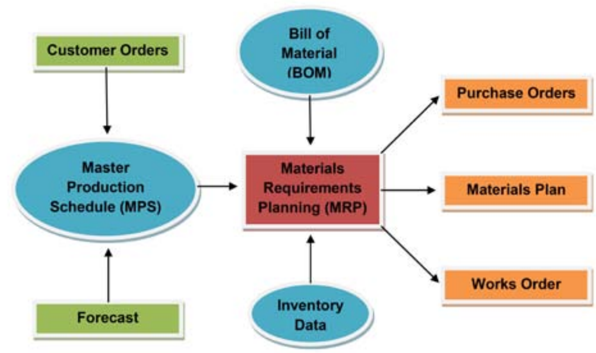

Figure 1 : Block diagram of MRP system

Before 1960's there was no satisfactory method available for handling the inventory of dependent items. A firm's formal inventory system was often patterned after order points and either misapplied or broken down into a maze of informal method when it comes to handling dependent items. There was no feasible method of keeping accurate records of thousands of inventory items to keep them out of too much scheduling trouble. Unfortunately, these did not always achieve the intended objective, however they always made a contribution to the inventory carrying and storage costs. During the 1960's the computer opened the door to an inventory system that could keep up to date records on the status of all inventory in stock. This brought a better understanding of production operation and new ways of managing production. It also brought out some new terminology, such as priority in material requirement planning system and capacity planning. The American production and inventory control society (APICS) has done much to standardize the terminology in this field and material requirement planning is popularly abbreviated as MRP in the world over [3].

In 1964, Joseph Orlicky as a response to the TOYOTA Manufacturing Program developed Material Requirements Planning (MRP). First company to use MRP was Black & Decker in 1964, with Dick Alban as project leader. In 1983 Oliver Wight developed MRP into manufacturing resource planning (MRP II) [4]. Orlicky's book is entitled The New Way of Life in Production and Inventory Management (1975). By 1975, MRP was implemented in 150 companies. This number had grown to about 8,000 by 1981. In the 1980s, Joe Orlicky's MRP evolved into Oliver Wight's manufacturing resource planning (MRP II) which brings master scheduling, rough-cut capacity planning, capacity requirements planning, S&OP in 1983 and other concepts to classical MRP. By 1989, about one third of the software industry was MRP II software sold to American industry ($1.2 billion worth of software) [5].

MRP is the way of life for many industries fabricating and assembling products like automobiles and radios. It is generally applicable in situations of multiple items with complex bills of materials and is especially suited to manufacturing settings where the demands of many of the components and subassemblies depend on the demands of items that face external demands. MRP is also suitable when the manufacturing cycle is long for the finished product and lead time for components and raw materials are relatively long. While demands for end items are independent the demands for components used to manufacture end items depend on the demands of the end items. The distinctions between independent and dependent demands are important in classifying inventory items and in developing systems to manage items within each demand classification [6].

The Master Production Schedule (MPS) includes quantities of products to be produced at a given time period. Quantities are included both at aggregate and detailed levels. Aggregate may refer to monthly production and detailed may refer to weekly or daily production. The master production schedule takes the form of a table in which rows represent products and columns represent time components [7]. The bill of materials (BOM) is a list of the raw materials, sub-assemblies, assemblies, parts and the quantities of each needed to manufacture an end product. Lead time is the time interval between ordering and receiving an item [8]. Sometimes it means the assembly time or processing time to produce an item.

A key variable in MRP system design is the selection of lot-sizing rule (how much to order) based on the lead time. The problem of lot sizing is one of satisfying the requirements while trying to minimize holding and setup costs. There are basically two major classes of lot sizing techniques namely Static and Dynamic. A static lot-sizing rule orders the same quantity each time an order is placed and often generating higher average on hand inventory for extra safety stock [9]. Dynamic decision rule changes the order quantity with each order such that each order is just large enough to prevent shortages over a specified time period by tying lot-size to gross requirements. It generally causes instability with lower-level components unable to respond sufficiently fast to changes in requirements [10] [11]. The lot-for-lot (LFL) ordering is the simplest approach and it refers to order the net requirements for a specific period. The LFL approach minimizes the holding cost by producing just-in-time. In lot-size (LS) ordering the order size must be in multiples of the lot size.

II. Methodology

The methodology used in developing the proposed MRP software adopts the following components namely, a) Problem Analysis b) Manual Method to Calculation c) Software Algorithm d) Software Input 6) Software Output.

a) Problem Analysis

To form a useful bill of material it is convenient to order the items by levels. The level of an item is the maximum number of stages of assembly required to get the item into an end product. Consider a specific final item named 'A' for a manufacturing firm.

MPS

Week/Day	3	7	8	10	12
Required Quantity (A)	250	200	150	300	250

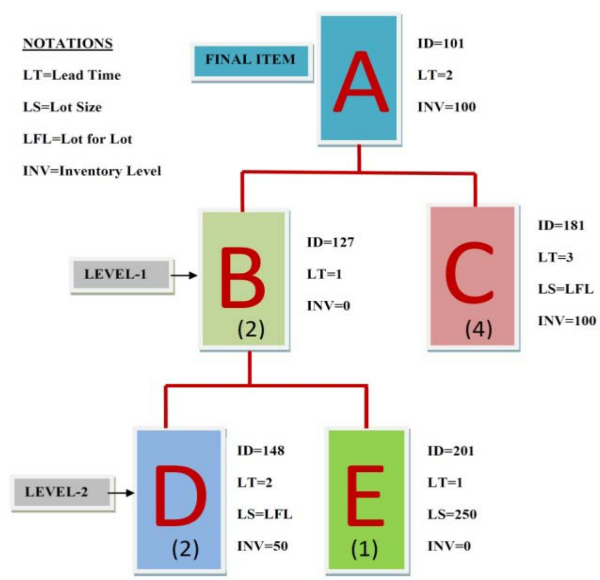

Figure 2 : MPS and Bill of Material for a specific product

According to above bill of material, one unit of final item 'A' requires two units of item 'B' and four units of item 'C'. Again, one unit of item 'B' requires two units of item 'D' and one unit item 'E'. Items 'C', 'D' and 'E' are purchased from different suppliers with various lead time. The beginning inventory levels of items 'A', 'B', 'C', 'D' and 'E' are 100, 0, 100, 50 and 0 respectively. The assembly time with items 'B' and 'C' to produce final item 'A' is 2 weeks. The assembly time with items 'D' and 'E' to produce item 'B' is 1 week. The time intervals between ordering and receiving for items 'C', 'D' and 'E' are 3, 2 and 1 week respectively. The items 'C' and 'D' are purchased with lot-for-lot (LFL) ordering policy but the item 'E' is purchased with lot-size (LS) ordering policy. There are total five orders in the master production schedule (MPS).

b) Manual Method of Calculation

MPS												
Week/Day	1	2	3	4	5	6	7	8	9	10	11	12
Required Quantity (A)			250				200	150		300		250
ITEM: A (LT= 2)												
Gross Requirements							200	150		300		250
Schedules Receipts												
Projected on Hand	100	100	100	100	100	100	100					
Net Requirements							100	150		300		250
Order Receipts							100	150		300		250
Order Releases					100	150		300		250		
ITEM: B (LT= 1)				100×2								
Gross Requirements					200	300		600		500		
Schedules Receipts												
Projected on Hand												
Net Requirements					200	300		600		500		
Order Receipts					200	300		600		500		
Order Releases				200	300		600		500			
ITEM: D (LT= 2)			200×2									
Gross Requirements				400	600		1200		1000			
Schedules Receipts												
Projected on Hand	50	50	50	50								
Net Requirements				350	600		1200		1000			
Order Receipts				350	600		1200		1000			
Order Releases		350	600		1200		1000					
ITEM: E (LT= 1)										500×1		
Gross Requirements				200	300		600		500			
Schedules Receipts												
Projected on Hand					50			150	150	150	150	150
Net Requirements				200	250		600		350			
Order Receipts				250	250		750		500			
Order Releases			250	250		750		500				
ITEM: C (LT= 3)											250×4	
Gross Requirements					400	600		1200		1000		
Schedules Receipts												
Projected on Hand	100	100	100	100	100							
Net Requirements					300	600		1200		1000		
Order Receipts					300	600		1200		1000		
Order Releases		300	600		1200		1000					

Table 1 : Manual method of calculating MRP problem

The required quantity of final item 'A' is 250 for the first order. The firm already has 100 units of final item in inventory. So the firm needs 150 units of 'A' to meet the first order. For 150 units of 'A' it requires 300 units of item 'B' and 600 units of item 'C'. Again, for 300 units of 'B' the firm needs 600 units of item 'D' and 300 units of item 'E'. The inventory level of item 'D' is 50. So, the net requirement of item 'D' is 550. If the firm orders today for 550 units of 'D' from supplier it can receive the order after two weeks. In the meantime the required quantity of item 'E' will be available for lower lead time. It will takes another one day to produce the required quantity of item 'B' with items 'D' and 'E'. In the meantime the required quantity of item 'C' will be available. Finally, it will take another two more days to produce the required quantity of final item 'A' with items 'B' and 'C'. It will take total five weeks to meet the first order. The first order can be delivered in the sixth week.

So, the order no.1 can't be met in third week. This order needs another 3 more weeks to meet.

c) Software Algorithm

Step 1 : Structure has been used to declare the variables of each item (item ID, item name, inventory level, lead time, lot size, number of item needed for each upper item, upper item ID, Number of lower item etc).

Step 2 : Input the total number of level and information of each item (Bill of Materials).

Step 3 : Input the total number of deliveries and timing & required quantity of final item for each delivery (Master Production Schedule).

Step 4 : Temporary inventory level variable is used to hold the inventory level of each item temporarily which will be destructed after calculation.

Step 5 : Finding out the order release date and temporary inventory level of independent item (final item) for each delivery

Step 6 : Finding out the order release date and temporary inventory level of all dependent items (sub items) for each delivery. If an item occurs more than once it will update the temporary inventory level for all repeated items simultaneously.

Step 7 : If the order release date of an item is negative it means that the Order Release falls before the planning period. So, the delivery can't be possible.

Step 8 : Then searching for the maximum negative value of order release date among all items for the deliveries which are not possible. This maximum negative value yields the number of weeks/days required to meet the missing deliveries.

Step 9 : For a missing delivery shift the inventory level of all items to the next delivery.

Step 10 : Again finding out the order release date and temporary inventory level of all items for the remaining deliveries because of missing the delivery

Step 11 : Repeat steps 9 and 10 for the remaining missing deliveries.

Step 12 : Holding the missing deliveries in an array.

Step 13 : Finally calculate the order release date and inventory level of all items for which deliveries are possible.

Step 14 : Show which deliveries can't be met and the required weeks/days to meet those deliveries.

Step 15 : Show the output of MRP that is the time-phased requirements for assemblies, parts and raw materials.

Step 16 : Show the final inventory level of all items.

Step 17 : Finally save the MRP output to a text file.

d) Software Input

Enter the total number of levels: 2
Enter the total number of items in level-1: 2
Enter the items ID for levels-1:
127
181
Enter the total number of items in level-2: 2
Enter the items ID for levels-2:
148
201
Give the information for final item:

ID: 101
Name: A
Inventory level: 100
Lead time: 2

Command
Input

Give the information for item ID-127:

Name: B
Upper item ID: 101
Number of lower item in the next level: 2
Number of item needed for each upper item: 2
Inventory level: 0
Lead time: 1
Give the information for item ID-181:

Name: C
Upper item ID: 101
Number of lower item in the next level: 0
Number of item needed for each upper item: 4
Inventory level: 100
Lead time: 3
Lot size [Enter 32000 when 'lot for lot' otherwise enter lot size]: 32000
Give the information for item ID-148:

Name: D
Upper item ID: 127
Number of lower item in the next level: 0
Number of item needed for each upper item: 2
Inventory level: 50
Lead time: 2
Lot size [Enter 32000 when 'lot for lot' otherwise enter lot size]: 32000
Give the information for item ID-201:

Name: E
Upper item ID: 127
Number of lower item in the next level: 0
Number of item needed for each upper item: 1
Inventory level: 0
Lead time: 1
Lot size [Enter 32000 when 'lot for lot' otherwise enter lot size]: 250
Enter the total number of orders: 5
In which week/day order no.1 has to be released: 3
Number of final item required for order no.1: 250
In which week/day order no.2 has to be released: 7
Number of final item required for order no.1: 200
In which week/day order no.3 has to be released: 8
Number of final item required for order no.1: 150
In which week/day order no.4 has to be released: 10
Number of final item required for order no.1: 300

In which week/day order no.5 has to be released: 12
Number of final item required for order no.1: 250

e) Software Output

The order no.1 can't be met. This order needs another 3 more days/weeks

	Item Name	Item ID	Quantity
Week/day-2			
	C	181	300
	D	148	350
Week/day-3			
	E	201	250
	C	181	600
	D	148	600
Week/day-4			
	B	127	200
	E	201	250
Week/day-5			
	A	101	100
	B	127	300
	C	181	1200
	D	148	1200
Week/day-6			
	A	101	150
	E	201	750
Week/day-7			
	B	127	600
	C	181	1000
	D	148	1000
Week/day-8			
	A	101	300
	E	201	500
Week/day-9			
	B	127	500
Week/day-10			
	A	101	250

INVENTORY LEVEL:

Item Name	Item ID	Inventory Level
A	101	0
B	127	0
C	181	0
D	148	0
E	201	150

The firm has to start purchase process from week no. 2 to meet the remaining orders. It should order 300 units of item 'C' and 350 units of item 'D' from suppliers in second week and so on. The firm should start assembly process with items 'D' and 'E' to produce 200 units of item 'B'.

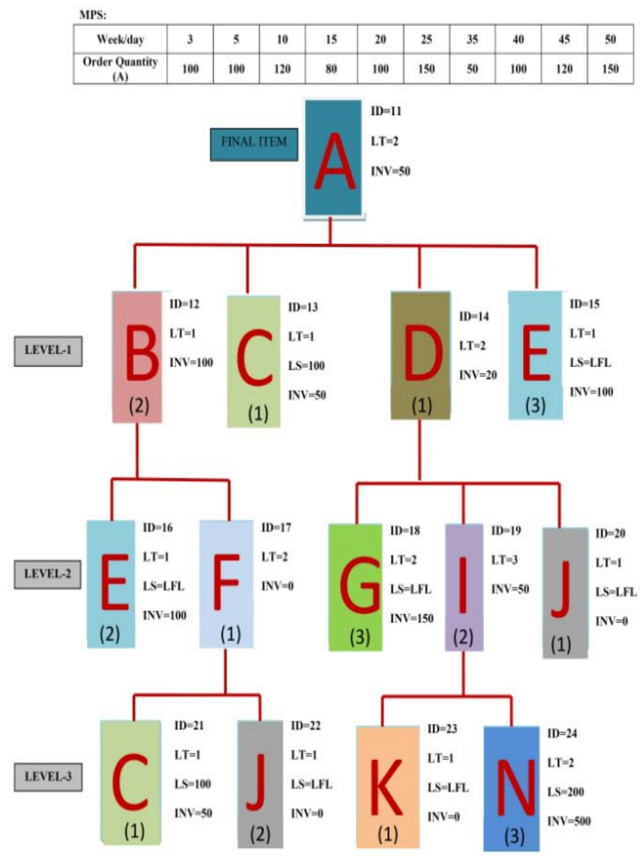

Figure 4 : MRP problem with complex BOM that can be solved with this software

III. Limitations

a) The maximum number of delivery is fifteen in MPS.
b) Capable of holding the information of thirty items for a specific MRP problem.
c) Not suitable to deliver the sub-assembly parts.
d) Only two types of lot sizing techniques were analyzed.
e) When user inputs wrong information then he has to start from the beginning.

IV. Conclusion

There are several sources of uncertainty that we have ignored so far. These include uncertainty in the quantity demanded (forecast errors) and the quantity supplied (yield losses), and uncertainty in the timing of demand and the timing of supply (random lead times). The largest cost or disadvantage of any MRP system is the cost of purchasing or leasing a computer system to support the function. However, with increasing inventory and production cost, along with decreasing computation costs the MRP system is getting easier to justify. The software is user friendly and was tested with various types of products and gave accurate results when verified with the manual method of calculation. So, the software is universal. The time-phased requirements for assemblies, parts and raw materials and final inventory level can easily be identified with the software. With the software local small scale manufacturing industries can improve customer service with lower inventories and reduce overtime and idle time.

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Software Coding

```
#include<stdio.h>
#include<conio.h>
#include<string.h>
void main() {
FILE *fp;
fp=fopen("MRP.txt", "w"); //Open a file to write the output
information
// Use structure in which the variables of each item has
been declared
struct item {
int id; // Item ID
char name[15]; // Item name
int u_id; // Upper item's ID
int item_n; // Item needed for each upper item
int n_l_item; // Number of lower items
int l_time; // Lead time
int i_level; // Inventory level
int t_i_level[16]; // Temporary inventory level
int level_n; // Item for which level
int l_size; // Lot size
int o_release[16]; // Order release
int o_quantity[16]; // Order quantity
};
// Variables declaration section
clrscr();
struct item info[30];
int
level,a=1,b[20],d,i,j,k,l,m,n,s,q,Q,p[50],c[16],g[16],x,y;
// Input total levels and information of each item
printf("\nEnter the total number of levels: ");
scanf("%d", &level);
b[0]=1;
for(i=1;i<=level;i++) {
printf("\nEnter the total number of items in level-%d: ",i);
scanf("%d", &n);
b[i]=n;
printf("\nEnter the items ID for level-%d:\n",i);
for(j=1;j<=n;j++) {
scanf("%d", &info[a].id);
info[a].level_n=i;
a++;
} }
info[0].level_n=0;
printf("\n\nGive the information for final item:\n--------------
---------------------\n");
printf("ID: ");
scanf("%d", &info[0].id);
printf("\nName: ");
scanf("%s",&info[0].name);
info[0].n_l_item=b[1];
printf("\nInventory level: ");
scanf("%d", &info[0].i_level);
printf("\nLead time: ");
scanf("%d", &info[0].l_time);
if (info[0].n_l_item==0) {
printf("\nLot size [use a huge number i.e.; 32000 when
'lot for lot' order]: ");
scanf("%d", &info[0].l_size); //Enter 32000 only when lot
for lot otherwise use the lot size
}
for(i=1;i<a;i++) {
printf("\n\n\nGive the information for item ID-%d:\n--------
---------------------------",info[i].id);
printf("\nName: ");
scanf("%s",&info[i].name);
printf("\nUpper item ID: ");
scanf("%d", &info[i].u_id);
printf("\nNumber of lower item in the next level: ");
scanf("%d", &info[i].n_l_item);
printf("\nNumber of item needed for each upper item: ");
scanf("%d", &info[i].item_n);
printf("\nInventory level: ");
```

```
scanf("%d", &info[i].i_level);
printf("\nLead time: ");
scanf("%d", &info[i].l_time);
if (info[i].n_l_item==0) {
printf("\nLot size [use a huge number i.e.; 32000 when 'lot for lot' order]: ");
scanf("%d", &info[i].l_size); //Enter 32000 only when lot for lot otherwise use the lot size
}
else
info[i].l_size=32000;
}
// Input the information of MPS
printf("\n\n\nEnter the total number of orders: ");
scanf("%d", &d);
printf("\n");
for(i=1;i<=d;i++) {
printf("\nIn which week/day order no.%d has to be released: ",i);
scanf("%d", &c[i]);
printf("\nNumber of final item required for delivery no.%d: ", i);
scanf("%d", &g[i]);
printf("\n");
}
s=c[i-1]; // The total number of weeks/days used according to MPS
// Use the temporary inventory level variables to hold the inventory level of each item temporarily which will be destructed after calculation
for(i=0;i<a;i++)
info[i].t_i_level[0]=info[i].i_level;
// Finding out the order release date and inventory level of independent item (final item) for each delivery
for(i=1;i<=d;i++) {
info[0].o_release[i]=c[i]-info[0].l_time;
info[0].o_quantity[i]=g[i]-info[0].t_i_level[i-1];
if(info[0].o_quantity[i]<=0) {
info[0].o_quantity[i]=0;
info[0].t_i_level[i]=info[0].t_i_level[i-1]-g[i];
}
else
info[0].t_i_level[i]=0;
}
// Finding out the order release date and inventory level of all dependent items (sub items) for each delivery
for(i=1;i<a;i++) {
for(j=0;j<a;j++) {
if(info[i].u_id==info[j].id) {
for(k=1;k<=d;k++) {
info[i].o_release[k]=info[j].o_release[k] - info[i].l_time;
info[i].o_quantity[k]=info[j].o_quantity[k]*info[i].item_n - info[i].t_i_level[k-1];
if(info[i].o_quantity[k]<=0) {
info[i].o_quantity[k]=0;
info[i].t_i_level[k]=info[i].t_i_level[k-1]-info[j].o_quantity[k]*info[i].item_n;
for(y=1;y<a;y++) {
if(y==i)
continue;
else {
if(strcmp(info[i].name,info[y].name)==0) //Finding out for repeated item
info[y].t_i_level[k]=info[i].t_i_level[k];
} } }
else
info[i].t_i_level[k]=0;
for(y=1;y<a;y++) {
if(y==i)
continue;
else {
if(strcmp(info[i].name,info[y].name)==0)
info[y].t_i_level[k]=info[i].t_i_level[k];
} } } } } }
j=1;
// Finding out which deliveries can't be met and the number of days required to meet the missing deliveries
for(k=1;k<=d;k++) {
m=1;
if(info[0].o_release[k]<=0 && g[k]>info[0].t_i_level[k-1] && info[0].n_l_item==0) {
m=info[0].o_release[k];
}
if(info[0].t_i_level[k-1]>=g[k])
continue;
for(i=1;i<a;i++) {
for(q=0;q<a;q++) {
if(info[i].u_id==info[q].id) {
if(info[i].o_release[k]<=0 && info[q].o_quantity[k]*info[i].item_n>info[i].t_i_level[k-1] && info[i].n_l_item==0) {
if(info[i].o_release[k]<m)
m=info[i].o_release[k];
} } } }
for(l=1;l<=level;l++) {
n=0;
for(i=1;i<a;i++) {
if(info[i].level_n==l) {
for(q=0;q<a;q++) {
if(info[i].u_id==info[q].id) {
if(info[q].o_quantity[k]*info[i].item_n<=info[i].t_i_level[k-1])
n++;
} } } }
if(n==b[l]) {
if(info[0].level_n==l-1) {
if(info[0].o_release[k]<m)
m=info[0].o_release[k];
}
for(i=1;i<a;i++) {
if(info[i].level_n==l-1 && info[i].n_l_item !=0) {
for(q=0;q<a;q++) {
if(info[i].u_id==info[q].id) {
if(info[q].o_quantity[k]*info[i].item_n>info[i].t_i_level[k-
```

```
1]) {
if(info[i].o_release[k]<m)
m=info[i].o_release[k];
}} } } } } }
// When the value of m is negative, it means the delivery is not possible and m holds the days required to meet the delivery
if(m<=0) {
//Shifting the inventory level of all items of the missing delivery to the next delivery
for(q=0;q<a;q++) {
info[q].t_i_level[k]=info[q].t_i_level[k-1];
}
//Again finding out the order release date and inventory level of all items for the remaining deliveries because of missing the delivery
for(i=k+1;i<=d;i++) {
info[0].o_release[i]=c[i]-info[0].l_time;
info[0].o_quantity[i]=g[i]-info[0].t_i_level[i-1];
if(info[0].o_quantity[i]<=0) {
info[0].o_quantity[i]=0;
info[0].t_i_level[i]=info[0].t_i_level[i-1]-g[i];
}
else
info[0].t_i_level[i]=0;
}
for(i=1;i<a;i++) {
for(x=0;x<a;x++) {
if(info[i].u_id==info[x].id) {
for(q=k+1;q<=d;q++) {
info[i].o_release[q]=info[x].o_release[q] - info[i].l_time;
info[i].o_quantity[q]=info[x].o_quantity[q]*info[i].item_n
- info[i].t_i_level[q-1];
if(info[i].o_quantity[q]<=0) {
info[i].o_quantity[q]=0;
info[i].t_i_level[q]=info[i].t_i_level[q-1]-
info[x].o_quantity[q]*info[i].item_n;
for(y=1;y<a;y++) {
if(y==i)
continue;
else {
if(strcmp(info[i].name,info[y].name)==0)
info[y].t_i_level[k]=info[i].t_i_level[k];
} } }
else {
info[i].t_i_level[q]=0;
for(y=1;y<a;y++) {
if(y==i)
continue;
else {
if(strcmp(info[i].name,info[y].name)==0)
info[y].t_i_level[k]=info[i].t_i_level[k];
} } } } } } }
p[j]=k; // Holding the missing deliveries in an array
j++;
x=-(1)*m;
if(x==0) {
printf("\n\nThe order no. %d can't be met. This order needs another %d more day/week",k,x+1);
fprintf(fp,"\nThe order no. %d can't be met. This order needs another %d more day/week",k,x+1);
}
else {
printf("\n\nThe order no. %d can't be met. This order needs another %d more days/weeks",k,x+1);
fprintf(fp,"\nThe order no. %d can't be met. This order needs another %d more days/weeks",k,x+1);
}} }
// Now calculate the order release date and inventory level of all items for which deliveries are possible
for(k=1;k<=d;k++) {
q=1;
for(m=1;m<j;m++) {
if(k==p[m]) {
q=0;
break;
} }
if(q==0)
continue;
else {
if(info[0].n_l_item==0) {
info[0].o_quantity[k]=g[k]-info[0].i_level;
if(info[0].o_quantity[k]<=0) {
info[0].o_quantity[k]=0;
info[0].i_level=info[0].i_level-g[k];
}
else if(info[0].o_quantity[k]<=info[0].l_size && info[0].l_size==32000)
info[0].i_level=0;
else {
for(l=1;l<=50;l++) {
if(info[0].o_quantity[k]<=info[0].l_size * l) {
Q=info[0].l_size * l;
info[0].i_level=Q - info[0].o_quantity[k];
info[0].o_quantity[k]=Q;
break;
} } } }
else {
info[0].o_quantity[k]=g[k]-info[0].i_level;
if(info[0].o_quantity[k]<=0) {
info[0].o_quantity[k]=0;
info[0].i_level=info[0].i_level-g[k];
}
else
info[0].i_level=0;
} } }
for(i=1;i<a;i++) {
for(n=0;n<a;n++) {
if(info[i].u_id==info[n].id) {
for(k=1;k<=d;k++) {
q=1;
for(m=1;m<j;m++) {
if(k==p[m]) {
q=0;
```

```
break;
} }
if(q==0)
continue;
else {
info[i].o_quantity[k]=info[n].o_quantity[k]*info[i].item_n
- info[i].i_level;
Q=info[i].o_quantity[k];
if(Q<=0) {
info[i].o_quantity[k]=0;
info[i].i_level=info[i].i_level-
info[n].o_quantity[k]*info[i].item_n;
for(y=1;y<a;y++) {
if(y==i)
continue;
else {
if(strcmp(info[i].name,info[y].name)==0)
info[y].i_level=info[i].i_level;
} } }
else if(Q<=info[i].l_size && info[i].l_size==32000) {
info[i].i_level=0;
for(y=1;y<a;y++) {
if(y==i)
continue;
else {
if(strcmp(info[i].name,info[y].name)==0)
info[y].i_level=info[i].i_level;
} } }
else {
for(l=1;l<=50;l++) {
if(Q<=info[i].l_size * l) {
Q=info[i].l_size * l;
info[i].i_level=Q - info[i].o_quantity[k];
for(y=1;y<a;y++) {
if(y==i)
continue;
else {
if(strcmp(info[i].name,info[y].name)==0)
info[y].i_level=info[i].i_level;
}
}
info[i].o_quantity[k]=Q;
break;
} } } }} } } }
//The output section
printf("\n\n\n\n                    Item_Name        Item_ID
Quantity\n");
printf("          ---------    -------     --------------");
fprintf(fp,"\n\n                    Item_Name        Item_ID
Quantity\n");
fprintf(fp,"          ---------    -------     --------------");
for(i=1;i<=s;i++) {
x=i;
for(k=1;k<=d;k++) {
q=1;
for(m=1;m<j;m++) {
if(k==p[m]) {
q=0;
break;
} }
if(q==0) {
continue;
}
else {
for(m=0;m<a;m++) {
if(info[m].o_release[k]==i && info[m].n_l_item==0 &&
info[m].o_quantity[k]!=0) {
if(x==i) {
printf("\n\nWeek/day-%d:\n",i);
fprintf(fp,"\n\nWeek/day-%d:\n",i);
x++;
}
printf("            ");
fprintf(fp,"            ");
printf("%s",info[m].name);
fprintf(fp,"%s",info[m].name);
printf("                                          %d
%d\n",info[m].id,info[m].o_quantity[k]);
fprintf(fp,"                                          %d
%d\n",info[m].id,info[m].o_quantity[k]);
} } } } }
printf("\n\n\n\n\n INVENTORY LEVEL:\n ---------------");
fprintf(fp,"\n\n\n\n\n INVENTORY LEVEL:\n ---------------");
printf("\n\n Item_Name Item_ID Inventory_level\n");
printf(" --------- ------- ---------------\n");
fprintf(fp,"\n\n                Item_Name                Item_ID
Inventory_level\n");
fprintf(fp,"    ---------     -------     ---------------\n");
for(i=0;i<a;i++) {

printf("      ");
fprintf(fp,"      ");
printf("%s",info[i].name);
fprintf(fp,"%s",info[i].name);
printf("          %d          %d\n",info[i].id,info[i].i_level);
fprintf(fp,"          %d          %d\n",info[i].id,info[i].i_level);
}
fclose(fp);
getch();
}
```

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Modified MEWMA Control Scheme for an Analytical Process Data

By Alpaben K. Patel & Jyoti Divecha
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Abstract - This article introduces Multivariate Modified Exponentially Weighted Moving Average (MMOEWMA) control chart, a chart for detecting shifts of all kinds in case of highly first order vector autoregressive VAR (1) process. This chart is based on modified MEWMA control chart statistic which is a correction of MEWMA chart statistic. The performance of MMOEWMA chart is illustrated along with MEWMA chart for a chemical process data. The average run length (ARL) properties of MMOEWMA scheme are derived using Markov Chain approach. Algorithm for the ARL computation and R-program of monitoring MMOEWMA control chart are provided.

Keywords : *abrupt change; average run length; MEWMA; multivariate modified EWMA; vector autoregressive.*

GJCST-C Classification : *E.m*

MODIFIED MEWMA CONTROL SCHEME FOR AN ANALYTICAL PROCESS DATA

Strictly as per the compliance and regulations of:

Modified MEWMA Control Scheme for an Analytical Process Data

Alpaben K. Patel [α] & Jyoti Divecha [σ]

Abstract - This article introduces Multivariate Modified Exponentially Weighted Moving Average (MMOEWMA) control chart, a chart for detecting shifts of all kinds in case of highly first order vector autoregressive VAR (1) process . This chart is based on modified MEWMA control chart statistic which is a correction of MEWMA chart statistic. The performance of MMOEWMA chart is illustrated along with MEWMA chart for a chemical process data. The average run length (ARL) properties of MMOEWMA scheme are derived using Markov Chain approach. Algorithm for the ARL computation and R-program of monitoring MMOEWMA control chart are provided.

Keywords : abrupt change; average run length; MEWMA; multivariate modified EWMA; vector autoregressive.

I. Introduction

Multivariate statistical process control is often used in chemical and process industries where autocorrelation is most prevalent. Traditional multivariate statistical process control techniques are based on the assumption that the successive observation vectors are independent. In recent years, due to automation of measurement and data collection systems, a process can be sampled at higher rates, which ultimately leads to autocorrelation. Consequently, when the autocorrelation is present in the data, it can have a serious impact on the performance of classical control charts. This point has been made by numerous authors, including Berthouex, Hunter, and Pallensen (1978), Harris and Ross (1991), Montgomery and Mastrangelo (1991). Runger (1996) has presented a realistic model that generates autocorrelation and cross correlation and provides a useful approach to characterizing process data. The interpretation of these charts: charts based on modeling residuals is not as simple as the authors suggest, and the alternative engineering feedback control methods are often more appropriate with such highly auto correlated data.

This article considers the problem of monitoring the mean vector of a process in which observations can be a highly first order vector autoregressive VAR (1) and propose a control chart called Multivariate Modified EWMA chart. Multivariate Modified EWMA chart as a modification in MEWMA (Lowery et. al, 1992) chart statistic. Multivariate Modified EWMA chart that combines the features of multivariate Shewhart chart (Hotelling, 1947) and MEWMA chart in a simple way and has ability to detect small as well as large shift as soon as possible as required by some industrial processes with high level of first order vector autoregressive data.

MMOEWMA control statistic gives weight to the past observation vectors in slightly different way than MEWMA and each current change is considered with full weight. This corrects MEWMA statistic for suffering from inertia problem. This article discusses the procedures to construct the Multivariate Modified EWMA chart. Simulate the average run length to assess the performance of the chart. The MMOEWMA vector auto correlated control chart is defined in second section and the derivation of upper control limits is kept with Appendix 1. Further, performance of MMOEWMA monitoring scheme is illustrated along with MEWMA scheme for real multivariate chemical process data in third section. ARL properties of MMOEWMA are derived and compared with MEWMA in fourth section. The comparisons reveals that MMOEWMA scheme outperform MEWMA scheme. Computation of ARL values were carried out using Markov chain approach described in Appendix 2.

II. Multivariate Control Charts for Monitoring the Process Mean

Suppose that the **p** x **1** random vectors Y_1, Y_2, Y_3, … each representing the p quality characteristics to be monitored, are observed over time. These vectors may represent individual observations or sample mean vectors. To study the performance of the various multivariate control charts, it will be assumed that $\mathbf{Y}_n$, n = 1, 2, …, are independent multivariate normal random vectors with mean vectors $\boldsymbol{\mu}_n$, n =1, 2,… For simplicity, it is assumed that each of the random vectors has the known co-variance matrix $\boldsymbol{\Sigma}$.

a) The Multivariate Shewhart Control Chart

Hotelling's (1947) introduced a multivariate control-chart procedure based on his Hotelling's chi-square statistics defined as $\chi_n^2 = Y_n'\Sigma^{-1}Y_n$. At any n^{th} stage in process,

$$\chi_n^2 = Y_n'\Sigma^{-1}Y_n > h, \tag{1}$$

signals that a statistically significant shift in the mean has occurred; that is process out-of-control, where *h* >

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0 is a specified control limit. Because this procedure is based on only the most recent observation, it is insensitive to small and moderate shifts in the mean vector.

b) The Multivariate EWMA (MEWMA) control chart

Lowery et al. (1992) proposed the MEWMA chart as natural extension of EWMA chart. It is a popular chart used to monitor a process with p quality characteristics for detecting small to moderate shifts. The in-control process mean is assumed without loss of generality to be a vector of zeros, and covariance matrix Σ. The MEWMA control statistic is defined as vectors,

$$X_n = \Lambda Y_n + (I-\Lambda)X_{n-1},\ n=1,2,\ldots, \tag{2}$$

where $X_0 = \mathbf{0}$, 1 x p vector and $\Lambda = \mathrm{diag}(\lambda_1, \lambda_2,\ldots, \lambda_p)$, $0<\lambda j\leq 1$, $j=1,2,\ldots,p$.

The MEWMA chart gives an out-of-control signal as soon as

$$T_{n1}^2 = X_n{}' \Sigma_{xn}{}^{-1} X_n > h_1, \tag{3}$$

where h_1 (>0) is chosen to achieve a specified in control ARL and Σ_{xn} is the covariance matrix of X_n given by $\Sigma_{xn} = \{\lambda/(2-\lambda)\}\Sigma$, under equality of weights of past observations for all p characteristics; $\lambda_1 = \lambda_2 = \ldots = \lambda_p = \lambda$. The UCL $= \left(\dfrac{\lambda}{2-\lambda}\right)^{1/2} (h_1)^{1/2}$. If one or more points fall beyond h_1, the process is assumed to be out-of-control. The magnitude of the shift is reflected in the non-centrality parameter $\boldsymbol{\mu}_1{}'\Sigma^{-1}\boldsymbol{\mu}_1$. They conclude that an assignable causes result in a shift in the process mean from $\boldsymbol{\mu}_0$ to $\boldsymbol{\mu}_1$.

c) MMOEWMA control chart for monitoring the first order vector autoregressive VAR (1) process mean

The MMOEWMA chart as natural extension of Patel and Divecha (2011) proposed Modified EWMA chart. The desirable properties of a multivariate auto correlated control chart are that it is easy to implement and is effective for detecting shifts of all sizes as per technical specifications. The Multivariate Modified EWMA chart that introduce considers past observations similar to MEWMA scheme and additionally considers past as well as latest change in the process. Let Y_n, n = 1,2,…, are sequence of first order auto correlated normal random vectors with mean vector $\boldsymbol{\mu}_n$, and common covariance matrix Σ. Further it is assumed without loss of generality that the in control process mean vector is $\boldsymbol{\mu}_0 = (0, 0,\ldots, 0)' = \mathbf{0}$.

The MMOEWMA chart statistic is a modification in MEWMA chart statistic. To define MMOEWMA control statistic as vector X_n given by,

$$X_n = \Lambda Y_n + (I-\Lambda)X_{n-1} + (Y_n - Y_{n-1}),\ n\geq 1, \tag{4}$$

where X_0 is the p-dimensional zero vector and $\Lambda = \mathrm{diag}(\lambda_1, \lambda_2,\ldots, \lambda_p)$, $0<\lambda j\leq 1$, $j=1,2,\ldots,p$. The MMOEWMA chart gives an out-of-control signal as soon as

$$T_{n2}^2 = X_n{}' \Sigma_{xn}{}^{-1} X_n > h_2, \tag{5}$$

where h_2 (>0) is chosen to achieve a specified in control ARL. If one or more points fall beyond h_2, the process is assumed to be out-of-control. Σ_{xn} is the covariance matrix of X_n given by $\Sigma_{xn} = \left(\dfrac{\lambda}{2-\lambda} + \dfrac{2\lambda(1-\lambda)}{2-\lambda}\right)\Sigma$, under equality of weights of past observations for all p characteristics; $\lambda_1 = \lambda_2 = \ldots = \lambda_p = \lambda$, and past and current changes. The upper control limit of MMOEWMA chart is, UCL $= \left(\dfrac{\lambda}{2-\lambda} + \dfrac{2\lambda(1-\lambda)}{2-\lambda}\right)^{1/2} (h_2)^{1/2}$ (discussed in Appendix 1).

III. Illustration

Table 1 : Temperatures Data

NO	Observations			Deviated Observations		
	Y_1	Y_2	Y_3	Y_1-μ_{01}	Y_2-μ_{02}	Y_3-μ_{03}
0	92.24	95.56	100.27	0.00	0.00	0.00
1	92.83	95.16	100.77	0.59	-0.40	0.50
…	…	…	…	…	…	…
12	92.84	95.16	100.76	0.60	-0.40	0.49
13	92.84	95.16	100.76	0.60	-0.40	0.49
14	92.84	95.16	100.76	0.60	-0.40	0.49
15	92.84	95.16	100.76	0.60	-0.40	0.49
…	…	…	…	…	…	…

279	92.59	95.10	100.47	0.35	-0.46	0.20
280	92.59	95.10	100.46	0.35	-0.46	0.19
281	92.58	95.10	100.46	0.34	-0.46	0.19
282	92.58	95.10	100.46	0.34	-0.46	0.19
…	…	…	…	…	…	…
588	91.37	95.27	99.73	-0.87	-0.27	-0.54
589	91.37	95.27	99.72	-0.88	-0.29	-0.55
590	91.36	95.27	99.72	-0.88	-0.29	-0.55
591	91.36	95.27	99.72	-0.88	-0.29	-0.55
592	91.35	95.28	99.72	-0.89	-0.28	-0.55
…	…	…	…	…	…	…
998	92.30	96.22	100.16	0.06	0.66	-0.11
999	92.30	96.21	100.16	0.06	0.65	-0.11
…	…	…	…	…	…	…
1200	92.67	95.84	100.72	0.43	0.28	0.45
1201	92.67	95.83	101.95	0.43	0.27	1.68
1202	92.67	95.83	100.73	0.43	0.27	0.46
…	…	…	…	…	…	…
1416	92.55	95.35	100.90	0.31	-0.21	0.63
1417	92.55	95.35	100.90	0.31	-0.21	0.63
…	…	…	…	…	…	…
1434	92.54	95.31	100.87	0.30	-0.26	0.60
1435	92.53	95.30	100.87	0.29	-0.26	0.60
…	…	…	…	…	…	…
1439	92.53	95.29	100.86	0.29	-0.27	0.59

a) *MMOEWMA chart for monitoring Multivariate Chemical Process using table 1 and table 2*

Table 1 displays the part of measurements on three temperature column taken every minute from a chemical process that is working in control and out of control situations, abrupt changes and small shifts occur. Here number of variable p=3. Three variables are temperature columns Y_1 with mean $\mu_{01}=92.24$, Y_2 with mean $\mu_{02}=95.56$, Y_3 with mean $\mu_{03}= 100.27$. To assume covariance matrix to be

$$\sum=\begin{pmatrix} V(Y_{11}) & C(Y_1,Y_2) & C(Y_1,Y_3) \\ C(Y_2,Y_1) & V(Y_{22}) & C(Y_2,Y_3) \\ C(Y_3,Y_1) & C(Y_3,Y_2) & V(Y_{33}) \end{pmatrix} = \begin{pmatrix} 1 & 0.5 & 0.5 \\ 0.5 & 1 & 0.5 \\ 0.5 & 0.5 & 1 \end{pmatrix}$$

Upper control limit of MEWMA UCL $=\left(\frac{\lambda}{2-\lambda}\right)^{1/2}(h_1)^{1/2}=0.882$, where $\lambda=0.1$, $h_1=14.7$, and MMOEWMA UCL $=\left(\frac{\lambda}{2-\lambda}+\frac{2\lambda\,(1-\lambda)}{2-\lambda}\right)^{1/2}(h_2)^{1/2}=0.839$, where $\lambda=0.1$, $h_2 = 5.417$. UCL is used in average run length to choose appropriate value of decision interval. The MMOEWMA chart gives an out-of-control signal as soon as

$$T^2_{n2} = X_n^{'}\,\mathbf{\Sigma}_{xn}^{-1}\,X_n > h_2, \qquad h_2 = 5.417$$

and the MEWMA chart gives an out-of-control signal as soon as

$$T^2_{n1} = X_n^{'}\,\mathbf{\Sigma}_{xn}^{-1}\,X_n > h_1,\ h_1 = 14.78.$$

Table 2 shows that, MMOEWMA vector gives best forecasts for the process mean vector; undoubtedly better than the MEWMA prediction barring abrupt change situation (1201st observation). MMOEWMA also detects all the shifts more timely as compared to MEWMA for chemical process data.

Table 2 : Monitoring performance of MEWMA and MMOEWMA for the Chemical Process three variate temperature Data

No.	MEWMA vector, λ=0.1, h_1 = 14.78			MEWMA statistics	MMOEWMA vector, λ=0.1, h_2 = 5.417			MMOEWMA statistics
	X_1	X_2	X_3	T_{n1}^2	X_1	X_2	X_3	T_{n2}^2
1	0.06	-0.04	0.05	0.24	0.56	0.46	0.55	2.91
…	…	…	…	…	…	…	…	…
12	0.43	-0.29	0.36	12.48	0.58	-0.14	0.51	5.19
13	0.44	-0.30	0.37	13.48	0.58	-0.16	0.50	**5.47***
14	0.47	-0.31	0.38	14.43	0.58	-0.19	0.50	5.73*
15	0.47	-0.32	0.39	**15.30***	0.58	-0.21	0.50	5.98*
…	…	…	…	…	…	…	…	…
279	0.39	-0.46	0.21	15.33*	0.36	-0.48	0.19	5.46*
280	0.38	-0.46	0.21	15.17*	0.36	-0.48	0.19	5.40
281	0.38	-0.46	0.21	15.02*	0.36	-0.48	0.19	5.35
282	0.37	-0.46	0.21	14.87*	0.35	-0.48	0.19	5.30
…	…	…	…	…	…	…	…	…
588	-0.84	-0.29	-0.52	14.26	-0.86	-0.32	-0.55	5.37
589	-0.84	-0.29	-0.52	14.41	-0.86	-0.32	-0.55	**5.42***
590	-0.84	-0.29	-0.53	14.56	-0.87	-0.31	-0.55	5.47*
591	-0.85	-0.29	-0.53	14.72	-0.87	-0.31	-0.55	5.53*
592	-0.85	-0.29	-0.53	**14.87***	-0.87	-0.31	-0.56	5.59*
…	…	…	…	…	…	…	…	…
998	0.02	0.67	-0.13	14.91*	0.05	0.70	-0.11	5.44*
999	0.03	0.67	-0.13	14.75	0.06	0.70	-0.10	5.38
…	…	…	…	…	…	…	…	…
1200	0.43	0.29	0.43	4.72	0.46	0.32	0.46	1.91
1201	0.43	0.29	0.55	6.49	**1.68**	**1.54**	**1.81**	**29.10***
1202	0.43	0.29	0.54	6.33	0.34	0.19	0.45	1.54
…	…	…	…	…	…	…	…	…
1416	0.31	-0.18	0.64	14.73	0.31	-0.19	0.63	5.24
1417	0.31	-0.19	0.63	**14.79***	0.30	-0.19	0.63	5.25
…	…	…	…	…	…	…	…	…
1434	0.30	-0.23	0.61	15.35*	0.28	-0.25	0.60	5.41
1435	0.30	-0.23	0.61	15.38*	0.28	-0.25	0.60	**5.43***
…	…	…	…	…	…	…	…	…
1439	0.30	-0.24	0.61	15.48*	0.28	-0.26	0.59	5.46*

In Table 2 observe that, MEWMA control chart detects shifts on observation 15th to 282nd, 592nd to 998th, and 1417th to 1439th. The MMOEWMA control chart detects shifts on observation 13th to 279th, 589th to 998th, and 1435th to 1439th. MMOEWMA chart detect abrupt change at observation 1201st, but MEWMA could not detect it.

Figure 1 and 2 depict MEWMA and MMOEWMA statistics charting.

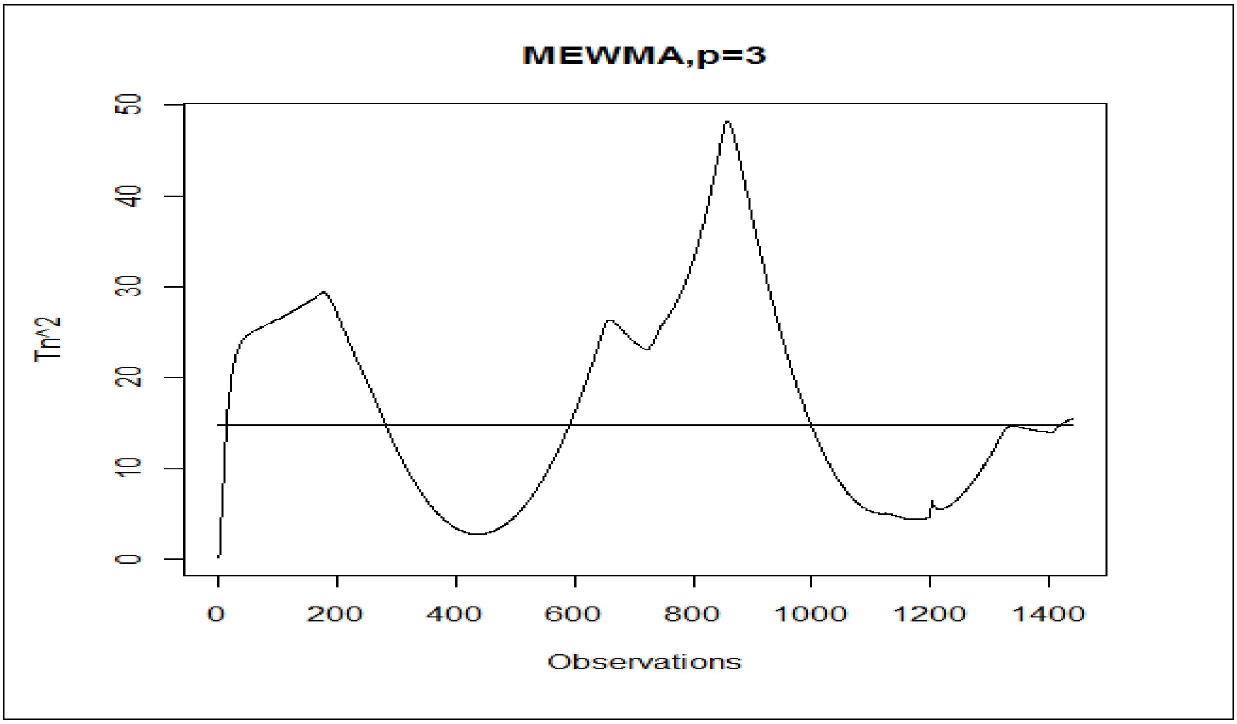

Figure 1 : MEWWA Control Chart (p=3)

Observe the shoot up bar showing abrupt shift in figure 2 which is completely missing in figure 1.

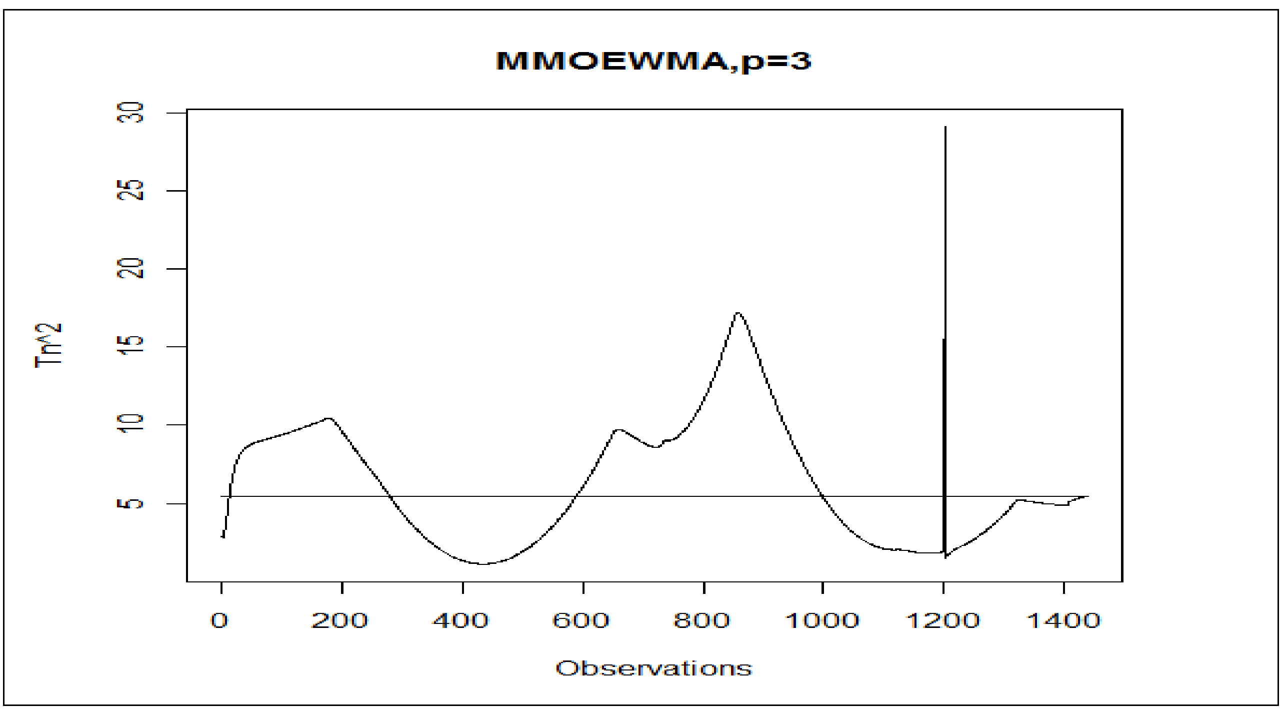

Figure 2 : MMOEWMA Control Chart (p=3)

Note that 1201st run has abrupt shift in variable Y_3.

b) Properties of MMOEWMA scheme and comparison with MEWMA scheme

All the ARL computations were carried out using Markov chain approach described in Appendix 2. MMOEWMA is the chart for multivariate processes having autocorrelated observations. However, assuming that MEWMA chart can be applied at least to the residual vectors, to compare the ARL values of MMOEWMA with that of MEWMA having common parameters.

Table 3 : Average Run Lengths of MEWMA Charts

ARL Values for MEWMA Charts (p=2, p=3 and p=4) from Lowery et. al. (1992)						
h_1=	10.75	12.34	13.10	14.78	15.16	16.94
Shift	P =2 and λ =0.10		p =3 and λ = 0.1		p =4 and λ = 0.1	
0.0	501	999	502	1007	497	995
0.5	39.5	51.1	45.6	61.2	52.3	68
1.0	12.1	13.7	13.5	15.3	14.5	16.5
1.5	7.03	7.69	7.66	8.40	8.20	8.99
2.0	4.97	5.39	5.43	5.83	5.79	6.23
2.5	3.90	4.23	4.26	4.54	4.51	4.81
3.0	3.27	3.49	3.52	3.75	3.74	3.97

Table 4 : Average Run Lengths of MMOEWMA Charts

ARL Values for Multivariate Modified EWMA (MMOEWMA) Charts (p=2, p=3 and p=4)						
h_2=	3.93	4.525	4.78	5.417	5.546	6.221
Shift	p =2 and λ =0.1		p =3 and λ = 0.1		p =4 and λ = 0.1	
0.0	500	1000	500	1000	500	1000
0.5	30.5	40.09	31.52	41.57	32.3	42.77
1.0	10.06	11.63	10.54	12.15	10.89	12.55
1.5	5.69	6.38	6.04	6.73	6.30	7.0
2.0	3.87	4.29	4.16	4.58	4.38	4.80
2.5	2.87	3.17	3.12	3.42	3.31	3.61
3.0	2.02	2.24	2.25	2.46	2.62	2.63

Table 3 to table 6 showed that the control limits for MMOEWMA are quite small than those of MEWMA as well as χ^2 chart for the same in control ARL. For two, three, four variable cases, the smaller out of control ARL imply that MMOEWMA chart performs excellent in detection of shifts, be it small, moderate or large for every of in control ARLs. MMOEWMA chart with $\lambda_1 = \lambda_2 = \ldots = \lambda_p = \lambda = 1$ is multivariate Shewhart chart version for multivariate autocorrelated process.

Table 5 : Average Run Lengths of Multivariate Charts

	χ^2 chart	MEWMA Chart				
λ =		0.1	0.2	0.4	0.6	0.8
	h	*h_1*				
	10.6	8.66	9.65	10.29	10.53	10.58
Shift	ARL values for p=2 from Lowery et. al. (1992)					
0	200.	200	201	199	200	200
0.5	116.	28.1	35.10	51.9	73.6	95.5
1.0	42.	10.2	10.10	13.2	19.3	28.1
1.5	15.8	6.12	5.50	5.74	7.24	10.3
2.0	6.9	4.41	3.80	3.54	3.86	4.75
2.5	3.5	3.51	2.91	2.55	2.53	2.75
3.0	2.2	2.92	2.42	2.04	1.88	1.91

Table 6 : Average Run Lengths of MMOEWMA Charts

	MMOEWMA Chart					
λ =	0.1	0.2	0.3	0.4	0.6	0.8
h_2=	3.135	3.742	4.223	4.705	5.85	7.561
Shift	ARL values for p=2					
0	200	200	200	200	200	200
0.5	21.1	24.76	29.9	29.9	51.6	74.98
1.0	8.12	7.88	8.65	8.65	14.93	23.99
1.5	4.78	4.11	4.06	4.06	5.75	8.92
2.0	3.29	2.64	2.44	2.44	2.92	4.12
2.5	2.45	1.87	1.69	1.69	1.86	2.36
3.0	1.90	1.43	1.32	1.32	1.41	1.63

IV. Conclusion

A simple multivariate control chart for monitoring small as well as large shifts in highly first order vector autoregressive VAR (1) process such as multivariate chemical process is given. It is good method to monitor first order vector autoregressive process in chemical/other industries.

Appendix 1 Derivation of the Covariance Matrix of MMOEWMA Statistic X_N

By repeated substitution in equation $X_n = \Lambda Y_n + (I - \Lambda)X_{n-1} + (Y_n - Y_{n-1})$, $n \geq 1$, it can be shown that

$$X_n = +(I-\Lambda)^n Y_0 + \sum_{j=0}^{n-1}(I-\Lambda)^j (Y_{n-j} - Y_{n-j-1}) \quad \text{(i)}$$

The expectation of X_n gives, $E(X_n) = \boldsymbol{\mu}$, (mean of Y_n).

Lemma 1: If $\lambda_1 = \lambda_2 = \ldots = \lambda_p = \lambda$, then the expression for Multivariate Modified EWMA statistic

$$X_n = \lambda \sum_{j=0}^{n-1} (1-\lambda)^j Y_{n-j} + (1-\lambda)^n Y_0 + \sum_{j=0}^{n-1} (1-\lambda)^j (Y_{n-j} - Y_{n-j-1})$$

Taking expectation on both side,

$$E(X_n) = \lambda \sum_{j=0}^{n-1} (1-\lambda)^j E(Y_{n-j}) + (1-\lambda)^n E(Y_0) + \sum_{j=0}^{n-1} (1-\lambda)^j E(Y_{n-j} - Y_{n-j-1})$$

But $\lambda \sum_{j=0}^{n} (1-\lambda)^j = \dfrac{\lambda\,[1-(1-\lambda)^n]}{[1-(1-\lambda)]} = [1-(1-\lambda)^n]$

$\therefore$ $E(X_n) = [1-(1-\lambda)^n]\mu + (1-\lambda)^n \mu + 0$

$= \boldsymbol{\mu}$

Lemma 2: If the starting value of process is, $X_0 = \mu_0 = Y_0$ and $0 < \lambda \leq 1$ is a constant. The mean is, $E(X_n) = E((1-\lambda)X_{n-1} + \lambda Y_n + (Y_n - Y_{n-1})) = \mu_0$.

For p = 2 and n=1, we have,

$$X_1 = \begin{bmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{bmatrix} \begin{bmatrix} Y_{11} \\ Y_{21} \end{bmatrix} + \begin{bmatrix} 1-\lambda_1 & 0 \\ 0 & 1-\lambda_2 \end{bmatrix} \begin{bmatrix} Y_{10} \\ Y_{20} \end{bmatrix} + \begin{bmatrix} Y_{11} - Y_{10} \\ Y_{21} - Y_{20} \end{bmatrix}$$

$$= \begin{bmatrix} \lambda_1 Y_{11} + (1-\lambda_1)Y_{10} + Y_{11} - Y_{10} \\ \lambda_2 Y_{21} + (1-\lambda_2)Y_{20} + Y_{21} - Y_{20} \end{bmatrix} = \begin{bmatrix} X_{11} \\ X_{21} \end{bmatrix} \text{ say,}$$

So that,

$$Cov(X_1) = \sum_{X1} = \begin{bmatrix} V(X_{11}) & Cov(X_{11}, X_{21}) \\ & V(X_{21}) \end{bmatrix} \quad \text{(ii)}$$

Where $V(X_{11})$ and $V(X_{21})$ are the variance of univariate modified EWMA statistic, and $Cov(X_{11}, X_{21}) = \lambda_1 \lambda_2 \sigma_{12} + (1-\lambda_1)(1-\lambda_2)\sigma_{12} + cov(Y_{11} - Y_{10}, Y_{21} - Y_{20})$.

Then as per (ii)

$$Cov(X_n) = \sum_{Xn} = \begin{bmatrix} V(X_{1n}) & Cov(X_{1n}, X_{2n}) \\ & V(X_{2n}) \end{bmatrix}$$

Now Y_n's are autocorrelated normal with covariance matrix $\boldsymbol{\Sigma}$, so that the $(Y_n - Y_{n-1})$'s ($n \geq 1$) have covariance matrix $2(\mathbf{I}-\mathbf{Rho})\boldsymbol{\Sigma}$ with $\mathbf{Rho} = diag(\rho_{y1}, \rho_{y2}, \ldots, \rho_{yp})$. Then, taking $\lambda_1 = \lambda_2 = \ldots = \lambda_p = \lambda$ and $\rho_{y1}, \rho_{y2}, \ldots, \rho_{yp} \to 1$, as n tends to infinity.

Lemma 3: The variance of univariate Modified EWMA (MOEWMA) control statistic X_n is,

$$V(X_n) = V(\lambda \sum_{j=0}^{n-1} (1-\lambda)^j Y_{n-j}) + V((1-\lambda)^n Y_0) + V(\sum_{j=0}^{n-1} (1-\lambda)^j (Y_{n-j} - Y_{n-j-1}))$$

$$V(X_n) = (1-\lambda)^{2n} V(Y_0) + \sum_{j=0}^{n-1}\lambda^2(1-\lambda)^{2j}V(Y_{n-j}) + 2\sum_{j=0}^{n-1}\lambda^2(1-\lambda)^{2j+1}Cov(Y_{n-j}, Y_{n-j-1}) +$$

$$\sum_{j=0}^{n-1}(1-\lambda)^{2j}V(Y_{n-j} - Y_{n-j-1}) + 2\sum_{j=0}^{n-1}(1-\lambda)^{2j+1}Cov[(Y_{n-j} - Y_{n-j-1}),(Y_{n-j-1} - Y_{n-j-2})]$$

$$+\sum_{j=0}^{n-1}\lambda(1-\lambda)^{2j}Cov\left(Y_{n-j},(Y_{n-j} - Y_{n-j-1})\right)+\sum_{j=0}^{n-1}\lambda(1-\lambda)^{2j+1}Cov\left(Y_{n-j-1},(Y_{n-j} - Y_{n-j-1})\right)$$

Since Y_n's are autocorrelated normal with variance σ^2, the variance of (Y_n-Y_{n-1}) $(n\geq1)$ is $\sigma_1^2 = 2\sigma^2 - 2\rho\sigma^2 = 2(1-\rho)\sigma^2$ (small when $\rho\rightarrow1$). The weights $\lambda(1-\lambda)^{2j}$ decrease geometrically with the age of sample mean. Suppose Y_n's are correlated to the forward fluctuation (Y_n-Y_{n-1}) $(n \geq 1)$ with common correlation ρ_1 and correlated to the backward fluctuation $(Y_{n+1}-Y_n)$, $(n\geq0)$ with common correlation ρ_2, and forward fluctuation (Y_n-Y_{n-1}) are correlated to the backward fluctuation $(Y_{n+1}-Y_n)$, $(n\geq1)$ with common correlation ρ_3, then asymptotic variance for large n,

$$V(X_n) = \frac{\lambda}{(2-\lambda)}\sigma^2 + \frac{2\lambda(1-\lambda)}{(2-\lambda)}\rho\sigma^2 + \frac{2(1-\rho)\sigma^2}{\lambda(2-\lambda)} + \frac{4\rho_3(1-\rho)(1-\lambda)\sigma^2}{\lambda(2-\lambda)} +$$
$$\frac{2\sqrt{2}\rho_1\sqrt{(1-\rho)}\sigma^2}{(2-\lambda)} + \frac{(1-\lambda)2\sqrt{2}\rho_2\sqrt{1-\rho}\sigma^2}{(2-\lambda)} \qquad \text{(iii)}$$

In normal autocorrelated process (a) with ρ_3 nearly negative half and ρ_1, ρ_2 nearly equal and opposite in sign and being monitored for small shifts, (b) with autocorrelation ρ nearly one $(\rho\rightarrow1)$ the above expression (iii), reduces to

$$V(X_n) = \frac{\lambda}{(2-\lambda)}\sigma^2 + \frac{2\lambda(1-\lambda)}{(2-\lambda)}\rho\sigma^2 \qquad \text{(iv)}$$

Let $\frac{2\lambda(1-\lambda)}{(2-\lambda)}\rho\sigma^2$ is a small value for high value of ρ and small λ, sometimes even negligibly small such that modified EWMA limits equal EWMA limits.

Therefore, $V(X_n) = \left[\frac{\lambda}{(2-\lambda)} + \frac{2\lambda(1-\lambda)}{(2-\lambda)}\right]\sigma^2$. (v)

Therefore, Multivariate MOEWMA covariance from equation (iv, v) becomes

$$V(X_{1n}) = \left[\frac{\lambda}{(2-\lambda)} + \frac{2\lambda(1-\lambda)}{(2-\lambda)}\right]\Sigma = V(X_{2n}) = Cov(X_{1n}, X_{2n}).$$

In general the best approximation of covariance matrix of the MMOEWMA p-variable vectors is given by,

$$\sum_{Xn} = \frac{\lambda}{(2-\lambda)}\Sigma + \frac{2\lambda(1-\lambda)}{(2-\lambda)}\rho\Sigma \qquad \text{(vi)}$$

The UCL of MMOEWMA control chart is

$$UCL = \left(\frac{\lambda}{(2-\lambda)} + \frac{2\lambda(1-\lambda)}{(2-\lambda)}\right)^{1/2}(h_2)^{1/2} \qquad \text{(vii)}$$

The MMOEWMA chart gives an out-of-control signal as soon as

$$T_{n2}^2 = X_n' \boldsymbol{\Sigma}_{xn}^{-1} X_n > h_2, \qquad \text{(viii)}$$

Where h_2 (>0) is chosen to achieve a specified in control ARL. If one or more points fall beyond h_2, the process is assumed to be out-of-control. The magnitude of the shift is reflected in the non-centrality parameter $\boldsymbol{\mu}_1'\Sigma^{-1}\boldsymbol{\mu}_1$. We conclude that an assignable causes result in a shift in the process mean from $\boldsymbol{\mu}_0$ to $\boldsymbol{\mu}_1$.

Appendix 2 ARL Computation for MMOEWMA Scheme using Markov Chain Approach

Following Runger and Prabhu (1996) and Molnau et al. (2001) the Markov chain approach of ARL for MMOEWMA has been derived. Different choices of λ (weighting factor), h_2 (decision value), and p (number of variable) are considered.

In and out of-Control Case

For the in or out control case, the ARL analysis can be simplified as a one dimensional Markov chain.

To approximate $\|X_n\|$, we partition the control region into m+1 transient states, each of width g = $\dfrac{2UCL}{(2m+1)}$.

In this case the two dimensional range of X_n is represented by the X_1 and X_2 axes, and the states used for the Markov chain are assumed as circular rings. Because Y_n has a spherical distribution, the probability of transitioning from state i to state j, denoted as p(i, j), depends only on the radii of states i and j. For i = 0,1,2,…,m and j not equal to zero.

$$p(i,j) = P\,(d_n \text{ in state } j \mid d_{n-1} \text{ in state } i)$$

$$= P\,[\,(j-0.5)\,g < \left\|\lambda Y_n + (1-\lambda)X_{n-1} + (Y_n - Y_{n-1})\right\| < (j+0.5)\,g \mid d_{n-1} = ig].$$

Given that d_{n-1} = ig, $X_{n-1}$is distributed as igU, and j =0,1,2,…,m

$$p(i,j) = P\,[\,(j-0.5)\,g < \left\|\lambda Y_n + (1-\lambda)igU + (Y_n - Y_{n-1})\right\| < (j+0.5)\,g \mid d_{n-1} = ig].$$

Let **e** denote the p component unit vector **e**' =(1,0,0,…,0). According to Runger and Prabhu (1996) Y_n and U are independent spherical random variables, without loss of generality it can assume that U is identity equal to e to obtain

$$p(i,j) = P\,[\,\{(j-0.5)\,g\}/\lambda < \left\|Y_n + [(1-\lambda)ige + (Y_n - Y_{n-1})]/\lambda\right\| < \{(j+0.5)\,g\}/\lambda].$$

Let $\chi^2(p,c)$ denote a non central chi square random variable with p degrees of freedom and non centrality parameter c. Then we have

For j not equal to zero (j ≠ 0),

$$p(i,j) = P\left[\frac{(j-0.5)^2 g^2}{\lambda^2} \prec \chi^2(p,c) \prec \frac{(j+0.5)^2 g^2}{\lambda^2}\right],$$

Where c = $[\{(1-\lambda)\ i\ g\ /\ \lambda\}+d]^2$, degree of freedom is p , d is the shift in mean vector.

For the case where j =0, we have

$$p(i,0) = P\,[\,\chi^2\,(p,c) < \{(0.5)^2\, g^2 / \lambda^2\}].$$

For any control chart that is approximated by a Markov chain, the run length performance can be determined from the transition probability matrix. Assume that a Markov chain has s states (see Brook and Evans (1972)). The transition probability matrix contains the transition probabilities for moving from state to state. Let this s x s matrix of transition probabilities be presented as **P**, where the process mean vector is such that the non centrality parameter is δ. Let the s x 1 vector **q** designate the starting state of the Markov chain. The vector **q** will have a one in the component corresponding to the starting state and zeros in all of the other components. The zero state ARL of a scheme modeled as a Markov chain represented by ARL=$\mathbf{q}'(\mathbf{I}-\mathbf{P})^{-1}\,\mathbf{1}$. (ix)

Steps of ARL Computation for MMOEWMA

Step-1 Choose the parameter λ (Weighting factor), h_2 (decision value), p (number of variable), and shift in mean vector d.

Step-2 The upper control limit of MMOEWMA chart is, UCL = $\left(\dfrac{\lambda}{2-\lambda} + \dfrac{2\lambda(1-\lambda)}{2-\lambda}\right)^{1/2} (h_2)^{1/2}$.

Step-3 Choose the number of states m.

Step-4 Compute width g = $\dfrac{2UCL}{(2m+1)}$.

Step-5 $\chi^2(p,c)$ denotes a non central chi square random variable with p degrees of freedom and non centrality parameter c.

Step-6 Non centrality parameter, c = $[\{(1-\lambda)\ i\ g\ /\ \lambda\}+d]^2$, degree of freedom is p , d is the shift in mean vector.

Step-7 For j not equal to zero (j ≠ 0),

$$p(i,j) = P\left[\frac{(j-0.5)^2 g^2}{\lambda^2} \prec \chi^2(p,c) \prec \frac{(j+0.5)^2 g^2}{\lambda^2}\right].$$

Step-8 For the case where j =0, we have

$$p(i,0) = P\,[\,\chi^2\,(p,c) < \{(0.5)^2\, g^2 / \lambda^2\}].$$

Step-9 Adjust the t. p.m.(R_a) such that row sums are unity.

Step-10 Compute u = $[I - R]^{-1}\,\mathbf{1}$

Step-11 Compute q = R_a'* I

Step-12 ARL = q' * u, OR ARL = $q'[I - R]^{-1}\,\mathbf{1}$

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R-Program for monitoring Modified Multivariate Exponentially Weighted Moving Average Control Chart

```
## Multivariate MOEWMA (MMOEWMA)
## Three Temperature Data
p<-3
X<-read.table("Rprogram/Temp3.txt",header=TRUE)
X
##Temperature T3=X1,T11=X2,T21=X3
X1<-as.matrix(X[1:1439,1])
X1
x1<-ts(X1)
ar1<-arima(x1,order=c(1,0,1))
a1<-mean(X1)
a1<-92.24
##a1=92.24
X2<-as.matrix(X[1:1439,2])
X2
x2<-ts(X2)
ar2<-arima(x2,order=c(1,0,1))
a2<-mean(X2)
a2<-95.56
## a2= 95.56
X3<-as.matrix(X[1:1439,3])
X3
x3<-ts(X3)
ar3<-arima(x3,order=c(1,0,1))
a3<-mean(X3)
a3<-100.27
## a3=100.27
## if we take unit variances and Correlation=0.5
cmat <- matrix(c(1,0.5,0.5,0.5,1,0.5,0.5,0.5,1), nrow = 3, ncol=3, byrow=TRUE)
cmat
cmat1<-solve(cmat)
cmat1
m<-1439
## Exponential Weight r, 0<r<=1
r<-0.10
```

```
## Difference Variance
##k<-0.095
k<-(2*r*(1-r))/(2-r)
Xn<-matrix(0,m,3)
for(i in 1:m)
{ for(j in 1:3)
{
Xn[i,1]<-X[i,1]-a1
Xn[i,2]<-X[i,2]-a2
Xn[i,3]<-X[i,3]-a3
}}
round(Xn,2)
## MMOEWMA Vector Zi= rXi+(1-r)Zi-1+(Xi-Xi-1), Z0=M0=X0=0
##Asymptotic Sz={(r/(2-r))+k}s
Sz<-{(r/(2-r))+k}*cmat
Si<-solve(Sz)
Si
Zi<-matrix(0,m,3)
Z1<-0
Z2<-0
Z3<-0
X0<-0
for(i in 1:m)
{  for(j in 1:3)
{
 Zi[i,1]<-r%*%Xn[i,1]+(1-r)*Z1+(Xn[i,j]-X0)
 Zi[i,2]<-r%*%Xn[i,2]+(1-r)*Z2+(Xn[i,j]-X0)
 Zi[i,3]<-r%*%Xn[i,3]+(1-r)*Z3+(Xn[i,j]-X0)
 if(i>1)
{
Zi[i,1]<-r%*%Xn[i,1]+(1-r)%*%Zi[i-1,1]+(Xn[i,j]-Xn[i-1,j])
Zi[i,2]<-r%*%Xn[i,2]+(1-r)%*%Zi[i-1,2]+(Xn[i,j]-Xn[i-1,j])
Zi[i,3]<-r%*%Xn[i,3]+(1-r)%*%Zi[i-1,3]+(Xn[i,j]-Xn[i-1,j])
}   }     }
round(Zi,2)
Tn<-matrix(0,m,1)
t1<-matrix(0,1,3)
s1<-matrix(0,3,3)
for(i in 1:m)
{  Tn[i,]<-t(Zi[i,])%*%Si[,]%*%Zi[i,] }
round(Tn,2)
h4<-matrix(5.417,m,1)
shift<-matrix(0,m,1)
for(i in 1:m)
{  if(Tn[i]>h4[i])
shift[i]<-1
else
shift[i]<-0
}
shift
n1<-matrix(0,m,1)
for(i in 1:m)
{ n1[i]<-i}
n1
plot(n1,Tn,type="l",xlab="Observations",ylab="Tn^2",main="MMOEWMA,p=3")
lines(h4)
##End of program
```

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3. Submission of Manuscripts,

4. Manuscript’s Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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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 definite statistics - 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.

Administration Rules Listed Before Submitting Your Research Paper to Global Journals Inc. (US)

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)

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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

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