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Empresarial Del Paraguay

Highlights

Input Sorting Algorithm

Future Technology Revolution

Discovering Thoughts, Inventing Future

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An Empirical Model for Thyroid Disease Classification using Evolutionary Multivariate Bayseian Prediction Method

By K.Geetha & Capt. S. Santhosh Baboo
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Abstract- Thyroid diseases are widespread worldwide. In India too, there is a significant problems caused due to thyroid diseases. Various research studies estimates that about 42 million people in India suffer from thyroid diseases [4]. There are a number of possible thyroid diseases and disorders, including thyroiditis and thyroid cancer. This paper focuses on the classification of two of the most common thyroid disorders are hyperthyroidism and hypothyroidism among the public. The National Institutes of Health (NIH) states that about 1% of Americans suffer from Hyperthyroidism and about 5% suffer from Hypothyroidism. From the global perspective also the classification of thyroid plays a significant role. The conditions for the diagnosis of the disease are closely linked, they have several important differences that affect diagnosis and treatment. The data for this research work is collected from the UCI repository which undergoes preprocessing. The preprocessed data is multivariate in nature. Curse of Dimensionality is followed so that the available 21 attributes is optimized to 10 attributes using Hybrid Differential Evolution Kernel Based Navie Based algorithm. The subset of data is now supplied to Kernel Based Naïve Bayes classifier algorithm in order to check for the fitness.

Keywords: classification, curse of dimensionality, kernel based naïve bayes classifier, differential evolutionary algorithm, multivariate bayseian prediction, thyroid disease, wrapper model.

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ANEMPIRICALMODELFORTHYROIDDISEASECLASSIFICATIONUSINGEVOLUTIONARYMULTIVARIATEBAYSEIANPREDICTIONMETHOD

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An Empirical Model for Thyroid Disease Classification using Evolutionary Multivariate Bayseian Prediction Method

K.Geetha [α] & Capt. S. Santhosh Baboo [σ]

Abstract- Thyroid diseases are widespread worldwide. In India too, there is a significant problems caused due to thyroid diseases. Various research studies estimates that about 42 million people in India suffer from thyroid diseases [4]. There are a number of possible thyroid diseases and disorders, including thyroiditis and thyroid cancer. This paper focuses on the classification of two of the most common thyroid disorders are hyperthyroidism and hypothyroidism among the public. The National Institutes of Health (NIH) states that about 1% of Americans suffer from Hyperthyroidism and about 5% suffer from Hypothyroidism. From the global perspective also the classification of thyroid plays a significant role. The conditions for the diagnosis of the disease are closely linked, they have several important differences that affect diagnosis and treatment. The data for this research work is collected from the UCI repository which undergoes preprocessing. The preprocessed data is multivariate in nature. Curse of Dimensionality is followed so that the available 21 attributes is optimized to 10 attributes using Hybrid Differential Evolution Kernel Based Navie Based algorithm. The subset of data is now supplied to Kernel Based Naïve Bayes classifier algorithm in order to check for the fitness. This iterative process takes 21 to 25 runs until the errors are reduced or the after the errors are stabilized, the data is classified. The accuracy of classification is observed to be 97.97%.

Keywords: classification, curse of dimensionality, kernel based naïve bayes classifier, differential evolutionary algorithm, multivariate bayseian prediction, thyroid disease, wrapper model.

I. Introduction

According to a recent study published by the daily Times of India, one in ten adults in India suffers from hypothyroidism. This estimation is found on the basis of a survey conducted by Indian Thyroid Society.

The study also depicts awareness for the thyroid disease and is ranked 9th when compared to other common diseases like asthma, cholesterol, depression, diabetes, heart problem and insomania. Medical practitioners say that the symptoms of thyroid are similar to other disorders. However, the survey revealed that only 50%, of the survey population are aware of thyroid disorder, know that there are diagnostic tests for detection of this disease [3].

Thyroid disorders damage the normal functioning of the thyroid gland which causes abnormal production of hormones leading to hyperthyroidism. The occurrence of hypothyroidism in the developed world is estimated to be about 4-5%. Hypothyroidism may cause high cholesterol levels, an increase in blood pressure, cardiovascular complications, decreased fertility, and depression if not properly treated.

Hence creating awareness among the public about the symptoms and types of this disease and its diagnosis plays a crucial importance of the hour. The main objective of this research work is to show the classification of more significant features from the available raw medical dataset which helps the physician to arrive at an accurate diagnosis of Thyroid among public.

This paper is organized in such a way that section 2 elaborates about thyroid disease types, symptoms and the ill effects. Section 3 deals with the background study conducted by various authors. Section 4 focuses towards the proposed methodology of thyroid classification supported by the results and discussion in section 5.

II. Overview of Thyroid

The thyroid is an organ present in the human body and is considered to be a part of the endocrine or the hormone, system. It is located in the human neck below the Adam's apple. The main purpose of thyroid is to produce thyroid hormones. The produced hormones go through the bloodstream to all the other organs which help to control metabolism and growth development in both in adults and in children.

The thyroid looks like butterfly shape. Figure 1 shows the thyroid and its parts. The right and left lobes of the thyroid looks similar to the two wings of a butterfly. They lie on both sides of the trachea or main breathing tube. The connection between the wings is called the isthmus [5]. The thyroid gland produces hormones which primarily control human body's growth and metabolism, which means that this energy is used for all the body processes. The thyroid gland acts as an important part in breathing, blood circulation, bowel

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movements, temperature of the body, muscle control, digestion, and brain function. An issue with the thyroid gland can result in problems all over the human body [6].

The thyroid gland functional data is more essential for the proper interpretation and diagnosis of the diseases associated with the gland. The principal role of the thyroid gland is to help regulation of the body's metabolism. Depending on the amount of secretion of this hormone may affect the human growth and development. When this hormone is produced very little thyroid hormone the type of disease is referred to as hypo-thyroidism. When this hormone is produced of too much it may lead to hyper-thyroidism [2].

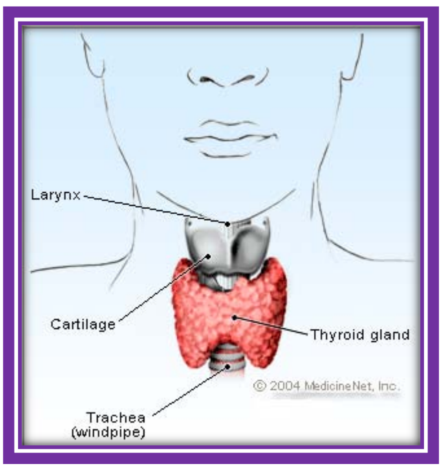

Fig. 1 : Thyroid in human body

a) Thyroid Harmones

The two hormones that are produced in the thyroid are L-thyroxine (T4) and tri-iodothyronine (T3)[5]. They regulate human body's metabolic functions such as heat generation, and the utilization of carbohydrates, proteins, and fats. Regulatory hormones from different parts of the brain control the thyroid's production of T4 and T3. In the pituitary gland, Thyrotropin-Stimulating Hormone (TSH) is released when more thyroid hormone is needed and travels via the bloodstream to the thyroid gland. TSH then stimulates the thyroid to produce T4 and T3 [5].

The pituitary gland acts like a thermostat to control the production of the hormone. When they are more in the bloodstream, the pituitary releases less TSH. When there are little in the bloodstream, the pituitary releases more TSH. With the help of this feedback system, the production of thyroid hormone is tightly controlled [5].

b) Thyroid And Health Effects

Thyroid diseases are one of the most common endocrine disorders worldwide. India too, is no exception. It is estimated that about 42 million people in India suffer from thyroid diseases [4][8].

Thyroid diseases are different from other diseases in terms of their ease of diagnosis, accessibility of medical treatment, and the relative visibility[4]. The thyroid gland secretes hormones which controls a lot of things in the human body system like metabolize the food, use energy, sleep patterns, temperature preferences, body weight balance and a lot more [7].

Both an increase and decrease in thyroid hormone production can cause health problems.

i. *Hyperthyroid*

Increase in the hormone production can cause hyperthyroidism. In medical field, "hyper" indicates too much. Hyperthyroidism crop up when the gland produces excess hormones. The most common cause for hyperthyroidism is the autoimmune disorder Graves' disease. It is also known as an overactive thyroid, the hormone overload can cause a extensive range of physical changes. Many symptoms overlap with hypothyroidism, including thinning hair, dry skin and temperature sensitivity. The symptoms that indicate the presence of hyperthyroidism includes weight loss in spite of a good food intake, an increase in heart rate, high blood pressure, nervousness, increased sweating, enlargement in your neck, shorter menstrual periods, frequent bowel movements and trembling hands [6]. The following figure 2 shows the list of symptoms of hyperthyroid.

Increased appetite
Blurred vision
Irregular menses
Diplopia
Exertional dyspnea
Fatigue
Heat intolerance
Diarrhea
Increased perspiration
Irritability
Muscle weakness
Nervousness
Palpitations
Photophobia
Sleep disturbances
Goiter
Fine resting tremors
Weight loss

Fig. 2 : Symptoms of Hyperthroid

ii. *Hypothyroid*

Decrease in the hormone production can cause hypothyroidism. In medical field, .the term hypo means deficient or not enough. For example, hypoglycemia is a term for low blood sugar. Hypothyroidism is a condition that the thyroid gland does not produce required hormones. Inflammation and damage to the gland causes hypothyroidism. Weight gain or failure to lose weight despite a proper weight loss regime, lethargy,

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reduced heart rate, increased cold sensitivity, numbness in hands, enlargement in the neck, dry skin and hair, heavy menstrual periods and constipation could indicate hypothyroidism. Symptoms vary from person to person, and if left untreated, they tend to worsen over time [6]. Figure 3 shows the list of symptoms of hypothyroid.

Brittle nails	Hoarseness
Cold hands and feet	Hypotension
Cold intolerance	Inability to concentrate
Constipation	Infertility
Depression	Irritability
Difficulty swallowing	Menstrual Irregularities
Dry skin	Muscle Cramps
Elevated Cholesterol	Muscle Weakness
Essential Hypertension	Nervousness
Eyelid swelling	Poor memory
Fatigue	Puffy eyes
Hair loss	Slower heartbeat

Fig. 3 : Symptoms of Hypothyroid

An increased risk of thyroid disease happens if there is a family history of thyroid disease like a type I diabetic, over 50 years of age and a stressful life [7].

Both hypothyroidism and hyperthyroidism can be diagnosed with thyroid function tests, which measures the levels of Thyroid-Stimulating Hormones (TSH) in bloodstream of human body [6].

III. Literature Review

There are many people who have studied various medical data and analyzed methods and models for preprocessing and classifying the data according to the need.

Ngan, Po Shun, et al (1999) introduced a system for discovering medical knowledge by learning Bayesian networks and rules. Evolutionary computation is used as the search algorithm. The Bayesian networks can provide an overall structure of the relationships among the attributes[13].

Ozyilmaz, Lale, and Tulay Yildirim (2002) proposed a system that includes Generalized Discriminant Analysis and Wavelet Support Vector Machine System (GDA_WSVM) method for diagnosis of thyroid diseases which includes three phases. They are feature extraction- feature reduction phase, classification phase, and test of GDA_WSVM for correct diagnosis of thyroid diseases phase, respectively [1]. The acceptable diagnosis performance of this GDA_WSVM expert system for diagnosis of thyroid diseases is estimated by using classification accuracy and confusion matrix methods, respectively. The classification accuracy of this expert system for diagnosis of thyroid diseases was obtained about 91.86% [1].

Ordonez et. al (2006) proposed a greedy algorithm to compute rule covers in order to summarize rules having the same consequent. The significance of association rules is evaluated using three metrics: support, confidence and lift [19].

Keleş, Ali, and Aytürk Keleş (2008) aims at diagnosing thyroid diseases with a expert system.In the proposed system, fuzzy rules by using neuro fuzzy method is incorporated [15].

Karaboga, D., & Basturk, B. (2008) compares the performance of ABC algorithm with that of Differential Evolution (DE), Particle Swarm Optimization (PSO) and Evolutionary Algorithm (EA) for multi-dimensional numeric problems [17].

Boryczka, Urszula (2009) focused on ant-based clustering algorithms. During the classification different metrics of dissimilarity like Euclidean, Cosine and Gower measures were used [18].

Kodaz, Halife, et al. (2009) proposed that Information gain based artificial immune recognition system (IG-AIRS) would be helpful in diagnosing thyroid function based on laboratory tests, and would open the way to various ill diagnoses support by using the recent clinical examination data. The classification used is distance-based classification systems [12].

Dogantekin et. al. (2010) introduced the diagnosis of thyroid disease. The feature reduction is performed by using Principle Component Analysis (PCA) method. The classification is done using Least Square Support Vector Machine (LS-SVM) classifier. The performance evaluation of the proposed Automatic Diagnosis System Based on Thyroid Gland ADSTG method is estimated by using classification accuracy, *k*-fold cross-validation, and confusion matrix methods respectively [14].

Karaboga et. al (2011) used ABC is used for data clustering on benchmark problems and the performance of ABC algorithm is compared with Particle Swarm Optimization (PSO) algorithm and other nine classification techniques. ABC algorithm can be efficiently used for multivariate data clustering test data sets from the UCI Machine Learning Repository are used to demonstrate the results of the techniques [10].

Stegmayer et. al (2012) proposed a novel integrated computational intelligence approach for biological data mining that involves neural networks and evolutionary computation. They used self-organizing maps for the identification of coordinated patterns variations; a new training algorithm that can include a priori biological information to obtain more biological meaningful clusters and evolutionary algorithm for the inference of unknown metabolic pathways involving the selected cluster [11].

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Yeh, Wei-Chang (2012) improved simplified swarm optimization (SSO) to mine a thyroid gland dataset collected from UCI databases. Close Interval Encoding (CIE) is added to efficiently represent the rule structure, and the Orthogonal Array Test (OAT) is added to powerfully prune rules to avoid over-fitting the training dataset [16].

Chen, Hui-Ling, et al (2012) proposed expert system, Fisher Score Particle Swarm Optimization Support Vector Machines (FS-PSO-SVM) has been rigorously evaluated against the thyroid disease dataset, which is commonly used among researchers who use machine learning methods for thyroid disease diagnosis [20].

Azar et. al (2013) performed a comparison between hard and fuzzy clustering algorithms for thyroid diseases data set in order to find the optimal number of clusters. Different scalar validity measures are used in comparing the performances. K-means clustering; K-medoids clustering; Fuzzy C-means; Gustafson–Kessel algorithm; Gath–Geva algorithm clustering results for all algorithms are then visualized by the Sammon mapping method to find a low-dimensional (normally 2D or 3D) representation of a set of points distributed in a high dimensional pattern space [9].

IV. Methodology

The framework of the proposed work is shown in the figure 4. The proposed work is based on the input from the UCI repository which involves 7200 multivariate type of records. Each record has 21 attributes. Out of the 21 attributes 15 are continuous data and 6 are discrete data.

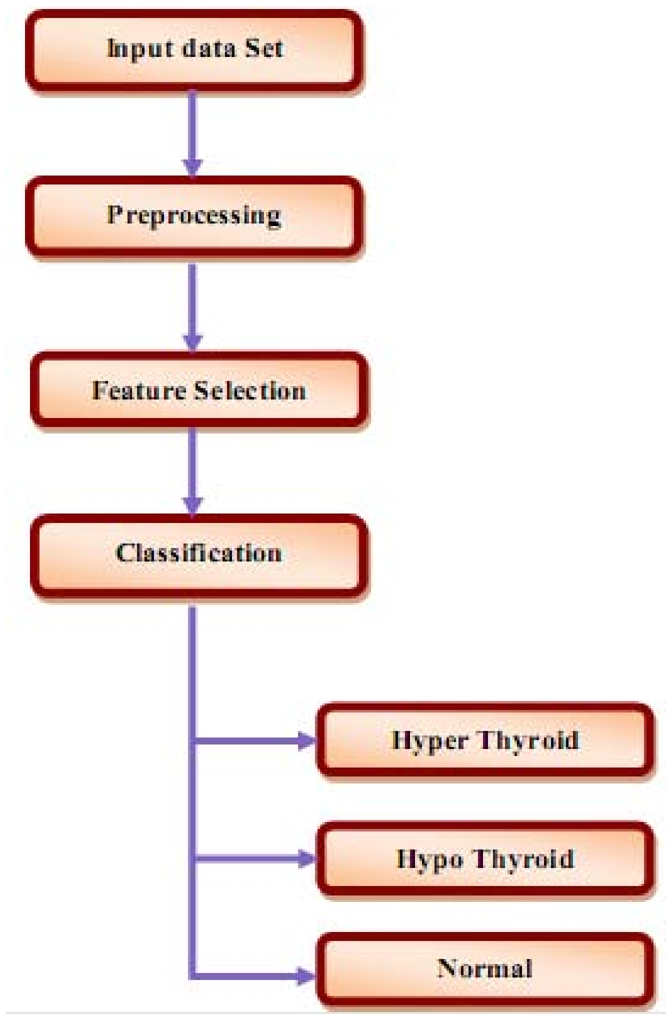

Fig. 4 : Framework of the proposed method

The following steps are involved in the process of the proposed work.

1. The data taken from UCI repository undergoes preprocessing where missing value and not a number constraint are checked using masking method. If the missing value or Not a Number (NaN) values are present it is replaced by the mean value of the column.
2. The preprocessed data is fed into a hybrid algorithm termed as Differential Evolution (DE). This algorithm

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is used for creating subset of child from the parent records.
3. The subsets of data are applied to Kernel Based Bayesian classifier algorithm to check the fitness. The fitness is measured by error stabilization.
4. After stabilization is achieved , the data is classified into 3 classes as
a. Hypo Thyroid
b. Hyper Thyroid
c. Normal

a) Data Set

The following table 1 shows the characteristics of Data set collected from UCI repository.

Table 1: Characteristics of Dataset

Data Set Characteristics	Multivariate, Domain-Theory
Attribute Characteristics	Categorical, Real
Associated Tasks	Classification
Number of Instances	7200
Number of Attributes	21 (Continuous -15; Discrete -6)

To ensure that the patterns derived are as accurate as possible, it is essential to improve the quality of the datasets in the pre-processing stage. Most real life data sets contain a certain amount of redundant data, which does not contribute significantly to the formation of important relationships. This redundancy not only increases the dimensionality of the data set and slows down the data mining process but also affects the subsequent classification performance [21].

Attribute selection is the process of removing the redundant attributes that are deemed irrelevant to the data mining task. However, the presence of attributes that are not useful to classification might interfere with the relevant attributes to degrade classification performance. This is due to the noise that is contributed by these additional attributes and raises the level of difficult [21].

The objective of attribute selection is therefore to search for a worthy set of attributes that produce comparable classification results to the case when all the attributes are used. In addition, a smaller set of attributes also creates less complicated patterns, which are easily comprehensible, and even visualized, by humans [21].

It has to be noted that for a data set with n attributes, there are 2^n–1 possible subsets. Therefore, an exhaustive search for an optimal set of attributes would be time-consuming and computationally expensive if n is large [21].

b) Preprocessing

The pre-processing step is necessary to resolve several types of problems including noisy data, redundant data, missing data values, etc. The high quality data will lead to high quality results and reduced costs for data mining. Missing data should be pre-processed so as to allow the whole data set to be processed by a required algorithm. Moreover, most of the existing algorithms are able to extract knowledge from data set that store discrete features. If the features are continuous, the algorithms can be integrated to create discrete attributes [22].

In the proposed work, the data taken from UCI repository has both continuous and discrete data which undergoes preprocessing. In this stage, the missing value and not a number constraint are checked using masking method. If the missing value or Not a Number (NaN) values are present it is replaced by the mean value of the column.

c) Feature Selection

Accurate diagnosis of diseases and subsequently, providing efficient treatment, forms an important part of valuable medical services given for patients in the health-care system. The unique characteristics of medical databases that pose challenges for data mining are the privacy-sensitive, heterogeneous, and voluminous data. These data may have valuable information which awaits extraction. The required knowledge is found to be encapsulated in/as various regularities and patterns that may not be evident in the raw data or the preprocessed data.

Extracting knowledge has proved to be priceless for future medical decision making. Feature selection is crucial for analyzing various dimensional bio-medical data. It is difficult for the biologists or doctors to examine the whole feature-space obtained through clinical laboratories at one time. All the computational algorithms recommend only few significant features for disease diagnosis. Then these recommended significant features may help doctors or experts to understand the biomedical mechanism better with a deeper knowledge about the cause of disease and provide the fastest diagnosis for recovering the infected patients as early as possible [24].

Feature selection methods tend to identify the features most relevant for classification and can be broadly categorized as either subset selection methods or ranking methods. The former type returns a subset of the original set of features which are considered to be the most important for classification [24][26].

Feature selection, is an effective in dimensionality reduction, by removing irrelevant and redundant data, increasing learning accuracy, and improving result comprehensibility [24][25]. Feature selection algorithms generally fall into two broad categories. They are:
A. The filter model
B. The wrapper model

i. *Filter Model*

The filter model depends on general characteristics of the training data to select some features without involving any learning algorithm. The

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filter model assesses the relevance of features from data alone, independent of classifiers, using measures like distance, information, dependency (correlation), and consistency [24][25].

ii. *Wrapper Model*

The wrapper model needs one predetermined learning algorithm in feature selection and uses its performance to evaluate and determine which features are selected. For each of the generated new subset of features, the wrapper model is supposed to learn the hypothesis of a classifier. It has a propensity to find features better suited to the predetermined learning algorithm resulting in superior learning performance, but it also tends to take more computation time and is more expensive than the filter model [24][25].

This research work uses the Wrapper model for feature selection. In wrapper methods, the algorithm that selects the features uses a classification algorithm for evaluation. Accordingly, wrapper methods are more precise but computationally more complex [27][28], and they also depend on the data selected for classifier development. Since these data guide the selection, they can lead to over-fitting [28][29]. A broad spectrum of various wrappers is used in today's approaches. For example, the forward and the backward floating search and their combinations are commonly used, where one feature is added or reduced at a time, depending on the classification accuracy, Evolutionary algorithms are also used.

iii. *Defferential Evolution*

Differential Evolution, or briefly DE [28][30][31][32] is a simple but effective search method for continuous optimization problems. According to Xinjie and Mitsuo (2010), DE represents a direction based search that maintains a vector population of candidate solutions. Like other usual Evolutionary Algorithms (EAs), it uses mutation, crossover and selection. The key part of DE, which differentiates it from standard EAs, is the mutation operator that perturbs the selected vector according to the scaled difference of the other two members of the population. The operation of DE is shown as pseudo-code in Algorithm 1.

Algorithm 1: Differential Evolution (DE)- pseudo-code.

```
Initialization and parameter setting
while termination condition not met do
for all population member—vector vi do
create mutant vector ui
crossover vi and ui to create trial vector ti
end for
for all population member—vector vi do
if f(ti) ≤ f(vi) then
vi ← ti
end if
```

The population of size NP contains vectors and each vector v_i, of dimensionality D, consists of real-valued parameters, $v_i = (v^1_i, \ldots, v^D_i) \in RD$, for $i = 1, \ldots, NP$. Usually the population is initialized with vectors of values obtained randomly in the interval $[v_{lb}, v_{ub}]$, where v_{lb} and v_{ub} represent the lower and upper bound, respectively. In each generation, a new population is created through mutation and crossover. This new population is composed of the trial vectors t_i. For each member of the current population, v_i (called the target vector), a new corresponding mutant vector u_i is formed using mutation. The mutation is conducted according to

$$u_i = vr1 + F \cdot (v_{r2} - v_{r3})$$

Here u_i is a mutant while vr1, vr2 and vr3 are population vectors selected randomly with the condition $i \neq r1 \neq r2 \neq r3$, and $F \in [0,\infty)$ is the scale factor which represents a parameter of the algorithm. After the mutation, crossover occurs between the target vector v_i and the corresponding mutant u_i creating a trial vector t_i. The crossover is done as follows:

$$tji = \begin{cases} u^j_i & \text{if } U[0, 1) \leq CR \text{ or } j = r_j, \\ v^j_i & \text{otherwise} \end{cases}$$

for $j = 1, \ldots, D$. Here t_i is a trial vector obtained through crossover, U[0, 1) is a variable with its value randomly selected from the interval [0, 1) with uniform distribution, r_j is a random variable with the value from the set $\{1, \ldots, D\}$, while $CR \in [0, 1)$ is the crossover rate and represents a parameter of the algorithm. The described crossover is called the binomial crossover. Once the trial vector population has been created, vectors that transfer over to the next generation, i.e., which will constitute the new population, are selected. A given trial vector t_i replaces the corresponding target vector v_i if it is of equal or lesser cost, according to the given objective/fitness function. Due to its simplicity, DE is a very popular search method that has been successfully applied to various problems [28].

d) *Classification*

A classifier is a function f that maps input feature vectors $x \in X$ to output class labels $y \in \{1, \ldots, C\}$, where X is the feature space [33].

i. *Kernel Based Naïve Bayian Classifier*

Naive Bayesian Classifier is a simple probabilistic classifier with an assumption of conditional independence among the features, i.e., the presence (or absence) of a particular feature of a class is unrelated to the presence (or absence) of any other feature. It only requires a small amount of training data to estimate the parameters necessary for classification. Many experiments have demonstrated that NB classifier has worked quite well in various complex real-world situations and outperforms many other classifiers. Kernel estimation has been used in cases of datasets with numerical attributes [23][24].

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The Naive Bayes classifier classifies data in two steps:

1. Training step: Using the training data, the method estimates the parameters of a probability distribution, with the assumption that the predictors are conditionally independent given the class.
2. Prediction step: For any unknown test data, the method computes the posterior probability of the sample belonging to each class. The method then classifies the test data.

The class-conditional independence assumption simplifies the training step and the estimate of the one-dimensional class-conditional density for each class is predicted individually [35].

Naive Bayes model is easy to build and particularly useful for very large data sets. Along with simplicity, Naive Bayes is known to outperform even highly sophisticated classification methods [34].

Naive Bayes is a conditional probability model: given a problem instance to be classified, represented by a vector

$$\mathbf{x} = (x_1, \dots, x_n)$$

representing some *n* features (independent variables), it assigns to this instance probabilities

$$p(C_k \mid x_1, \dots, x_n)$$

for each of *K* possible classes [36][37]. If the number of features *n* is large, the conditional probability can be decomposed as

$$p(C_k \mid \mathbf{x}) = \frac{p(C_k)\ p(\mathbf{x} \mid C_k)}{p(\mathbf{x})}.$$

The advantage of using Naive Bayes algorithm are

- It is easy and fast to predict class of test data set. It also perform well in multi class prediction [34].
- When assumption of independence holds, a Naive Bayes classifier performs better compared to other models like logistic regression and less training data is required[34].

V. Results and Discussion

The proposed model is developed using Matlab. The proposed work is designed to have two panels. One is the display panel and the other is analysis panel. The following figure 5 shows the framework of the Evolutionary Multivariate Bayesian prediction method where the data is loaded from the repository. Figure 6 and figure 7 displays the preprocessing and feature selection stage respectively.

Data distribution and error stabilization is shown in display panel of figure 8. The classification is evaluated based on ten evaluation metrics whose values are shown in the figure 9. 21 epohs (runs) are carried out for the data. After stabilization is achieved , the data is classified into 3 classes.

1. Hypo Thyroid
2. Hyper Thyroid
3. Normal

The accuracy of classification is achieved as 97.97%.

With the aim of accessing the classifier and to compare the output classes, Receiver Operating Characteristic (ROC) is used. The ROC is shown in the figure 10 which compare each class of thyroid based on their True Positive rate and False Positive rate. The number of instances of Hyper thyroid and hypothyroid among male and female is shown in figure 11.

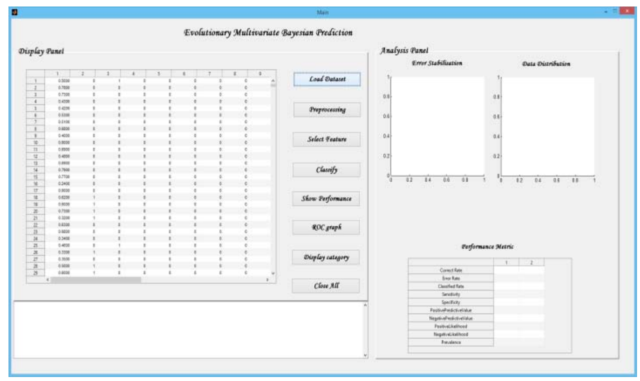

Fig. 5 : Data Load from the repository

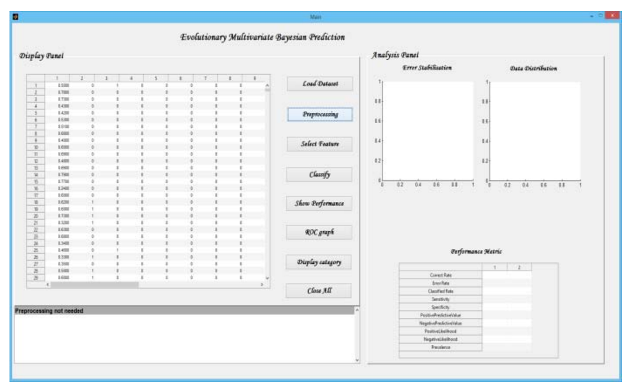

Fig. 6 : Preprocessing

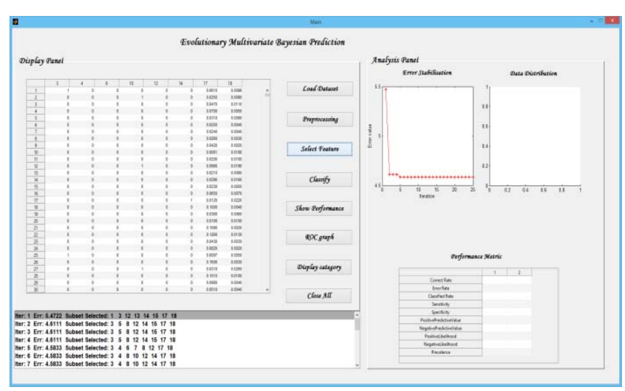

Fig. 7 : Feature Selection

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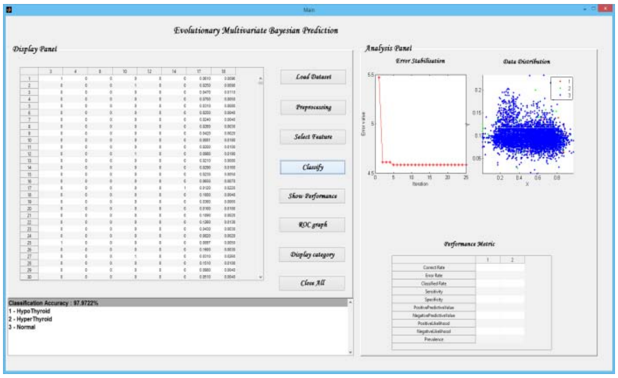

Fig. 8 : Classification

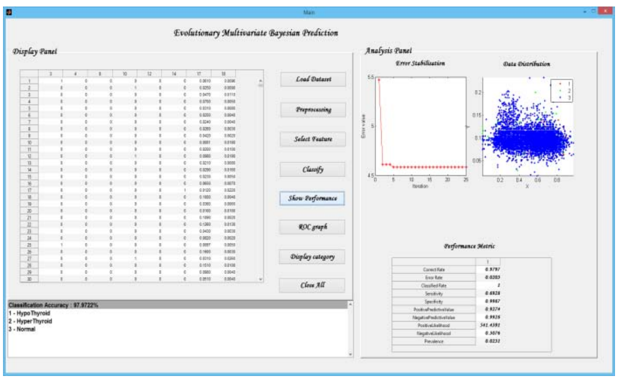

Fig. 9 : Performance metrics

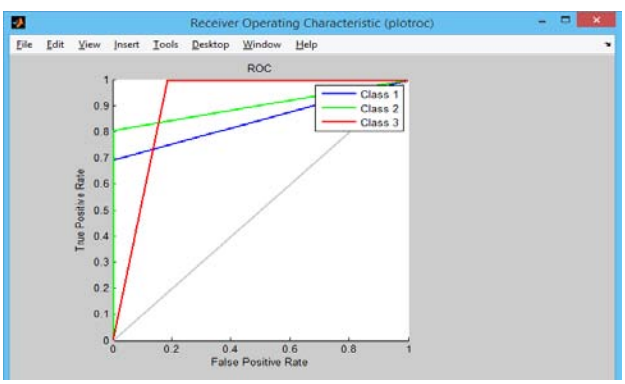

Fig. 10 : Receiver Operating Characteristic (ROC)

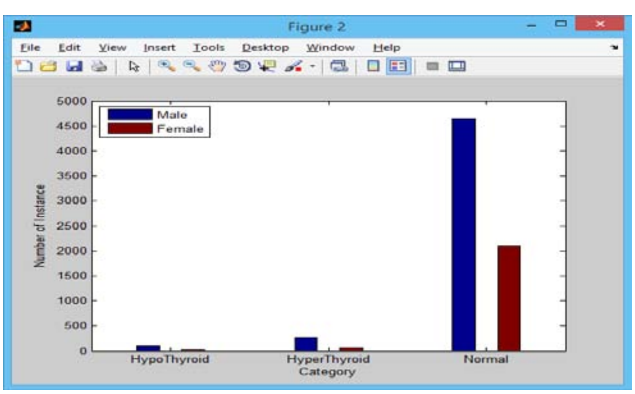

Fig. 11 : Number of instances of Hyper thyroid, Hypo thyroid among male and female

VI. Conclusion

The objective of this research work is aimed to show the classes of thyroid from the available raw medical dataset helps the physician to arrive at an accurate diagnosis. The results show that the proposed Evolutionary Multivariate Bayisean Prediction classifier model achieves remarkable dimensionality reduction from among the 7200 medical datasets obtained from the UCI repository with 21 attributes (Continuous -15; Discrete - 6). 21 epohs (runs) are carried out for the data and after stabilization, the data are classified as Hyper, Hypo and Normal classes. The results are evaluated based on ten evaluation metrics and the accuracy of classification is 97.97%.

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An Optimized Input Sorting Algorithm

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Abstract- One of the fundamental issues in compute science is ordering a list of items. Although there is a huge number of sorting algorithms, sorting problem has attracted a great deal of research, because efficient sorting is important to optimize the use of other algorithms. Sorting involves rearranging information into either ascending or descending order. This paper presents a new sorting algorithm called Input Sort. This new algorithm is analyzed, implemented, tested and compared and results were promising.

Keywords: *algorithm, sorting, input sort, insert.*

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ANOPTIMIZEDINPUTSORTINGALGORITHM

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An Optimized Input Sorting Algorithm

Anshu Mishra [α] & Garima Goyal [σ]

Abstract- One of the fundamental issues in compute science is ordering a list of items. Although there is a huge number of sorting algorithms, sorting problem has attracted a great deal of research, because efficient sorting is important to optimize the use of other algorithms. Sorting involves rearranging information into either ascending or descending order. This paper presents a new sorting algorithm called Input Sort. This new algorithm is analyzed, implemented, tested and compared and results were promising.

Keywords: algorithm, sorting, input sort, insert.

I. Introduction

Information growth rapidly in our world and to search for this information, it should be ordered in some sensible order. Many years ago, it was estimated that more than half the time on many commercial computers was spent in sorting. Fortunately this is no longer true organizing data, methods which do not require that the data be kept in any special order [1].

Many algorithms are very well known for sorting the unordered lists. Most important of them are Bubble, Heap, Merge, Selection[2]. As stated in [3], sorting has been considered as a fundamental problem in the study of algorithms, that due to many reasons:

1. The need to sort information is inherent in many applications.
2. Algorithms often use sorting as a key subroutine.
3. In algorithms design there are many essential techniques represented in the body of sorting algorithms.
4. Many engineering issues come to the fore when implementing sorting algorithms.

Efficient sorting algorithms is important to optimize the use of other algorithms that require sorted lists to work correctly; it is also often in producing human readable output. Formally, the output should satisfy two major conditions:

1. The output is in non-decreasing order.
2. The output is a permutation or reordering of the input.

Since the early beginning of computing, the sorting problem has attracted many researchers, perhaps due to the complexity of solving it efficiently. Bubble sort was analyzed as early as 1956[6].

Many researchers considered sorting as a solved problem. Even so, useful new sorting algorithms are still being invented. For example, library sort was first published in 2004. Sorting Algorithms are prevalent in introductory computer science classes, where the abundance of algorithm for the problem provides a gentle introduction of core algorithm concepts[4,5].

In [4], they classified sorting algorithms by:

1. Computational complexity (worst, average and best)of element comparison in terms of list size(n).For typical sorting algorithms good behavior is O(nlogn) and bad behavior is $\Omega(n^2)$. Ideal behavior for a sort is O(n). Sort algorithms which only use an abstract key comparison operation always need Ω(nlogn) comparison in worst case.
2. Use of memory and computer resources. Some sorting algorithms are "in-place", such that only O(1)or O(log n)memory is needed beyond the items being stored, while others need to create auxiliary locations for data to temporally stored.
3. Recursion some algorithms are either recursive or non recursive, while others may be both (e.g merge sort).
4. Whether or not they are a comparison sort. A comparison sort examines the data only by comparing two elements with a comparison operator.

This paper presents a new sorting algorithm called input sort. Its typical use is when sorting the elements of a stream from file.

II. Input Sort

a) Concept

A simple sorting algorithm which sort the data whenever it is input from any input source e.g. keyboard or data from a stream of file. when new item comes then it is inserted at its specific position through a recursive function if there are n elements then n items 1 at a time is inserted in array which increase array size automatically and take its appropriate position.

b) Steps

The procedure of the algorithm can be described as follows:

1. Input one element one at a time.
2. Call the INPUT-SORT function to insert the item.
3. Recursive function determines where is to be the new item inserted in existing array by comparing from the middle element and place it at its specific position
4. After inserting n elements we have new array which is finally sorted.
5. End.

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c) Pseudo Code

```
Size:=0,array c[1…max]  //Global variables
INPUT_SORT(ele , p,r)
q:=(p+r)/2//calculate mid position
if p == r  //base criteria for recursion
{
INSERT(ele,p)
return;
}
 if(ele<c[q]
INPUT_SORT(ele,p,q)
else
INPUT_SORT(ele,q+1,r)
end.

INSERT(ele,pos)
for   j= size down to pos
c[j+1]:=c[j]
c[pos]:=ele
size:=size+1
end.

GET_INPUT( )
for  i = 1  to  n
{
scan(c[i])
call INPUT_SORT(c[i],1,size+1)
}
end
```

III. Working

Suppose we have array c[1…5] of five elements as follows:

First we call GET_INPUT() function and read input from input source

5	4	3	2	1

During 1st Pass: insert 5 call INPUT_SORT(1,1)

Content of array c[size] i.e c[1]

5

P=1,q=1,r=1,size=1

During 2nd Pass: insert 4 call INPUT_SORT(1,2)

Content of array c[size] i.e c[2]

4	5

P=1,q=1,r=2

P=1,q=1,r=1

Similarly ,

During 5th Pass: insert 4 call INPUT_SORT(1,5)

Content of array c[size] i.e c[1…5]

1	2	3	4	5

P=1,q=3,r=5

P=1,q=2,r=3

P=1,q=1,r=2

P=1,q=1,r=1

Now finally: Content of Array c[1…5]

1	2	3	4	5

Which is Sorted Array .

IV. Complexity

Generally the complexity of an algorithm is measured in two phases. When one measures the complexity of an algorithm by pen and paper, he/she can only predict the complexity which give an idea how much time and space this algorithm takes to finish in its execution. This phase is called priory analysis. After implementing the algorithm in computer, we get the actual time and space. This phase of analyzing the algorithm is called the posterior analysis. complexity of an algorithm can be of two types:

1. *Time Complexity:* The analysis of algorithm for the prediction of computation time for execution of each and every instruction in the algorithm is called the time complexity.
2. *Space Complexity:* The analysis of algorithm for prediction of memory requirement of the algorithm is known as space complexity.

The complexity of the algorithms are as follows:

1. Our algorithm run in O(n log n) time
2. Better in average and worst case of bubble and Insertionsort.
3. Better in all cases of selection sort.
4. Better from worst case of quick sort.
5. Easy to implement.
6. It required less memory space than Heap and Merge Sort

Sorting	**Best Case**	**Average**	**Worst**
Bubble	$\theta(n)$	$\Theta(n^2)$	$O(n^2)$
Insertion	$\theta(n)$	$\Theta(n^2)$	$O(n^2)$
Selection	$\theta(n^2)$	$\theta(n^2)$	$O(n^2)$
Merge	θ (nlogn)	θ (nlogn)	O(nlogn)
Quick	θ (nlogn)	θ (nlogn)	$O(n^2)$
Heap	θ (nlogn)	θ (nlogn)	O(nlogn)
Input	**θ (nlogn)**	**θ (nlogn)**	**O(nlogn)**

V. Recurrence Equation of Input Sort

Using the standard recurrence equation $T(n)=aT[n/b]+f(n)$ get this equation:

$T(n)=2T[n/2]+n$ $a=2$ $b=2$ $f(n)=n$

$n^{\log_b a} = n^{\log_2 2} = n$

using master method's 2nd case apply

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if $f(n)=\theta(n^{\log_b a})$, then

$T(n)= \theta(n^{\log_b a} . \log n)$

Time complexity of Input Sort is

$T(n)= \theta(n \log n)$

VI. Comparison with Heap and Merge Sort

Now if we talk about heap merge sort than our algorithm is better from two in the sense that In merge sort we need two extra temporary array which increase its space complexity but no need of extra memory in our algorithm. our algorithm has order of O(nlog n) but it execute fast because of less comparisons than Merge heap and Quick sort.

VII. Conclusion

In this paper new sorting algorithm is presented INPUT-SORT has O(nlog n) complexity but it is faster than existing sort mentioned in section 4 in detail. INPUT-SORT is definitely faster than other sort to sort n elements. Furthermore, the proposed algorithms are compared with some recent sorting algorithms; selection sort and bubble sort, heap, merge, insertion, quick sort. These algorithm can be applied on a real world application. any sorting algorithm might be a subroutine of another algorithms which affects its complexity.

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Las Tecnologías DE LA Información Y Comunicación EN EL sector empresarial DEL Paraguay

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Consejo Nacional de Ciencia y Tecnología, Paraguay

Abstract- It is irrefutable that the development, incorporation, and use of technology information and communications originated an impact in the business sector. It is also a fact, the existence of a marked asymmetry between developed and developing countries. Furthermore, the measurement and generation of indicators in the information, communication technology ICT sector is also an asymmetric reality, as models and approaches for their measure are still an issue.

Nevertheless, the effort made by less developed countries, including Paraguay, is evident, and the milestones achieved are remarkable and there are emblematic cases that deserve to be replicated, but it is still insufficient to reach the penetration levels and use achieved by more developed countries. A pending task, both for Paraguay as well as many Latin American countries, is to fill in this information gap by means of the generation and measurement of indicators that are reliable and representative of the ICT sector, thus enabling the development of programs and activities designed to incorporate all areas, such as: business, education, healthcare, and government.

Keywords: *ICT; technological innovation; technological switch, productivity.*

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LASTECNOLOGASDELAINFORMACINYCOMUNICACINENELSECTOREMPRESARIALDELPARAGUAY

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Las Tecnologías DE LA Información Y Comunicación EN EL Sector Empresarial DEL Paraguay

Dra. Emilce Sena Correa [α], Dr. Luis Alberto Dávalos Dávalos [σ] & Dr. Sergio Duarte Masi [ρ]

Resumen- Es indudable el impacto originado por la incorporación, utilización y desarrollo de las Tecnologías de la Información y Comunicación en el sector empresarial. Ahora bien, es marcada la asimetría entre los países desarrollados y los de pequeña economía. Así también, la medición y generación de indicadores, en el sector de las Tecnologías de la Información y Comunicación (TICs), es aún una realidad asimétrica, pues aún se debaten modelos y enfoques para la medición de las mismas.

A pesar de ello, es notorio el esfuerzo que hacen los países menos desarrollados, entre ellos Paraguay, y son destacables los hitos logrados y los casos emblemáticos que merecen ser replicados, pero aún insuficientes para llegar a los niveles de penetración y utilización que han logrado los países más desarrollados. Una tarea pendiente tanto para el Paraguay, así como para muchos países latinoamericanos es llenar las lagunas de información a través de la generación y medición de indicadores confiables y representativos del sector de las TICs que permitan el desarrollo de programas y acciones tendientes a incorporarlas en todos los sectores, tales como: empresarial, educación, salud, y gobierno.

Considerando el relevamiento y análisis realizado por el Gobierno de Paraguay y plasmado en el Plan Director (2011), el informe de la Mesa Sectorial de Tecnologías de la Información y Comunicación (TIC) de la Red de Inversiones y Exportaciones de Paraguay (REDIEX) (2008) y los indicadores del Foro Económico Mundial (*World Economic Forum*) en su Informe Global de Tecnología de la Información 2010-2011 (*The Global Information Technology Report* – GITR - 2010-2011) se puede concluir que el Paraguay presenta avances en el área de las Tecnologías de la Información y Comunicación, pero aún la penetración en el sector empresarial es bajo.

Palabras Claves: TICS; innovación tecnológica; cambio tecnológico; productividad.

Abstract- It is irrefutable that the development, incorporation, and use of technology information and communications originated an impact in the business sector. It is also a fact, the existence of a marked asymmetry between developed and developing countries. Furthermore, the measurement and generation of indicators in the information, communication technology ICT sector is also an asymmetric reality, as models and approaches for their measure are still an issue.

Nevertheless, the effort made by less developed countries, including Paraguay, is evident, and the milestones achieved are remarkable and there are emblematic cases that deserve to be replicated, but it is still insufficient to reach the penetration levels and use achieved by more developed countries. A pending task, both for Paraguay as well as many Latin American countries, is to fill in this information gap by means of the generation and measurement of indicators that are reliable and representative of the ICT sector, thus enabling the development of programs and activities designed to incorporate all areas, such as: business, education, healthcare, and government.

Considering the survey and analysis conducted by the Government of Paraguay and reported in the Master Plan (2011), the report of the Information Technology and Communication (ICT) Board of the Investment and Export Network of Paraguay (REDIEX) (2008) and the World Economic Forum (WEF) Indicators in it's Global Information Technology 2010-2011 Report (GITR - 2010-2011) we can conclude that Paraguay presents advances in the area of Technology Information and Communication, but still the penetration in the business sector is low.

Keywords: ICT; technological innovation; technological switch, productivity.

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I. Introducción

El presente trabajo aborda la adopción de las TICs en las empresas del Paraguay y su situación en general, considerando la perspectiva global de los indicadores del Foro Económico Mundial (*World Economic Forum* - WEF) en su Informe Global de Tecnología de la Información 2010-2011 (*The Global Information Technology Report* – GITR - 2010-2011) y una comparación con los indicadores de la Organización para la Cooperación y el Desarrollo Económico (OCDE).

Por tanto en primer término se presenta la visión general del impacto de las TICs en el sector empresarial, atendiendo la clasificación de las empresas propuestas por Sartor y Veiga (2011), pasando por la situación de los países miembros de la OCDE y Latinoamerica y culminando con la situación y logros en el sector de las TICs del Paraguay.

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II. Metodología

Como método de investigación se propone el análisis comparativo, respecto a la situación de los países de la OCDE y los de Latinoamérica considerando dos dimensiones de utilización de las TICs: porcentaje de penetración de internet y porcentaje de utilización de Internet de las empresas de estos países.

Debido a que aún no existen datos relevados de la utilización de internet en las empresas latinoamericanas, se propone una aproximación, considerando un comportamiento similar al que experimentan las empresas pertenecientes a la OCDE: es decir, que se espera un 14 % menos de utilización por parte del sector empresarial, respecto a los valores establecidos en la penetración en la población, para la situación latinoamericana. Esta misma relación se utiliza para aproximar la penetración de las TICs en las empresas latinoamericanas, incluidas las paraguayas.

Así también, se presenta un relevamiento general de las TICs y su impacto en las empresas y una descripción de avances observados en el Paraguay mediante un recorrido en el periodo 2001 – 2012.

El enfoque es principalmente cuantitativo, referente al análisis de los principales indicadores de las TIC´s. Para conseguir lo propuesto, se analizan datos secundarios, utilizando estudios, informes y otros artículos referentes al tema.

III. Generalidades

La definición de la Comisión Económica para América Latina (CEPAL) considera que las Tecnologías de Información y Comunicación (TICs) se definen como sistemas tecnológicos mediante los que se recibe, manipula y procesa información, y que facilitan la comunicación entre dos o más interlocutores. Por lo tanto, las TICs son algo más que informática y computadoras, puesto que no funcionan como sistemas aislados, sino en conexión con otras mediante una red. Son más que tecnologías de emisión y difusión (como televisión y radio), puesto que no sólo dan cuenta de la divulgación de la información, sino que además permiten una comunicación interactiva. El actual proceso de convergencia de TIC (es decir, la fusión de las tecnologías de información y divulgación, las tecnologías de la comunicación y las soluciones informáticas) tiende a la coalescencia de tres caminos tecnológicos separados en un único sistema que, de forma simplificada, se denomina TIC (CEPAL, 2003).

Prácticamente existe unanimidad entre la mayoría de los investigadores en el área de las TICs, y en este sentido podemos citar a Diaz-Guerra (2004), Manero et al (2012), Fuentelsaz (2005), Martínez Jurado el al (2012), entre otros, al afirmar que durante los años noventa el panorama del sector de las telecomunicaciones se caracterizó por disponer de un mercado estable, la existencia de un sector fuertemente intervenido, un servicio telefónico dominante y la capacidad de generar grandes economías. Hoy, entrada la segunda década del 2000, la realidad es diferente y cambia aceleradamente: *el mundo se expone a la llamada "revolución de las comunicaciones", que trae consigo un importante crecimiento económico, una agigantada evolución tecnológica y un amplio desarrollo de la movilidad e Internet*, en el que se deben plantear proyecciones, del futuro de las comunicaciones, la satisfacción cada vez más crucial del cliente y el fuerte impacto en los mercados.

Este fenómeno expansivo y penetrante de las TICs ha sido aprovechado con especial intensidad por las empresas, por una parte y de manera muy especial en las empresas del sector de los servicios y del sector turístico, tal como lo menciona Manero et al. (2012), afectando a las funciones de distribución y comercialización de sus productos/servicios y generando cambios en su sistema de distribución, como por ejemplo en la estructura del sistema, la posición de poder de los operadores y los procesos productivos y productos-servicios; y por la otra, en el sector manufacturero-industrial, afectando positivamente en la productividad (López Sánchez, 2004), especialmente en los procesos de automatización, diseño, control de calidad y la producción en gran escala. Empero, este mismo autor hace mención de la necesidad de mayor inversión en TICs, sobre todo si comparamos la situación Ibeoramericana con respecto de los países más desarrollados de la OCDE, y que dichas inversiones pueden traducirse en mejoras de la productividad. En general, según Fuentelsaz et al (2005), las TICs poseen y ejercen un intenso potencial para trasladarse al resto de los sectores productivos en términos de mejoras en la productividad total de los factores (PTF)[1]. Además, su impacto trasciende a lo económico hasta el punto que es habitual referirse a esta Era como la Era o Sociedad de la Información, en clara alusión a la generalización de las TIC en cualquier ámbito cotidiano.

Entonces, una primera afirmación, siguiendo a Fuentelsaz et al (2005), radica en que las TICs están en todas partes incluso en las estadísticas de productividad y están comprobados los factores determinantes de la productividad empresarial a la hora de incorporar las TICs, y que se presenta en la Figura

[1] El concepto de productividad multifactorial o total de los factores (PTF) ha recibido importantes aportes teóricos y econométricos tendientes a cuantificar y explicar dicha productividad. Se basan en representaciones conceptuales; ejemplos son "el diamante" de Porter (1990), "el doble diamante de Rugman" (Rugman y D´Cruz (1993)) o "el modelo de los nueve factores de Cho" (Cho y Moon, 2000), entre otros. Estos aportes dieron lugar a indicadores de competitividad que son utilizados con fines prácticos pero sin estar aún fundamentados en un modelo formal que de sustento a las relaciones causales que dicen sostener.

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Nº1, que explica cómo los países que más han invertido en TICs, en la década comprendida entre 1990 a 2000 - como el caso de Canadá, Dinamarca, Estados Unidos de Norteamérica, Finlandia, Suecia, entre otros – han tenido un salto cuantitativo y cualitativo en su productividad.

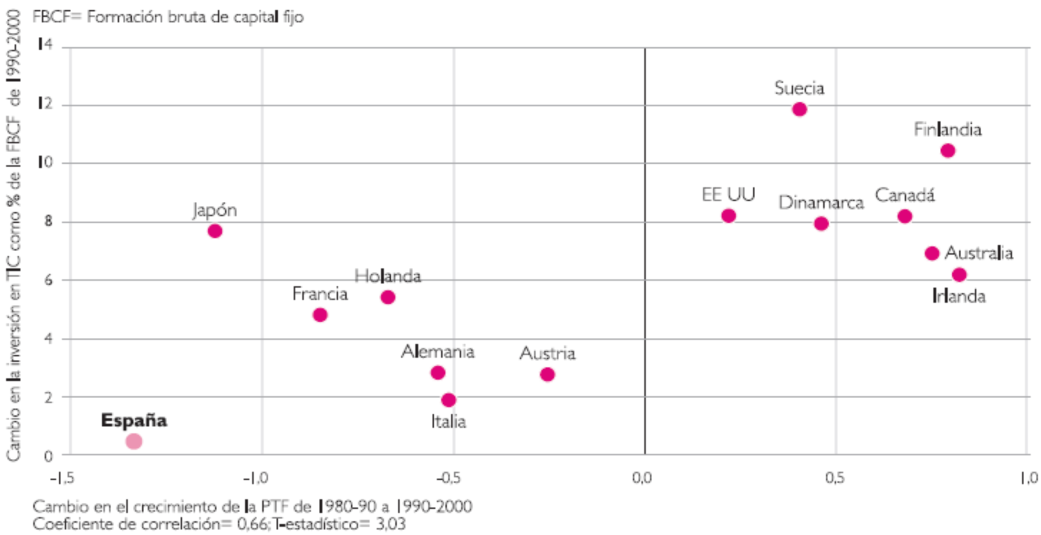

Figura 1 : Incorporación de TICs y productividad total de los factores (PTF)

Fuente: Fuentelsaz, L., Maicas, J., & Polo, Y. (2005) – Página 44.

Así también, según Spiezia, V. (2011), las TICs tienen el potencial de aumentar la innovación, acelerando la difusión de información, favoreciendo la creación de redes entre las empresas, lo que permite estrechar los vínculos entre éstas y los clientes, reduciendo las limitaciones geográficas y aumentando la eficiencia en la comunicación. Un análisis confirma que las TIC juegan un papel importante en el proceso de innovación, como lo mencionan Brynjolfsson y Hitt, 2000; Gago y Rubalcaba, 2007; Crespi et al, 2007; Eurostat, 2008; Van Leeuwen, 2008; Polder et al, 2009, en Spiezia (*op. cit*) y estos estudios, sin embargo, difieren en cuanto a su metodología y cobertura en los diversos países.

Ya en segundo lugar y como beneficios indirectos, siguiendo al mismo autor (Spiezia, 2011), los efectos derivados de la utilización de las TIC, puede ser fuentes de ganancias para la productividad. En este sentido presenta un ejemplo, en el cual el personal de las empresas que han adoptado Internet de banda ancha es capaz de colaborar con redes más amplias de académicos e investigadores internacionales para el desarrollo de innovaciones y mantenerse informado a cerca de las tendencias actuales de los consumidores. Cabe ejemplificar aquí el caso de la incorporación de las Tecnologías de la Información y la comunicación (TICs) en el sector artesanal de fabricación de alfombras en la India, presentado por Misra, H., y Choudhary, K. (2010). Los tejedores artesanales han allanado el camino para mejorar el desempeño de la industria de las alfombras en la India, aplicando las TICs, específicamente en la gestión de la cadena de suministro y en la participación de todos los actores de la cadena de valor a través de una red activa y de la integración de los distintos componentes de la cadena. Se constituyen las TICs entonces, en una herramienta para innovar procesos, productos y servicios para el establecimiento de mejores prácticas de gestión.

Después de dos décadas de lento crecimiento de la productividad en los países desarrollados, tanto la productividad laboral como la productividad multifactorial se aceleraron después de 1995. Una serie de trabajos intentaron demostrar que esta aceleración era consecuencia de las Tecnologías de la Información. Entre estos trabajos cabe destacar el artículo de Brynjolfsson y Hitt (1996), en López Sánchez (2004), el cual se ha convertido en una referencia ineludible.

Estos autores encontraron una relación positiva entre las Tecnologías de la Información y la productividad, analizaron el impacto tanto de la inversión en ordenadores personales y grandes computadoras como del gasto en personal del departamento de sistemas de información, sobre la productividad de una muestra de empresas.

El autor Fuentelsaz et al (2005) hace hincapié en España, que está entre los países que menos han invertido y sitúa al mencionado país en una posición desventajosa respecto de su productividad.

A partir de la afirmación anterior, se presenta el contexto Iberoamericano, y a pesar de que la implantación de las nuevas tecnologías de la información supone una atractiva oportunidad para la **empresa**, su tasa de adopción sigue siendo lenta, tal como lo menciona Ortega et al (2006), pero si se destaca una significativa implantación de tecnología e intensidad de uso de los nuevos programas de gestión

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online, así como las diferencias existentes entre aquellas organizaciones que pertenecen al sector específicamente de las telecomunicaciones y el resto de **empresas** dedicadas a otras actividades denominadas tradicionales, y que aún presentan resistencia a la incorporación integral de esta variable.

También señalan Ortega et al (2006), Pérez y González (2006) que son los recursos humanos el factor clave para la implantación de herramientas tecnológicas en las pequeñas y medianas **empresas** (pymes). Una de las causas de la baja adopción es la dificultad para los gestores de valorar y medir los beneficios generados por dichas tecnologías dentro de las organizaciones.

Al mismo tiempo, en que se considera a la TICs como un factor importante para el desarrollo empresarial, otros autores, Sartor y Veiga (2011), atribuyen a las TICS como uno de los factores del deterioro de las ventajas competitivas, debido especialmente a la reducción de los ciclos tecnológicos involucrados, y a causa de su avance y desarrollo vertiginoso. De ahí que con frecuencia, las TICs sean percibidas como "el villano de la película" por los empresarios de sectores tradicionales, maduros, bien establecidos, pues han venido a cambiar las reglas y sacudir los pilares en los cuales se fundamentaba su posición competitiva. Sin embargo, no todas son malas noticias, como dicen los autores: "*las empresas que juegan su partido en sectores como los mencionados pueden revertir esta lógica y transformar a las TIC en aliadas que potencien su desarrollo*".

Sartor y Veiga (2011: 30), proponen una agrupación de empresas de acuerdo al rol que juegan las TICs en las mismas:

1. Las que "son TICs", es decir, que tienen a las TICs en su esencia; aquí hacen mención a Microsoft, Intel, Google, Oracle, IBM y Cisco.
2. Las que nacen y se desarrollan en torno a las TIC, teniendo sentido gracias a las mismas. En este apartado citan a Facebook, AT&T e iTunes.
3. Las "tradicionales", que proveen ciertos productos y servicios desde tiempos muy anteriores al desarrollo de las TICs, y ahora hacen uso de las mismas como herramienta para llevar adelante sus actividades. Aquí se sitúan sectores como el *retailing*, la vestimenta y el turismo, coincidente con Manero et al. (2012), citado anteriormente.

Las empresas de tipos 1 y 2, continúan los autores (Sartor y Veiga), naturalmente, "viven" al ritmo del desarrollo de las TIC: "*en ellas encuentran sus oportunidades para nacer, crecer, y también los riesgos de ser superadas por sus competidoras, morir o ser fagocitadas*". Las empresas del tipo 3, deben por el contrario convivir con el desarrollo de las TICs, beneficiándose de las mismas, en lugar de resignarse a ver cómo destruyen en un lustro las posiciones ventajosas cimentadas durante décadas y considerando que la dinámica competitiva de un sector determinado tenderá entonces hacia uno de dos tipos de resultado: el *oligopolio o la marginalidad*.

Merece la pena relatar un caso (en Sartor y Veiga, 2011) de cómo las TICs se tornan aliadas en redefinir el servicio –léase, redefinir el producto–. Se trata de la empresa "Mercado Libre", que generó un servicio distinto, con las siguientes características que fueron viables gracias al desarrollo de las tecnologías de la información y comunicaciones:

- El costo prácticamente nulo subyacente a un aviso, tanto para quien publica como para la empresa. Habilita un modelo donde el precio del aviso se condiciona al valor del bien a vender, a la concreción de la operación, y permite capturar un mundo de operaciones (artículos de muy bajo precio) que no era accesible a través de los avisos clasificados tradicionales.
- Se prioriza el uso de imágenes –que "*valen más que 1000 palabras*"– lo que aproxima más el producto al comprador, como sucede en la feria.
- Se agrega valor nuevo y original por la vía del sistema de reputación. Este se vuelve un factor fundamental para la viabilidad del nuevo sistema.

En definitiva, "Mercado Libre" es una genuina redefinición del producto que supo aprovechar las potencialidades de las TICs.

A continuación se procede a realizar una aproximación comparativa de algunos indicadores de la OCDE y de la Internet World Stats[2], tomando específicamente dos dimensiones: en primer termino el acceso y penetración de Internet en la población de cada país, y en según termino el porcentaje de utilización de banda ancha por parte de las empresas de dos contextos bien diferenciados: los países miembros de la OCDE y los países de la Región Sudamericana.

[2] Internet World Stats es un sitio web internacional que cuenta hasta la fecha el uso mundial de Internet, Estadísticas de Población, Estadísticas de Viajes y Datos de Internet de investigación de mercado, de más de 233 países y regiones del mundo. http://www.internetworldstats.com

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Tabla N° 1 : Distribución porcentual de la penetración de Internet en la población en países de la OCDE (2010-2011)

Países de la OCDE	Penetración (% Población)
Suecia	92,90%
Australia	89,80%
Holanda	89,50%
Dinamarca	89,00%
Finlandia	88,60%
Alemania	82,70%
Canadá	81,60%
Japón	80,00%
Estados Unidos	78,30%
Francia	77,20%
Austria	74,80%
Irlanda	66,80%
España	65,60%
Italia	58,70%

Fuente: Internet World Stats (2012)

En los países pertenecientes a Latinoamérica (ver tabla Nº 2) la penetración de Internet referido a la población –con excepción de Argentina (que se acerca al 70%)- está en la franja significativamente dispersa que va desde un 20% a un 60%, y que refleja una brecha profunda, y que permite establecer tres estratos: por un lado aquellos países que están alrededor del 60% como promedio (Colombia, Uruguay, Chile), aquellos que están en el estrato más bajo con cifras cercanas al 20% (Ecuador, Paraguay, Bolivia) y en una franja intermedia, con valores entre 30% al 40% (Costa Rica, Brasil, Panamá, Perú).

Tabla N° 2 : Distribución porcentual de la penetración de Internet en países de América del Sur (2010-2011)

AMÉRICA DEL SUR	Población% (Penetración)
Argentina	67,00%
Chile	59,20%
Uruguay	56,10%
Colombia	55,90%
Costa Rica	43,70%
Panamá	43,40%
Venezuela	39,70%
Brasil	39,00%
Perú	34,01%
Ecuador	27,20%
Paraguay	23,60%
Bolivia	19,60%

Fuente: Internet World Stats (2011)

Revisando las tablas Nº1 y Nº 2 se percibe una brecha marcada entre los países más desarrollados pertenecientes a la OCDE con respecto a los países de Latinoamérica, esto se puede apreciar en la figura N° 2. En el primer grupo (OCDE) la penetración de Internet referido a la población, en la mayoría de los países –con excepción de España, Italia e Irlanda - está en la franja de 70 a 90 % y que es coherente con la Figura Nº

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1 que muestra a los mismos países que encabezan este grupo como los que más invierten en TICs y por ende los más productivos.

El impacto del uso de internet como herramienta para aumentar la productividad de las empresas depende de la velocidad de conexión y de la capacidad de los recursos humanos para implementar soluciones técnicas adecuadas que optimicen la circulación de los flujos de información en los procesos productivos, de comercialización y de administración. Pese a los niveles existentes de conectividad en la región sigue existiendo una importante brecha con los países desarrollados en cuanto al aprovechamiento productivo de las inversiones realizadas en materia de TICs. Este hecho surge de comparar el impacto en la mejora de la productividad empresarial en función de las inversiones realizadas para renovar las TICs (Lemarchand, 2010).

Algunos estudios realizados por la CEPAL (2008) muestran que las empresas suelen aplicar mayoritariamente las redes informáticas para procesos de manejo de contabilidad, finanzas, comunicación y gestión de recursos humanos. Una proporción menor, pero en expansión, usa las TICs para la automatización de ventas o gestión de productos. Las pequeñas y medianas empresas más innovadoras comenzaron a aplicar las TICs también en los procesos de producción. Esto señala una tendencia hacia el aprendizaje y reorganización de los procesos internos y externos de producción a fin de lograr la automatización productiva, optimizando recursos físicos y humanos.

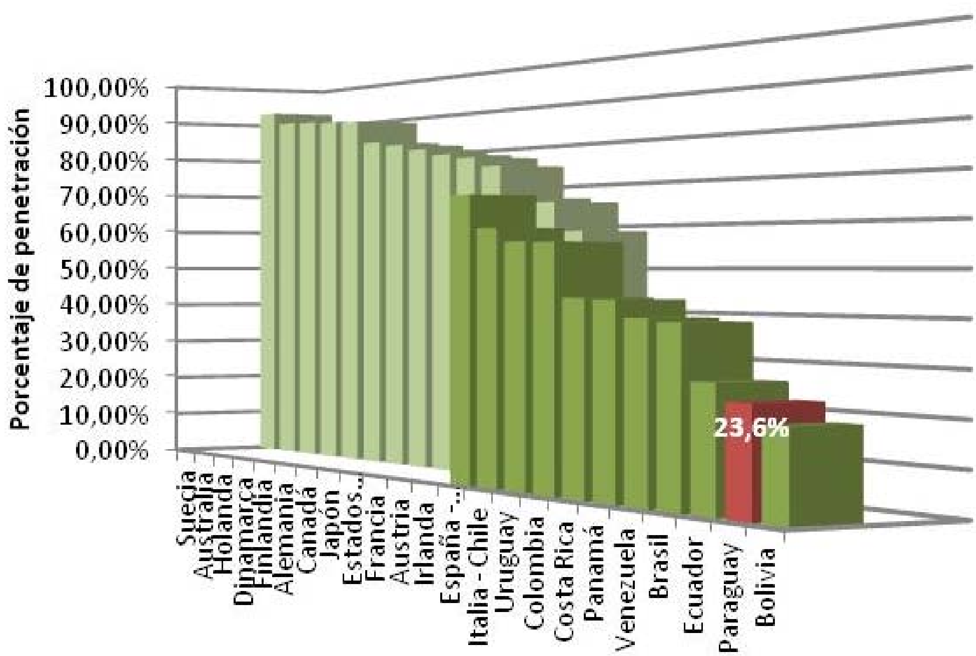

Figura N° 2 : Comparación de la distribución porcentual de la penetración en la población de Internet entre los países de la OCDE y los países de América del Sur (2011)

Fuente: Elaboración propia a partir de los datos de la OCDE y la Internet World Stats (2011)

La difusión en Latinoamérica de la banda ancha y la disminución de su costo relativo representan grandes desafíos. Por ejemplo, en el 2009, dentro de los países de la OCDE la tarifa promedio más baja de acceso a la banda ancha tenía un costo de USD 19.-, por otra parte en países como México y Argentina era de USD 30.-, mientras que en Chile y Uruguay era de USD 38.-. En cuanto a la velocidad de acceso, en los países de la OCDE se accede a una velocidad promedio de descarga de 17 Mbps (megabytes por segundo), en tanto que en los países más avanzados de América Latina, para las tarifas mencionadas las velocidades de descarga oscilan en alrededor de 2 Mbps. Se debe considerar que, en términos generales la velocidad de subida de datos suele ser mucho menor, lo que dificulta sensiblemente las estrategias empresariales y gubernamentales de comunicación, comercio y gobierno electrónico (Lemarchand, 2010).

El Internet World Stats (2012) también describe la situación Latinoamericana considerando la situación de otros indicadores de TICs como ser: las líneas fijas, telefonía móvil y la utilización de banda ancha. Latinoamérica presenta apenas un 18% de densidad telefónica, las suscripciones a la telefonía móviles ha superado a sus homólogos de líneas fijas en todos los países, excepto Cuba. Paraguay lidera la tendencia, con doce teléfonos móviles por cada línea fija en servicio. La penetración móvil en América Latina y el Caribe fue superior al 66% a principios de 2008, muy por encima de la media mundial, que fue de alrededor del 46%.

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La subscripción a Banda Ancha creció a una tasa anual de alrededor del 40% en 2007, pero la penetración de banda ancha es del 3,4%, considerablemente inferior a la media mundial del 5,9%. Algunos países están migrando a nuevas aplicaciones y tecnologías como VoIP, WiMAX, y Triple Play, mientras que los gobiernos luchan por reducir la brecha digital y buscar una solución a la insuficiencia de telefonía rural.

Yendo específicamente a la telefonía fija y el acceso a Internet, Paraguay tiene la más baja teledensidad de líneas fijas y penetración de Internet de América del Sur, aunque no mucho menor de lo que cabría esperar teniendo en cuenta el PIB limitado de la población per cápita, y especialmente focalizando el estudio en incorporación de banda ancha, es todavía más baja, con velocidades pobres y precios altos, según los comentarios de la Internet World Stats (2012). En cambio, la penetración de la telefonía móvil, sin embargo, es de aproximadamente 11% mayor que el promedio regional, siguiendo la explicación del párrafo anterior, y que constituye un logro excepcional teniendo en cuenta otros indicadores económicos de Paraguay.

Estos mismos indicadores son analizados seguidamente en el Sector Empresarial. En la Figura Nº 2, se muestra la posición de los países más desarrollados respecto de la incorporación de las TICs en las empresas. Aquí se puede observar los países que están a la vanguardia en la utilización de las TICs por parte de sus empresas, llegan entre el 90 al 100 %, siendo estos: Suecia, Dinamarca, Italia, Japón, Canadá, etc. La posición menos favorable la tiene España, con niveles inferiores al 80 %. Esta misma tendencia puede asociarse con la Figura 1 que se refería a la Incorporación de TICs y productividad total de los factores (PTF).

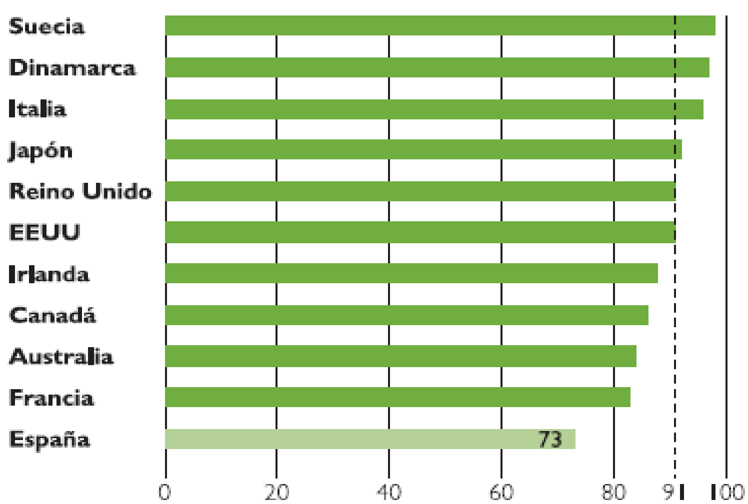

Figura 2 : Incorporación de TICs en las empresas de la OCDE

Fuente: López Sánchez, J. (2004).– Página 93

Así también, considerando el ranking del Foro Económico Mundial y el porcentaje de uso de Internet (*Internet World Stats*, 2011) por parte del Sector Empresarial se puede establecer revisando la tabla N°3 una correlación positiva que encabeza Suiza y deja en últimas posiciones a España e Italia.

Tabla Nº 3: Incorporación de las TICs en los países de la OCDE considerando la utilización de Internet en las Empresas

Países OCDE	Ranking	Índice	Porcentaje de uso
Suiza	1	6,58	35,82
Estados Unidos	7	6,18	25,80
Canadá	9	6,16	30,50
Japón	11	6,05	24,84
Holanda	16	5,98	37,09
Dinamarca	17	5,97	37,43
Finlandia	19	5,89	27,33
Australia	20	5,89	23,69
Francia	21	5,88	30,36

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Alemania	22	5,81	30,51
Austria	24	5,79	22,45
Irlanda	32	5,59	21,53
España	67	4,89	21,31
Italia	71	4,79	20,38

Fuente: Elaboración propia a partir de los datos del Foro Económico Mundial (2010-2011) y la OCDE (2009)

Si se comparan las Tabla Nº 1 y la Tabla Nº 3, se observa un promedio de 14 % menos al momento de presentar los datos de utilización de internet en el sector empresarial de los países pertenecientes a la OCDE. Debido a que no existen datos relevados de la utilización de internet en las empresas latinoamericanas, se propone una aproximación, considerando este mismo comportamiento: es decir, que se espera un 14 % menos de utilización por parte del sector empresarial, respecto a los valores establecidos en la penetración en la población, para la situación latinoamericana.

De igual manera que la comparación anterior referida a la penetración de Internet de los países de la OCDE versus los países de América del Sur, se presume la misma analogía para esta segunda dimensión: utilización de Internet por parte del Sector Empresarial, revisando la tabla N° 4 se presenta el porcentaje estimado de uso de las empresas de cada país:

Tabla Nº 4 : Incorporación de las TICs en los países de Latinoamérica, considerando la utilización de Internet de las empresas

Países de América del Sur	Ranking (a)	Índice (b)	Porcentaje de uso (c) (estimado)
Brasil	25	5,74	39,00%
Chile	34	5,47	51,93%
Panamá	57	5,02	38,07%
Colombia	58	5,01	49,04%
Uruguay	69	4,88	49,21%
Argentina	83	4,63	58,77%
Perú	95	4,49	29,83%
Ecuador	105	4,21	23,86%
Venezuela	110	4,17	39,70%
Bolivia	115	4,06	17,19%
Paraguay	124	3,92	20,70%

Fuente: Columnas (a) y (b): elaboración propia a partir de los datos del Foro Económico Mundial (2010-2011). Columna (c) estimada a partir de los datos de penetración en la población.

Lemarchand (2010), sostiene que es interesante comprobar que dentro de las 2000 empresas que más invierten en I+D en el mundo, solo 3 están en América Latina y el Caribe (European Commission, 2006). Todas son de origen brasileño: la Empresa Brasileña de Aeronáutica (EMBRAER), la Compañía Vale do Rio Doce (CVRD), que pertenece al sector minero y Petróleo Brasileiro (PETROBRAS). Este hecho se interpreta a la luz de la forma en que Brasil articuló la política industrial con la política científico-tecnológica durante las últimas décadas. Por ejemplo, en 1948 se funda en Brasil la Sociedad Brasilera para el Progreso de la Ciencia (SBPC) y en 1951 el Consejo Nacional de Pesquisas Científicas (CNPq). No es un hecho menor, que el primer proyecto de ley de creación de un Ministerio de Ciencia y Tecnología en Brasil data del año 1963, cuando prácticamente no existían este tipo de instituciones en ninguna otra parte del mundo.

A continuación se presentan los porcentajes de utilización de internet en el sector empresarial, tanto en los países de la OCDE como en los sudamericanos. (ver Figura Nº 4)

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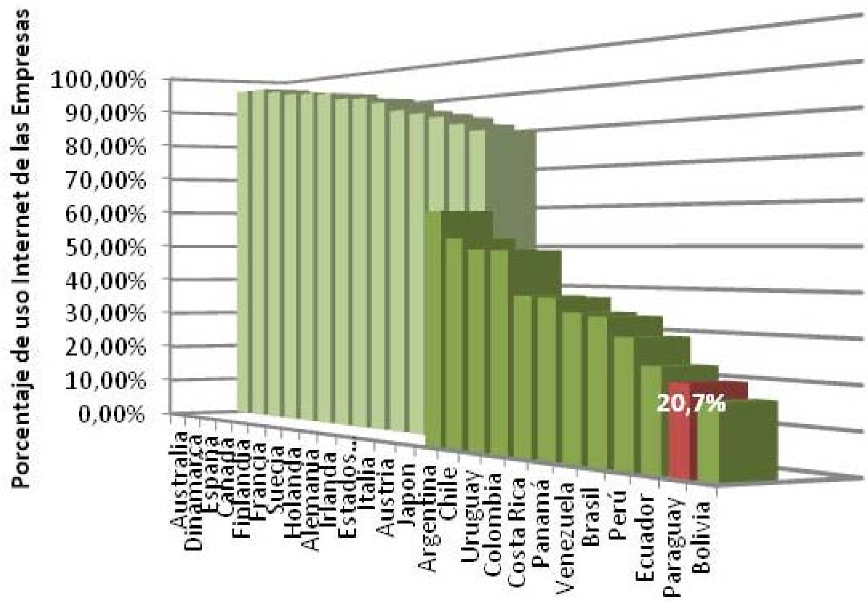

Figura N° 4 : Comparación de la distribución porcentual de la penetración en las empresas de Internet entre los países de la OCDE y los países de América del Sur (datos estimados para los países de América del Sur)

Fuente: Elaboración propia a partir de los datos de la OCDE y la *Internet World Stats* (2011), valores estimados para los países sudamericanos.

Lemarchand (2010), muestra que entre el 2002 y 2006, en el sector farmacéutico de Brasil obtuvo 33 patentes en EEUU, seguido por Argentina y Cuba con 14 patentes cada uno. Por otro lado, si se considera el número de patentes relacionadas con artefactos eléctricos durante el mismo período, México obtuvo solo 13 patentes, Brasil 10 y Argentina 3.

Así también, la región ha comenzado a distinguir en sus planificaciones de mediano y largo plazo del sector ciencia, tecnología e innovación la importancia de desarrollar capacidades endógenas en los nuevos paradigmas tecno-económicos como las TIC, la nanotecnología y las biotecnologías. Las mismas representan tecnologías genéricas que afectan transversalmente un amplio conjunto de sectores productivos. Sin embargo, la región tiene una debilidad estructural que la coloca en una posición de rezago con respecto a otras regiones.

IV. Esfuerzos en Paraguay Acerca de las TIC

La Internet World Stats (2011), describe el esfuerzo que realizan desde varias décadas los países latinoamericanos en la implantación y el desarrollo de las TICs. Paraguay pertenece a este grupo de países y ha conseguido importantes avances en la organización y gobernanza de este sector. En la actualidad el Gobierno Paraguayo adopta una política de estado en relación a las TICs, y la considera una herramienta para disminuir los problemas sociales y desarrollar la economía.

La organización del sector de las TICs comienza con la creación de la Comisión Nacional de Telecomunicaciones (CONATEL), en virtud de la Ley 642/205, promulgada el 29 de diciembre de 1995. La misma otorga las competencias estatales necesarias para la regulación de las telecomunicaciones en el Paraguay.

En el año 2002 se da inicio a las primeras acciones para la Modernización del Estado Paraguayo, creando una estructura encargada de liderar este proceso, denominada Unidad Técnica de Modernización de la Administración Pública (UTMAP), dependiente de la Presidencia de la República. Tres años después, en 2005 se conforma la Mesa Sectorial de TICs de la REDIEX (Red de Inversiones y Exportaciones), instancia que reúne a varios sectores involucrados a las TICs, tales como: Sector Productivo, la Academia, el Gobierno y ONGs con el fin de establecer mecanismos que faciliten y mejoren las exportaciones tomando como punto de partida sus problemáticas y necesidades. También se conforman otras instituciones como la Cámara de Tecnología de la Información del Paraguay (CTIP), la Cámara Paraguaya de la Industria del Software (CiSOFT), la Cámara de Mayoristas de Informática de Asunción (CADMI) y finalmente a inicios del 2012 se crea la Secretaria de Tecnologías de la Información y Comunicación (SETICs) dependiente de la Presidencia de la Republica.

Desde 2003 se vienen trabajando en distintos ámbitos e involucrando al mayor número de actores en la redacción, discusión y presentación de varias propuestas de ley, buscando establecer un marco legal

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adecuado y propicio para la inversión en el país. Se destacan las siguientes: ley de modificación del código penal de delitos informáticos, ley de expedientes electrónicos, ley de incentivos al ensamblaje de bienes de alta tecnología y otros que ya se encuentran en audiencia: ley de datos personales, ley de la agencia de gobierno electrónico, ley de comercio electrónico, reforma de la ley de telecomunicaciones. En setiembre del 2011 se reglamenta el uso de la firma electrónica y digital; esta ley es inicio de los trabajos necesarios para el fortalecimiento del comercio electrónico en el país y con otros países.

Pasando al sector académico, se inicia el trabajo (2001) de crear una red académica que permita la conexión entre instituciones de Paraguay y posteriormente la conexión con redes académicas internacionales. A finales del 2011, queda constituida la Red Arandu mediante un acta fundacional y con la participación de cinco instituciones, esta red permite a investigadores por ejemplo formar parte de redes de investigación con intercambio de información y acceso a información con velocidades mayores a la ofrecida por la Internet tradicional.

Siguiendo en el ámbito académico, se destaca durante el 2005 la fuerte inversión del sector en la instalación de entornos virtuales del aprendizaje (EVAs), que llevan consigo la tarea de formación y capacitación, así como la adecuación de los contenidos curriculares para el *e-learning* y el *blending-learning*. Estas inversiones y esta nueva metodología de enseñanza, genera una nueva necesidad, la de una capacitación educativa en los distintos niveles de enseñanza tanto para alumnos como para docentes en el uso de las TICs; es así que en el 2010 finalmente se implanta de manera experimental el Programa "una computadora por niño", en el Departamento de Cordillera y se promulga la Ley del "Fondo para la Excelencia de la Educación e Investigación" (FONACIDE) en septiembre de 2012, que proveerá fondos para dar continuidad a la expansión de este modelo y al desarrollo de nuevos programas que involucran al docente y la actualización del contenido académico entregado.

Otros emprendimientos importantes de destacar y realizados con fondos públicos y con fondos privados durante los años 2005-2012 que tienen como fin dar acceso a Internet son: instalación de telecentros en la capital y ciudades del interior del país, acceso a internet en plazas públicas, bibliotecas viajeras, instalación de *cybers,* análisis e implementación de estrategias para la disminución de costos y fortalecimiento de la infraestructura nacional en lo relacionado a tendido de fibra óptica. En este punto se destaca la inversión de las telefonías móviles en el sistema de cableado para dar acceso a internet en las ciudades alejadas a la capital del país. Esto sumado a la libre competencia existente en el Paraguay en lo relacionado a la venta de servicios de telefonía móvil y la ampliación de servicios como la de acceso a internet, cuyo despegue se dio a inicios del año 2008, con la instalación de cuatro (4) firmas de telefonía, y que impacta positivamente en la utilización y el acceso a la comunicación por parte de la ciudadanía, ya que el 90 % de la población paraguaya utiliza la telefonía móvil y el 50 % de esta población accede a los servicios de internet (según datos de CONATEL, 2010). Estas respectivas firmas se encuentran incorporando nuevos servicios durante el 2012, como ser la TV Digital, internet móvil, portabilidad numérica.

Considerando la agrupación de empresas de acuerdo al rol, propuesto por Sartor y Veiga (2011: 30), se pueden identificar algunos ejemplos de empresas en el Paraguay del tipo 2 "que nacen y se desarrollan con las TICs":

El caso de la plataforma del sitio web de ventas CLASIPAR, una innovación en la venta a terceros, se deja de lado el uso de la prensa escrita, de la propaganda visual, para pasar a utilizar una plataforma informática en línea de libre acceso, que se posiciona como un punto de referencia al momento de buscar algunos productos (electrodomésticos, inmuebles, rodados, tecnología, etc.) para realizar la compra se utiliza un sistema sencillo y para ofertar el producto: una descripción mínima, la oportunidad de incluir imágenes, y datos de contacto, punto de referencia; resulta: cómodo, practico y de libre acceso. Permite el contacto entre comprador-vendedor sin intermediarios, los dueños de la plataforma además de haber ideado una denominación ideal, establecieron unas bases y condiciones claras de uso, y servicios adicionales pagos que le permiten obtener ganancias, incluyen la opción de pagar por publicidad, considerando el ranking o el número de visitas de la pagina, mantienen una estadística sobre: persona que visita la pagina, gustos, búsquedas, horarios, etc. y con esta información realizan ofertas de ventas y presencia de marca (www.clasipar.com.py).

Otro caso destacable es la de una plataforma para Comunidades Digitales denominada TEKOHA, permite la integración de las comunidades mediante las TICs, en un entorno nacional, regional y global a través de internet. Además incluye un módulo de comercio electrónico que permite a las comunidades exponer sus productos y ofrecerlos a través de la red. Agrupa a artesanos, pequeñas y medianas empresas diseminadas por ciudades ubicadas en el interior del país, esta plataforma ofrece una imagen de cada una de estas microempresas, generando una oferta de los productos y los datos necesarios para contactar e iniciar la compra; además ofrece la oportunidad de contacto entre microempresas, generando oportunidad para sinergias, intercambio de insumos y sobre todo el intercambio de mejores prácticas en ventas e imagen (www.tekoha.net).

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Considerando el rol de las empresas, también se destaca el comercio de artículos o componentes de las TICs existente en la zona fronteriza con el Brasil y su aumento en la ciudad de Asunción, son artículos importados de marcas reconocidas y en una minoría marcas genéricas que son ensambladas en el país para la venta. Este grupo de empresas se encuentra en la ciudad de Ciudad del Este, un modelo económico que año a año incorpora a nuevas empresas y amplia la gama de productos que son ofrecidos; estas empresas permiten la compra online de sus productos.

En general las empresas presentan una fuerte apropiación o utilización de las TICs en su relacionamiento con el cliente y la divulgación de sus servicios; tomando como ejemplo las empresas de telefonía móvil del Paraguay, se puede mencionar la inversión en infraestructura, en capacitación para el uso de las mismas, reestructuración del equipo de trabajo, implementación de una nueva imagen corporativa basada en las redes sociales y en la presencia de marca en Internet; modernización de la entrega de información: permiten al cliente el almacenamiento de su información en espacios virtuales, acceder a su información histórica mediante un sitio web y las informaciones son entregadas en distintos medios que van desde un mensaje de texto hasta llegar a conversaciones en línea (chat). Un mejoramiento de la calidad de los servicios por la utilización de tecnología de vanguardia y una mayor rapidez en la incorporación de nuevos servicios, una constante competencia en ofrecer nuevos servicios.

El caso de la Empresa Tigo, cuyo lema es "un mundo de posibilidades con tigo", con un crecimiento marcado gracias a su evolución constante en el uso de las TICs, llega al Paraguay en el 2004 de la mano de *Millicom International Cellular* S.A. (NYSE: MICC) que es un operador de telefonía móvil que opera comercialmente bajo la marca Tigo, con presencia en América, Europa, África y Asia. Con oficinas centrales en Luxemburgo, la compañía provee de servicios móviles, Televisión y de internet en más de 16 países. Tigo dirige desde Paraguay, la mayor parte de las operaciones en Latinoamérica. Desde entonces sus servicios han aumentado: desde el acceso a telefonía a los siguientes servicios: acceso a internet banda ancha, internet móvil, servicios corporativos a medida, *hosting* para empresas, servicios de email, tigo *Money* (giros de dinero entre usuarios tanto nacional como internacional, pago de servicios a empresas), servicios innovadores para sus usuarios como: llamadas y mensajes por cobrar, buzón de voz, préstamo de saldo; todos logrados mediante una apropiación de las TICs (www.tigo.com.py).

Para determinar la capacidad de utilización de las TICs del Paraguay, se presenta a continuación en la tabla N° 5, los indicadores del Foro Económico Mundial (*World Economic Forum*) en su Informe Global de Tecnología de la Información 2010-2011 (*The Global Information Technology Report – GITR - 2010-2011*) donde ubica al Paraguay en el puesto 127, de 138 países, con un índice de 3.0 puntos de los 7.0 posibles, distribuidos en los distintos componentes que integran la medición: Entorno (mercado, política y regulación, infraestructura); Preparación (individual, empresas, gobierno); Uso (individual, empresa, gobierno). También se demuestra el mejoramiento del índice en el tiempo, no se percibe en el ranking esta mejora debido al aumento de la muestra, de los países que son analizados.

Tabla Nº 5 : Paraguay, avance en el índice de capacidad de utilización de las TIC en los últimos años

Años	Nro. países participantes	Índice (total: 7.0)	Puesto en el Ranking (total: nro. de participantes)
2010 - 2011	138	3.0	127
2009 - 2010	133	2.9	127
2008 - 2009	134	2.9	122
2007 - 2008	127	2.9	120
2006 - 2007	122	2.7	114

Fuente: FEM (2010-2011)

Considerando el mismo informe, se destacan algunos indicadores como el de acceso de la población a internet, se cuenta con un índice de 17,4 % y una ubicación en el puesto 91, utilización de telefonía móvil un índice de 88,5 % y ubicación en el puesto 78 y lo relacionado a la tenencia de computadoras en el hogar un índice de 13,9 % que corresponde a una ubicación en el puesto 90 del ranking, siempre de un total de 138 países.

Observando a los países vecinos, Brasil cuenta con un índice del 3.90 y ocupa el puesto 56; seguido por Uruguay con un índice de 4.06 con el puesto 45 y Argentina con un índice de 3.47 y ocupando el puesto 96 y finalmente Bolivia con 2.89 de índice y el puesto 135; Paraguay solo se encuentra por delante de Bolivia, según estos indicadores.

El aspecto positivo se refleja en los índices obtenidos y comparados con la situación de años anteriores van en aumento, pero haciendo una comparación con los índices de los países vecinos, Paraguay **mantiene una brecha digital**, si tenemos en cuenta territorio y población Uruguay es el que guarda

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mayor similitud con Paraguay y el índice de Uruguay es 1.06 más que el de Paraguay.

V. Conclusiones

Es indudable el impacto originado por la incorporación, utilización y desarrollo de las TICs en el sector empresarial y que permite y facilita de algún modo la realización de innovación, tal como lo menciona Spiezia, V. (2011). Ahora bien, es marcada la asimetría respecto de este impacto y la clasificación propuesta por Sartor y Veiga (2011), referente a aquellas empresas que tienen a las TICs en su esencia, por un lado y a aquellas que nacen y se desarrollan en torno a las TICs. En ambas tipologías es donde se evidencia un cambio significativo -cuantitativo y cualitativo- respecto a su productividad y competitividad; y por el otro, existe una marcada diferenciación entre las denominadas "empresas tradicionales", que lograron hacer uso efectivo de dichas tecnologías en sus procesos y actividades, y que han logrado mediante ello una posición vanguardista, en algunos casos, o en otras formar parte de un oligopolio, de las otras que no lo han logrado y que finalmente decaen en competitividad.

Así también, la medición y generación de indicadores en el sector de las TICs es aún una realidad asimétrica, pues aún se debaten modelos y enfoques para la medición de las mismas: por un lado, un enfoque de desarrollo, instalación y utilización de infraestructura, y por el otro el considerar el impacto socio-económico de las TICs. Esta situación genera una dificultad a la hora de establecer comparaciones entre países y entre regiones. Ahora bien, es notoria la brecha existente entre los países de la OCDE y aquellos de economías pequeñas pertenecientes a la región iberoamericana. Y nuevamente en Latinoamérica, puede establecerse un agrupamiento, de aquellos países y empresas que han apostado a las TICs, y de aquellos que presentan una escasa inversión, del mismo modo cuando se reportan los indicadores de inversión en investigación y desarrollo experimental (I+D): en el grupo que más ha invertido y que se evidencia la incorporación de las TICs en el sector empresarial están Brasil, Argentina, Uruguay, Chile y México; y en el grupo que menos invierte están el resto de los países, incluido el Paraguay.

A pesar de esta situación desventajosa respecto de la inversión e incorporación de las TICs en Latinoamérica merecen destaque los esfuerzos realizados por los países y en ello está Paraguay, con varios avances e hitos importantes tales como:

1. La organización específica del sector de TICs en el Paraguay, con la creación del Consejo Nacional de las Telecomunicaciones (CONATEL), en 1995; la implantación de la Unidad Técnica de Modernización de la Administración Pública (UTEMAP) en 2002, la conformación de la Mesa Sectorial de TICs del REDIEX (Red de Inversiones y Exportaciones) en 2005; la Generación de un Plan Director de TICs en 2011 y la creación de la Secretaria de TICs en el 2012.
2. La creación de un marco legal para las TICs referente a la implementación de la firma digital y electrónica, beneficios para empresas dedicadas al área de las TICs, protección y seguridad de datos personales y la reforma de la ley de delitos informáticos.
3. Infraestructura y conectividad para la interconexión del sector académico nacional e internacional, denominada Red Arandú (lanzada en 2011).
4. Implantación experimental del Programa "una computadora por niño" en 2010, en el Departamento de Cordillera y con la promulgación de la Ley del FONACIDE (en 2012) que proveerá fondos para dar continuidad a la expansión de este modelo.
5. El enfoque de los telecentros, implantados desde el año 2000, y que actualmente siguen vigentes y con un nuevo impulso desde 2012 respaldados por el sector empresarial, sumando otros esfuerzos de disminuir la brecha digital y proveer de acceso a banda ancha al mayor número de habitantes del país.
6. La instalación y libre competencia en lo relacionado a la telefonía móvil y el acceso a internet.
7. Fuerte inversión del sector académico en la instalación de entornos virtuales del aprendizaje (EVAs), que llevan consigo la tarea de formación y capacitación, así como la adecuación de los contenidos curriculares para el *e-learning* y el *blending-learning*.
8. Fuerte inversión del sector empresarial de TICs (las empresas de telefonía celular, internet y TV cable, tales como TIGO, Personal, Claro y VOX); las empresas tradicionales y que se han generado a partir del uso de las TICs, como ser el sector de financiero y bancario (INTERBANCO, ahora ITAÚ; Banco Visión; Banco Familiar, entre otros); sector de ventas y servicios (Clasipar, TEKOJA, Villandry Flores; Vemay, etc.); sector gráfico y audiovisual (Geno medios; Bruno Masi Producciones); sector gastronómico (WokIn.com.py; Burger King), entre otros.

A manera de final, se puede concluir que es notorio el esfuerzo que hacen los países de economías pequeñas, entre ellos el Paraguay y que también son destacables los hitos logrados y los casos emblemáticos que merecen ser replicados, pero aún son insuficientes para llegar a los niveles de penetración y utilización que han logrado los países más desarrollados. Una tarea pendiente tanto para el Paraguay, así como para muchos países latinoamericanos es llenar las lagunas de información a

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través de la generación y medición de indicadores confiables y representativos del sector de las TICs que permitan el desarrollo de programas y acciones tendientes a incorporarlas en todos los sectores, tales como: empresarial, educación, salud, y gobierno.

Esta ausencia de indicadores no permite cuantificar el impacto de las TICs en las empresas, si se pueden identificar y observar avances, la incorporación y apropiación de las TICs en las mismas es notoria debido al éxito logrado año a año y al crecimiento que demuestran, manteniéndose en un mercado competitivo; otro punto destacable es que a raíz de esta ausencia tampoco es posible comparar la situación del país con los demás países para identificar fortalezas y debilidades.

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Internet of Things (LOT) for Smart Cities- The Future Technology Revolution

By Nikhita Reddy Gade, Nishanth Reddy Gade & G. J. Ugander Reddy
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Abstract- Today the world is becoming connected. The number of devices that are connected are increasing day by day. Many studies reveal that about 50 billion devices would be connected by 2020 indicating that Internet of things have a very big role to play in the future to come. The applications of IoT are immense which include Energy, Healthcare, and Agriculture to name a few. IoT is an emerging technology that works with the integration of many other present day technologies. There are many threats to the environment today among them urbanization is one. The growing needs of the uraban population across the world are posing a serious threat to the environment. We need to act fast and meet these needs by developing technologies that cater the world problems. One such solution is to develop a smart world. The most important application of IoT is smart cities. Smart city represents one of the most promising, important and difficult Internet of Things (IoT) applications. In the last few years, the smart city concept has played an important role in both scholastic and industry fields, with the advancement and operation of various middleware platforms and IoT-based infrastructures. This paper talks about the role of IoT in developing smart cities for a smarter world.

Keywords: internet, cloud, big data, smart cities, smart healthcare.

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Internet of Things (LOT) for Smart Cities- The Future Technology Revolution

Nikhita Reddy Gade [α], Nishanth Reddy Gade [σ] & G. J. Ugander Reddy [ρ]

Abstract- Today the world is becoming -connected. The number of devices that are connected are increasing day by day. Many studies reveal that about 50 billion devices would be connected by 2020 indicating that Internet of things have a very big role to play in the future to come. The applications of IoT are immense which include Energy, Healthcare, and Agriculture to name a few. IoT is an emerging technology that works with the integration of many other present day technologies. There are many threats to the environment today among them urbanization is one. The growing needs of the uraban population across the world are posing a serious threat to the environment. We need to act fast and meet these needs by developing technologies that cater the world problems. One such solution is to develop a smart world. The most important application of IoT is smart cities. Smart city represents one of the most promising, important and difficult Internet of Things (IoT) applications. In the last few years, the smart city concept has played an important role in both scholastic and industry fields, with the advancement and operation of various middleware platforms and IoT-based infrastructures. This paper talks about the role of IoT in developing smart cities for a smarter world.

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I. Introduction

Smart city is a terminology that we are going to hear a lot more in the future years. It's predicted that by the year 2020 about 50 billion devices would be connected around the world. Internet of Things (IoT) is a recent communication idea that visualizes a near future, where the objects or devices used in everyday life will be equipped with sensors, microcontrollers, trans-receivers for digital communication, and suitable protocol stacks and network models will make these devices to communicate with each other and with the users, becoming an essential part of the Internet.

The initiative of the IoT (Internet of Things) was developed in parallel to Wireless Sensor Networks, and refers to distinctively identifiable objects in the environment and the object's virtual representations in an "internet-like" model. Though IoT does not follow a particular communication technology, but wireless communication technologies will play a major role in the advancement of the IoT. The development of a technology like IoT will make every part of the world connected. The rural and remote areas will be the one's that will enjoy the benefits of IoT the most.

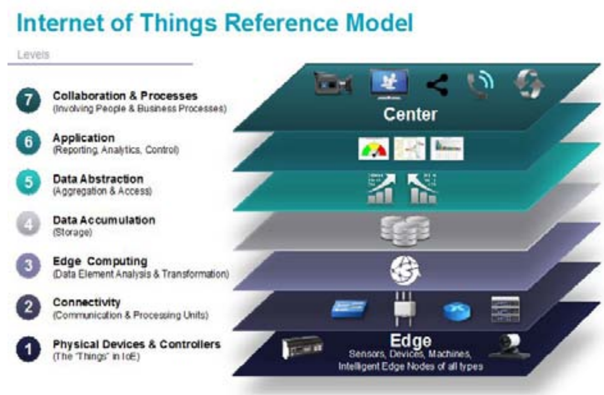

Fig.1.

The above figure is a reference model for the Internet of Things which contains 7 layers.

- The first layer i.e the Physical Device layer is the first layer which consists of user devices which are equipped with sensors, nodes micro chips etc.
- The second layer, Connectivity layer consists of several communication protocols and communication models used for inter communication of the devices
- The third layer is the edge computing layer which performs data element analysis and data manipulations.
- The fourth layer is the data accumulation layer. As the name goes all the data that is collected by the mobile devices is stored here.
- The fifth layer is the Data Abstraction layer that performs aggregation on the data.
- The sixth layer, Application layer performs operations like displaying analytics and reposting them so that the user can understand the trends and data patterns.
- The last layer is the Collaboration and process layer which people and business models and processes.

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II. Smart Cities

Smart City: A smart city is one that has mobile technology rooted across all functions of the city. A Smart City usually consists of basic infrastructure in an order to provide a good quality of life and a clean and lively environment for a smart living.

Smart Cities uses the mobile technology and information and communication technologies (ICT) to improve the quality and performance in order to connect with its people in an more active and efficient manner.

The components of a smart City includes smart government services, efficient transport system, smart traffic monitoring, sustainable energy, smart health care, improved water and waste management.

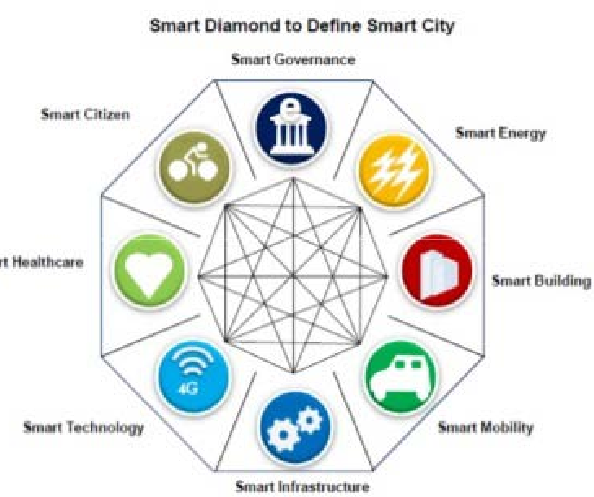

Fig. 2 : The major changes in technology, environment and economy have generated curiosity in building smart cities. The major goals of smarter city applications are improving the governance and transforming the lives in urban areas

As per the report released by Juniper Research in 2015 Barcelona is named the world's smartest city. The research inspected several aspects like technologies used, transportation systems, buildings, utilities etc. The study also predicted that there would be more number of smart cities coming up in the near future.

III. Role of IoT in Building Smart Cities

Until now, the Internet has been used primarily as a medium for the transmitting and collecting the data and information. Experts of the industry now believe that the next chapter in the "Internet devised for the People" is opened by the rise of the Internet of Things (IoT).

IoT is leading to a change in the culture as a huge number of devices, sensors, actuators, and other objects are being interconnected to each other and to next level systems. The connectivity of a huge number of devices that are programmed to collect the data gave rise to an entirely new services and features which form the basis of some important concepts like the "Smart Cities".

IoT and big data are both technology-driven developments. The applications of IoT for Smart City will bring huge market opportunities and will make lives of the people smarter. Today the devices around us are day by day becoming more intelligent. Further more, these developments are bound to change our behaviour and the way we use them.

We are in the middle of an era where we are trying to discover new opportunities brought to life by new software and hardware designed to take advantage of the flow of new personal and global data. Cities are likely to invest about $41 trillion on IoT technologies in the next 20 years. In order to make cities smarter, the governments have started promoting several startups and other industries in order to work on the IoT technologies so that they can be implemented in several spheres of urban living. Here are some of the areas that the governments must work to achieve their goal of building smart cities.

1. *Smart Grids*: Creating smart energy sources to meet the need of the increasing urban population is an important step in building a smart city. Thus to achieve this we implement the concept of smart grid. A smart grid is one of the most successful IoT technologies that are being used. A smart grid simply means computerizing the existing power grid. Additionally it has two way digital communication technologies embedded for communicating directly with the grid. Each device on the network consists of a sensor to collect data, two way communication between the device in the field and the grid's main network operations center. A key feature of the smart grid is computerization technology that lets the grid to adjust and control each individual device or millions of devices connected to it from a single location.
2. *Smart Environment*: The governments these days are planning to deploy sensors that collect the climatic data at several parts of the cities. This data collected by these devices will be continuously monitored by research institutes, so that they can predict the patterns in the changes of the climate and make predictions about the local issues like congestion. Further this data is made available to the public, so that they can know more about the surrounding environmental issues.
3. *Smart Water System*: Smart water system is a vital part of the smart city, and the IoT, linked to smart energy, smart grid and the "smart city" implementation. It is also a move towards e-governance, enabling households to have the actual knowledge of their utilization and interaction with the water resources, which helps improve energy efficiency, through Smart Water and Energy

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applications. Apart from this the implementation of smart irrigation for agriculture is again another innovation in the smart water system. This smart irrigation system will help farmers incur the losses occurred due to wastage of water resources by following traditional irrigation methods. Hence this smart irrigation helps developing better agricultural facilities for the farmers and improves the crop yield.

4. *Waste Management System:* Both private waste management companies and government municipalities can benefit from smart waste technology. Usually one of the methods for implementing smart waste management is by embedding sensors in the trash bin which can communicate directly with the central server which in turn indicates the local municipality about the amount of trash being dumped into the bin. By doing so, will make the trash being cleared as soon as the trash bin is full leading to a clean surroundings. Further people should be educated to segregate the waste appropriately and proper recycle techniques must be implemented for the waste disposal.
5. *Smart Transport System*: With the increasing world population day by day, the problems people face due to traffic congestion is very high. Hence the governments these days are working on building a smart transport system in the cities. With many devices being connected by various communication technologies like GPS, Cloud, Machine to Machine communication, huge amounts of data regarding the location can be collected. The collected data can be used to predict the traffic movements, traffic congestions, estimated travel time, best route possible etc. This data when made available to the public eases the traffic management in the city and hence leads to a smooth flow of traffic leading to less congestion. Further a new technology called vehicle to vehicle communication is being experimented. As a part of this the vehicles, communicate with each other and intimate the driver about the possible risks that may occur by choosing the route.
6. *Smart Parking*: This is a part of smart traffic management. With increase in number of vehicles and buildings, finding an appropriate parking space for the vehicle has become difficult. Hence leading to parking of vehicles on busy roads and increase in traffic congestion. Thus the governments have come up with a solution of installing sensors which direct the vehicle owner to the available parking space in the nearby area, thereby reducing the problems caused by unavailability of parking grounds.
7. *Smart HealthCare*: Smart Healthcare system is the most promising segment in the Internet of things domain. It is estimated that its market size will grow up to $117Billion by 2020. Smart Beds are one concept that is being implemented; these beds indicate about the patient movements to the hospital staff so that they can take the necessary actions. The various medical reports of the patient generated by various machines can be directly accessed by the doctor if they are connected. Further a lot of research is being done on the devices that can indicate any significant alterations (like change in heart beat, increased blood sugar levels, clots etc) in the patient's body directly to the doctor.
8. *Smart Buildings:* Smart Buildings have several advantages. A smart building is equipped with a smart energy system that would help people know their energy usage and manage accordingly. Any internal changes like changes in water pressure in the pipes are continuously monitored using sensors and hence will not result in hindrance to living. Further smart buildings implement high security levels by always monitoring the people who enter and leave the building.

Hence all the above are the integral part of a smart cities that the governments must incorporate and develop.

IV. Key Technologies for Smart Cities

The key enabling technologies that must be used along with IoT to achieve the goals of the smart cities are as follows:

1. *Big Data Analytics*: In smart cities, large amount of sensors will be installed so as to collect huge amounts of data. Hence this will create large amounts of data that should be stored and managed in order to achieve the goals of smart cities. Hence big data analytics forms a key technology for building smart cities. The data collected is analyzed and suitable predictions are made to attain p
2. roper governance. Some of the advantages of embedding big data analytics with IoT for smart cities are as follows:

- Big data can help in traffic and vehicle management. It helps in reducing the emissions from the vehicles. Sensors fitted on roads at various parts of the cities can help us by collecting data about the traffic at different times of the data and the volume of vehicles and their emission levels. This data collected at central server can be used by traffic cops to control the traffic and divert them accordingly to prevent congestion.
- Smart parking system can be easily implemented using data collected from different parts in the nearby locality.
- Keeping a track of the daily energy consumption and giving a detailed analysis of the areas using

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high energy utilities and areas using lower energy utilities can be balanced if proper data is collected.

- Huge amounts of citizen data should be organized properly. This make governance easy as the entire citizen database is made available to the government in an organized manner.

Apart from the above points there are several applications of big data analytics in IoT for building smart cities, as huge amounts of data collected must also be efficiently organized and used.

3. *Cloud Computing*: Cloud computing solutions provide a good solutions for the cities to have a strong physical architectural platform. Cloud computing represents a new paradigm for delivering both software and hardware resources to its users. Today Internet of Things is one of the most important concepts of ICT. By using cloud computing technology, the delivery of the software and hardware resources are made available on demand as a service over the internet. Further the IoT concept envisions modern devices like the sensors, actuators and other mobile devices will be connected to each other through Internet and provide different services and data to its users. The data collected from various IoT devices can be easily managed and handled by implementing the decentralized cloud model.

Usually in a cloud based approach, the government provides technological platform for gathering, mining the data and provides this data over the public internet platform to a third party cloud vendors. Doing so will reduce the burden for the government and also helps cutting the unnecessary cost of having excess storage for the data. The data collected from the sensors can be transmitted to each other via Internet and hence cloud architecture will be the most apt model by providing both the hardware and software services over the internet.

Fig. 3 : Proposed IBM Infrastructure

4. *Mobility:* The mobile devices are the major devices that collect and transfer the data over the internet. These devices enable the user to access the information from any point of the globe on a simple device and take necessary actions. These mobile devices include our smart phones, wearable etc.
5. *Social*: The social platform is yet another technology that educates people about the usage of their mobile devices and the current changes occurred as a part of developing a smart city. By using a social platform communication between the government and common public would become even easier.

V. Challenges Faced for Developing Smart Cities

Though IoT provides immense opportunities to improve efficiency of governance, public safety and support development, it also offers some challenges for the cities to overcome in order to build the dream smart cities. Some of the challenges are:

1. *Security and Privacy*: Maintaining privacy and security for the data being collected is one of the biggest concerns. Since the entire data is being collected over the internet, cyber security is a very important aspect. Ensuring the privacy of the citizen's data is the most difficult deed for the governments. Hacking a single smart device can cause a huge loss to the city. Hence following a strict cyber security policies and implementing high level security protocols is very important.
2. *Using the right technology:* This is another challenge. Cities already have lots of data in their existing data base systems but lack the skills of implementing the right technology necessary for handling it. Hence cities must ensure that they deploy proper data gathering systems along with analytics, so that data can be analysed and used properly. Further people with proper technical skills must be employed for handling the citizen data.

VI. Conclusion

In the future, all cities will be smart cities .With smart and forward-looking governance and management, IoT has the possibility to create a revolution in urban organization and development. By implementing the true potential of IoT, governments can improve services to its citizens, increase sustainability, and make the existing cities a better and more livable place for all its citizens. Our future life in smart cities is full of promise. All the discussed technologies will develop and there will also be many new innovations coming up as well. In other words, we would be witnessing some exciting times soon. With more than one-half of the world's population living in cities pioneering new IoT solutions, such as smart healthcare, smart parking, smart energy, connected waste, and traffic management, holds great promise for fighting the major challenges of high end urbanization. We are likely to see many smart cities of the future coming to life

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overnight. However, like in the past with the adoption of revolutionary technologies such as electricity, traffic lights, green buildings and the Internet, governments will gradually execute IoT solutions to save money, shape the future and make the cities a smarter and a better place to live.

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Inductively Computable Hierarchies and Inductive Algorithmic Complexity

By Mark Burgin
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Abstract- Induction is a prevalent cognitive method in science, while inductive computations are popular in many fields of computer and network technology. The most advanced mathematical model of inductive computations and reasoning is an inductive Turing machine, which is natural extension of the most widespread model of computing devices and computations - Turing machine. In comparison with Turing machines, inductive Turing machines represent the next step in the development of computer science providing better models for contemporary computers and computer networks. In this paper (Section 3), we study relations between inductively computable sets, inductively recognizable sets, inductively decidable sets and inductively computable functions. In addition (Section 4), we apply the obtained results to algorithmic information theory demonstrating how inductive Turing machines allow obtaining more information for essentially decreasing complexity in comparison with Turing machines.

Keywords: algorithmic information theory, inductive computation, turing machine, inductive turing machine, kolmogorov complexity, inductive computability, inductive complexity, inductive decidability.

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INDUCTIVELYCOMPUTABLEHIERARCHIESANDINDUCTIVEALGORITHMICCOMPLEXITY

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Keywords: algorithmic information theory, inductive computation, turing machine, inductive turing machine, kolmogorov complexity, inductive computability, inductive complexity, inductive decidability.

I. Introduction

For a long time, Turing machines dominated theoretical computer science as researchers assumed that they were absolute and all-encompassing models of computers and computations. Although Turing machines are functionally equivalent to many other models of computers and computations, such as partial recursive functions, cellular automata or random access machines (RAM), which are called recursive algorithms or recursive automata, computer scientists and mathematicians have been mostly using Turing machines for theoretical exploration of computational problems.

However, with the discovery of super-recursive algorithms and exploration of unconventional computations, more powerful models than Turing machines came to the forefront of computer science (Burgin, 2005; Burgin and Dodig-Crnkovic, 2012). One of the most natural extensions of conventional algorithmic models is inductive Turing machine, which is an innovative model of computations, algorithms and information processing systems more powerful than Turing machine. Inductive Turing machines can solve problems unmanageable by Turing machines providing means for decreasing complexity of computations and decision-making (Burgin, 2005). Consequently, in comparison with Turing machines and other recursive algorithms, inductive Turing machines represent the next step in the development of computer science as well as in the advancement of network and computational technology.

In additi on, inductive Turing machines supply more adequate than recursive algorithms and automata models of computations, algorithms, networks, and information processing systems. As a result, inductive Turing machines have found diverse applications in algorithmic information theory and complexity studies (Burgin, 2004; 2010), software testing (Burgin and Debnath, 2009; Burgin, Debnath and Lee, 2009), high performance computing (Burgin, 1999), machine learning (Burgin and Klinger, 2004), software engineering (Burgin and Debnath, 2004; 2005), computer networks (Burgin, 2006; Burgin and Gupta, 2012) and evolutionary computations (Burgin and Eberbach, 2009; 2009a; 2012). For instance, inductive Turing machines can perform all types of machine learning – TxtEx-learning, TxtFin-learning, TxtBC-learning, and TxtEx*-learning, (Beros, 2013). While the traditional approach to machine learning models learning processes using functions, e.g., limit partial recursive functions (Gold, 1967), inductive Turing machines are automata, which can compute values of the modeling functions and perform other useful operations while functions only describe such operations.

Inductive Turing machines also provide efficient tools for algorithmic information theory, which is one of the indispensable areas in information theory and is based on complexity of algorithms and automata (Chaitin, 1977; Burgin, 2010). There are different kinds and types of complexity with a diversity of different complexity measures. One of the most popular and important of them is Kolmogorov, also called algorithmic, complexity, which has turned into an important and popular tool in many areas such as information theory, computer science, software development, probability theory, and statistics. Algorithmic complexity has found applications in medicine, biology, neurophysiology, physics, economics, hardware and software engineering. In biology, algorithmic complexity is used for estimation of

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protein identification (Dewey, 1996; 1997). In physics, problems of quantum gravity are analyzed based on the algorithmic complexity of a given object. In particular, the algorithmic complexity of the Schwarzschild black hole is estimated (Dzhunushaliev, 1998; Dzhunushaliev and Singleton, 2001). Benci, et al (2002) apply algorithmic complexity to chaotic dynamics. Zurek elaborates a formulation of thermodynamics by inclusion of algorithmic complexity and randomness in the definition of physical entropy (Zurek, 1991). Gurzadyan (2003) uses Kolmogorov complexity as a descriptor of the Cosmic Microwave Background (CMB) radiation maps. Kreinovich, and Kunin (2004) apply Kolmogorov complexity to problems in classical mechanics, while Yurtsever (2000) employs Kolmogorov complexity in quantum mechanics. Tegmark (1996) discusses what can be the algorithmic complexity of the whole universe. The main problem with this discussion is that the author identifies physical universe with physical models of this universe. To get valid results on this issue, it is necessary to define algorithmic complexity for physical systems because conventional algorithmic complexity is defined only for such symbolic objects as words and texts (Li, and Vitanyi, 1997). Then it is necessary to show that there is a good correlation between algorithmic complexity of the universe and algorithmic complexity of its model used by Tegmark (1996).

In economics, a new approach to understanding of the complex behavior of financial markets using algorithmic complexity is developed (Mansilla, 2001). In neurophysiology, algorithmic complexity is used to measure characteristics of brain functions (Shaw, et al, 1999). Algorithmic complexity has been useful in the development of software metrics and other problems of software engineering (Burgin, and Debnath, 2003; Lewis, 2001). Crosby and Wallach (2003) use algorithmic complexity to study low-bandwidth denial of service attacks that exploit algorithmic deficiencies in many common applications' data structures.

Thus, we see that Kolmogorov/algorithmic complexity is a frequent word in present days' scientific literature, in various fields and with diverse meanings, appearing in some contexts as a precise concept of algorithmic complexity, while being a vague idea of complexity in general in other texts. The reason for this is that people study and create more and more complex systems.

Algorithmic complexity in its classical form gives an estimate of how many bits of information we need to build or restore a given text by algorithms from a given class. This forms the foundation for algorithmic information theory (Chaitin, 1977; Burgin, 2010). Conventional Kolmogorov, or recursive algorithmic complexity and its modifications, such as uniform complexity, prefix complexity, monotone complexity, process complexity, conditional Kolmogorov complexity, quantum Kolmogorov complexity, time-bounded Kolmogorov complexity, space-bounded Kolmogorov complexity, conditional resource-bounded Kolmogorov complexity, time-bounded prefix complexity, and resource-bounded Kolmogorov complexity, use conventional, i.e., recursive, algorithms, such as Turing machines. Inductive complexity studied in this paper is a special type of the generalized Kolmogorov complexity (Burgin, 1990), which is based on inductive Turing machines. It is possible to apply inductive algorithmic complexity in all cases where Kolmogorov complexity is used and even in such situations where Kolmogorov complexity is not defined. In particular, inductive algorithmic complexity has been used in the study of mathematical problem complexity (Calude, et al, 2012; Hertel, 2012; Burgin, et al, 2013), as well as for exploration of other problems (Burgin, 2010a).

The goal of this work is to find properties of inductively computable and inductively decidable sets and functions applying these properties to inductive algorithmic complexity. This paper has the following structure. In Section 2, we give definitions of simple inductive Turing machines, which can compute much more than Turing machines. In Section 3, we study relations between inductively computable sets, inductively recognizable sets, inductively decidable sets, and inductively computable functions. In Section 4, we use the obtained relations to advance inductive algorithmic complexity and algorithmic information theory. Utilization of inductive algorithmic complexity makes these relations more exact as for infinitely many objects, inductive algorithmic complexity is essentially smaller than Kolmogorov complexity (Burgin, 2004). Section 5 contains conclusion and directions for further research.

II. Simple Inductive Turing Machines as a Computational Model

Here we consider only simple inductive Turing machines (Burgin, 2005) and for simplicity call them inductive Turing machines although there are other kinds of inductive Turing machines. A simple inductive Turing machine *M* works with words in some alphabet and has the same structure and functioning rules as a Turing machine with three heads and three linear tapes (registers) – the input tape (register), output tape (register) and working tape (register). Any inductive Turing machine of the first order is functionally equivalent to a simple inductive Turing machine. Inductive Turing machine of higher orders are more powerful than simple inductive Turing machines allowing computation of more functions and sets.

The machine *M* works in the following fashion. At the beginning, an input word *w* is written in the input tape, which is a read-only tape. Then the machine *M*

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rewrites the word w from the input tape to the working tape and starts working with it. From time to time in this process, the machine M rewrites the word from the working tape to the output tape erasing what was before written in the output tape. In particular, when the machine M comes to a final state, it rewrites the word from the working tape to the output tape and stops without changing the state.

The machine M gives the result when M halts in a final state, or when M never stops but at some step of the computation, the content of the output tape (register) stops changing. The computed result of M is the word that is written in the output tape of M. In all other cases, M does not give the result.

This means that a simple inductive Turing machine can do what a Turing machine can do but in some cases, it produces its results without stopping. Namely, it is possible that in the sequence of computations after some step, the word (say, w) on the output tape (in the output register) is not changing, while the inductive Turing machine continues working. Then this word w is the final result of the inductive Turing machine. Note that if an inductive Turing machine gives the final result, it is produced after a finite number of steps, that is, in finite time, even when the machine does not stop. So contrary to confusing claims of some researchers, an inductive Turing machine does not need infinite time to produce a result.

We assume that inductive Turing machines work with finite words in some alphabet Σ or with natural numbers represented by such words. Consequently, inductive Turing machines compute sets X of finite words in Σ, i.e., $X \subseteq \Sigma^*$ where Σ^* is the set of all finite words in the alphabet Σ, or sets of natural numbers $Z \subseteq \mathbf{N}$ represented by words. As it is possible to code any alphabet by words in the alphabet $\{0, 1\}$, we can assume (when it is necessary) that this binary alphabet is used by all considered inductive Turing machines.

If an inductive Turing machine M transforms words from Σ^* into words from Σ^*, then Σ^* is called the *domain* and *codomain* of M.

If an inductive Turing machine M transforms numbers from $\mathbf{N}$ into numbers from $\mathbf{N}$, then $\mathbf{N}$ is called the *domain* and *codomain* of M.

The set of words (numbers) for which the machine M is defined (gives the result) is called the *definability domain* of M.

The set of words (numbers) computed (generated) by the machine M is called the *range* of M.

III. Inductively Computable and Inductively Decidable Sets

Definition 3.1. A set $X \subseteq \Sigma^*$ or $X \subseteq \mathbf{N}$ is called *inductively computable* if there is an inductive Turing machine M with the range X.

Informally, an inductively computable set consists of all final results of some inductive Turing machine M.

Sets Σ^* and $\mathbf{N}$ are simple examples of inductively computable sets.

We remind that a *recursively computable* set, which is also called a *recursively enumerable* set, is the range of some Turing machine or of another recursive algorithm (Burgin, 2005).

Inductively computable sets are closely related to inductively computable functions, which have the form $f: \Sigma^* \to \Sigma^*$ or $g: \mathbf{N} \to \mathbf{N}$.

Definition 3.2. A functions f is called *inductively computable* if there is an inductive Turing machine M that computes X, i.e., given an arbitrary input x, the machine M computes the value $f(x)$ when f is defined for x and does not give the result when f is undefined for x. The domain, codomain, definability domain and range of an inductively computable function coincides with the domain, codomain, definability domain and range, respectively, of the inductive Turing machine that computes this function.

We remind that a *recursively computable* function, which is also called a *partial recursive* function, is a function computed by some Turing machine or of another recursive algorithm (Burgin, 2005).

As it is possible to simulate any Turing machine by an inductive Turing machine (Burgin, 2005), we have the following result.

Proposition 3.1. Any recursively computable function is inductively computable.

Definition 3.3. a) A set $X \subseteq \Sigma^*$ or $X \subseteq \mathbf{N}$ is called *inductively recognizable*, also called *inductively semidecidable*, if there is an inductive Turing machine M such that gives the result 1 for input x if and only if x belongs to X.

b) A set $X \subseteq \Sigma^*$ or $X \subseteq \mathbf{N}$ is called *inductively corecognizable* if there is an inductive Turing machine M such that gives the result 1 for input x if and only if x does not belong to X.

Definition 3.4. A set $X \subseteq \Sigma^*$ or $X \subseteq \mathbf{N}$ is called *inductively decidable* if there is an inductive Turing machine M such that gives the result 1 for any input x from X and gives the result 0 for any input z from $\Sigma^* \backslash X$ (from $\mathbf{N} \backslash X$).

Informally, a set X is inductively decidable if some inductive Turing machine M can indicate whether an arbitrary element belongs to X or does not belong. In other words, a set X is inductively decidable if its indication (characteristic) function is inductively computable.

Lemma 3.1. A set $X \subseteq \Sigma^*$ or $X \subseteq \mathbf{N}$ is inductively recognizable if and only if it is inductively computable.

Proof. Sufficiency. Let us consider an inductively computable set X. By definition, there is an inductive Turing machine M_X the range of which is equal to X. It is

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possible to assume that the machine M_X gives the result if and only if its output stabilizes.

To show that X is inductively recognizable, we add a new component (subprogram) C to the machine M_X , building the new inductive Turing machine N_X . After each step of the machine M_X (as a subprogram of the machine N_X), the subprogram C checks if the two consecutive intermediate outputs of M_X are equal or not. When they are equal, the machine N_X gives the intermediate output 1and then the machine M_X (as a subprogram of the machine N_X) makes the next step.

When the two consecutive intermediate outputs of M_X are not equal, the machine N_X gives the intermediate output 1, followed by the intermediate output 0 and then the machine M_X (as a subprogram of the machine N_X) makes the next step.

This construction shows that the output of N_X stabilizes if and only if the output of M_X stabilizes. It means that the inductive Turing machine N_X gives the result 1 for any input x from X and does not gives the result otherwise. Thus, the set X is inductively recognizable.

Necessity. Let us consider an inductively recognizable set X. By definition, there is an inductive Turing machine K_X that gives the result 1 for any input x from X and either does not give the result otherwise or gives the result 0. It is possible to assume that the machine K_X gives the result if and only if its output stabilizes and all intermediate outputs of K_X are equal either to 1 or to 0.

To show that X is inductively computable, we transform the machine K_X , building the new inductive Turing machine N_X . At the beginning, K_X stores the input x. Then when the machine K_X gives the intermediate output 1, the machine N_X gives the intermediate output x. When the machine K_X gives the intermediate output 0 the first time, the machine N_X gives the intermediate output w, which is not equal to x. When the machine K_X gives the intermediate output 0 next time, the machine N_X gives the intermediate output x. Next time, the machine K_X gives the intermediate output 0, the machine N_X gives the intermediate output w and so on. Thus, even if the machine K_X obtains the result 0, the machine N_X does not give the result.

In such a way, the machine N_X obtains the result if and only if the machine K_X obtains the result. In addition, all results of N_X belong to the set X and only to it because K_X computes the indicating function of X. Thus, X is equal to the range of the function computed by N_X and consequently, X is inductively computable.

Lemma is proved.

Lemma 3.2. The range of a total monotone inductively computable function is inductively decidable.

Proof. Let us consider a total monotone inductively computable function f with the range X. Then there is an inductive Turing machine M that computes f. We build an inductive Turing machine K that gives 1 as its result for all inputs from X and gives 0 as its result for all inputs that does not belong to X. It means that K decides the set X.

To achieve this goal, we include the machine M as a part (in the form of subroutine) of the machine K and define functioning of K in the following way. When K obtains a word x as the input x, the goal is to whether x belongs to the set X or does not belong. To do this, the machine K starts simulating the machine M for all inputs $x_1 , x_2 , \ldots , x_n$ that are less than x in a parallel mode. It means that each step is repeated for all inputs $x_1 , x_2 , \ldots , x_n$, then the next step is also repeated for all inputs $x_1 , x_2 , \ldots , x_n$, and so on. On each step, the machine K compares intermediate outputs of the machine M with the word x. When, at least, one of the intermediate outputs of the machine M for these inputs is equal to x, the machine K gives the intermediate output 1. When no intermediate outputs of the machine M for these inputs coincide with x, the machine K gives the intermediate output 0.

As the inductive Turing machine M computes a total function, all intermediate outputs start repeating at some step of the machine M computation. That is why the word x belong to X if on this step, it coincides with one of the outputs. By construction, the machine K continues to repeat the output 1 forever. If the word x does not coincide with any of the outputs of the machine M, then the word x does not belong to X because x can be the value of f only for arguments $x_1 , x_2 , \ldots , x_n , x$ as f is a monotone function.

In such a way, the machine K decides whether an arbitrary word belongs to X or does not belong.

Lemma is proved.

These lemmas allow us to prove existence of definite relations between inductively computable sets and inductively decidable sets.

Theorem 3.1. Any infinite inductively computable set contains an infinite inductively decidable subset.

Proof. Let us consider an inductively computable set X. By Lemma 3.1, the set X is inductively recognizable. It means that there is an inductive Turing machine K_X that gives the result 1 for any input x from X and either does not give the result otherwise or gives the result 0. It is possible to assume that the machine K_X gives the result if and only if its output stabilizes and all intermediate outputs of K_X are equal either to 1 or to 0 (Burgin, 2005).

As we know, there is the natural order in the set $\boldsymbol{N}$ and the lexicographical order in the set Σ^* (cf., for example, (Burgin, 2005)). It means that the domain of any inductive Turing machine is the ordered sequence $\{x_1 , x_2 , x_3 , \ldots , x_n , \ldots\}$ where $x_k < x_{k+1}$ for all $= 1, 2, 3, \ldots$.

To find an inductively decidable subset in the set X, we extend the alphabet Σ by adding a new symbol

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and build a new inductive Turing machine M, output of which can include this new symbol #. The machine M contains the machine K_X as a component (subroutine), a component (subroutine) G, which generates words x_1, x_2, x_3, … , x_n, … one after another, and a counter C as another component (subroutine) C.

The machine M processes information in cycles organized in the following way.

Cycle 1*1: When the machine M gets the word x_1 as its input, it gives x_1 to the machine K_X, which starts processing it. At the same time, the counter C counts the number of steps made by K_X. When the machine K_X gives the intermediate output 1, the machine M gives the intermediate output x_1, which is stored in the memory of M. When the machine K_X gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_X stops processing x_1, the number n_1 of steps made by K_X is stored in the memory of M and the generator G generates the word x_2.

Cycle 1*2: Then the machine M gives x_2 to the machine K_X, which starts processing it. At the same time, the counter C counts the number of steps made by K_X. When the machine K_X makes less than n_1 steps, the machine M always gives the intermediate output x_2. After n_1 steps, when the machine K_X gives the intermediate output 1, the machine M gives the intermediate output x_2. When the machine K_X gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_X stops processing x_2, the number n_2 of steps made by K_X is stored in the memory of M and the machine K_X starts once more processing the word x_1. At the same time, the counter C counts the number of steps made by K_X.

Cycle 1*3: When the machine K_X makes less than n_2 steps, the machine M always gives the intermediate output x_1. After n_2 steps, when the machine K_X gives the intermediate output 1, the machine M gives the intermediate output x_1. When the machine K_X gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_X stops processing x_1, the number n_3 of steps made by K_X is stored in the memory of M and the machine K_X starts once more processing the word x_2. At the same time, the counter C counts the number of steps made by K_X.

Cycle 1*4: When the machine K_X makes less than n_3 steps, the machine M always gives the intermediate output x_2. After n_2 steps, when the machine K_X gives the intermediate output 1, the machine M gives the intermediate output x_2. When the machine K_X gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_X stops processing x_2, the number n_4 of steps made by K_X is stored in the memory of M and the generator G generates the word x_3.

Cycle 1*5: Then the machine M gives x_3 to the machine K_X, which starts processing it. At the same time, the counter C counts the number of steps made by K_X. When the machine K_X makes less than n_4 steps, the machine M always gives the intermediate output x_3. After n_4 steps, when the machine K_X gives the intermediate output 1, the machine M gives the intermediate output x_3. When the machine K_X gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_X stops processing x_3, the number n_5 of steps made by K_X is stored in the memory of M and the machine K_X starts once more processing the word x_1. At the same time, the counter C counts the number of steps made by K_X.

This process continues until it stabilizes, which happens because the definability domain of the machine K_X is not empty.

In such a way, the machine M makes the machine K_X to process more and more elements x_n, making more and more steps with each of them as its input. As the definability domain of the machine K_X is not empty, at some step m_1, the machine K_X continues forever repeating 1 as its output for an input x_k. By construction, the machine M continues forever repeating x_k as its output for an input x_1. It means $M(x_1) = x_k$. Note that $x_1 \leq x_k$ and x_k may be not the least element in the definability domain X of the machine K_X.

Given the word x_2 as its input, the machine M performs similar cycles as before but with pairs of words (x_i, x_j).

Cycle 2*1: Thus, at the beginning when the machine M gets the word x_2 as its input, it gives x_2 and the word x_3 generated by G to the machine K_X, which starts processing both words in a parallel mode. At the same time, the counter C counts the number of steps made by K_X. When the machine K_X gives the intermediate output 1 for both inputs, the machine M gives the intermediate output x_3, which is stored in the memory of M. When the machine K_X gives the intermediate output 0 for the input x_2 before it gives the intermediate output 0 for the input x_3, the machine M gives the intermediate output #, the machine K_X stops processing the pair (x_2, x_3), the number n_1 of steps made by K_X is stored in the memory of M, the generator G generates the word x_4 and the machine M goes to the cycle 2*2.

When the machine K_X gives the intermediate output 0 for the input x_3 at the same time or before it gives the intermediate output 0 for the input x_2, the machine M gives the intermediate output #, the machine K_X stops processing the pair (x_2, x_3), the number n_2 of steps made by K_X is stored in the memory of M, the generator G generates the word x_4 and the machine M goes to the cycle 2*3.

Cycle 2*2: Then the machine M gives the pair (x_3, x_4) to the machine K_X, which starts processing it in a parallel mode. At the same time, the counter C counts the number of steps made by K_X. When the machine K_X makes less than n_1 steps, the machine M always gives the intermediate output x_4. After n_1 steps, when the

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machine K_X gives the intermediate output 1 for both inputs, the machine M gives the intermediate output x_4. When the machine K_X gives the intermediate output 0 for the input x_3 before it gives the intermediate output 0 for the input x_4, the machine M gives the intermediate output #, the machine K_X stops processing the pair (x_3, x_4), the number n_3 of steps made by K_X is stored in the memory of M and the machine M goes to the cycle 2*4. When the machine K_X gives the intermediate output 0 for the input x_4 at the same time or before it gives the intermediate output 0 for the input x_3, the machine M gives the intermediate output #, the machine K_X stops processing the pair (x_2, x_3), the number n_2 of steps made by K_X is stored in the memory of M, the generator G generates the word x_4 and the machine M goes to the cycle 2*5.

Cycle 2*3: Then the machine M gives the pair (x_2, x_4) to the machine K_X, which starts processing it in a parallel mode. At the same time, the counter C counts the number of steps made by K_X. When the machine K_X makes less than n_2 steps, the machine M always gives the intermediate output x_4. After n_1 steps, when the machine K_X gives the intermediate output 1 for both inputs, the machine M gives the intermediate output x_4. When the machine K_X gives the intermediate output 0 for the input x_2 before it gives the intermediate output 0 for the input x_4, the machine M gives the intermediate output #, the machine K_X stops processing the pair (x_2, x_4), the number n_2 of steps made by K_X is stored in the memory of M and the machine M goes to the cycle 2*6. When the machine K_X gives the intermediate output 0 for the input x_4 at the same time or before it gives the intermediate output 0 for the input x_3, the machine M gives the intermediate output #, the machine K_X stops processing the pair (x_2, x_3), the number n_2 of steps made by K_X is stored in the memory of M, the generator G generates the word x_4 and the machine M goes to the cycle 2*7 and so on.

This process continues until it stabilizes, which happens because the definability domain of the machine K_X is infinite.

In such a way, the machine M makes the machine K_X to process more and more pairs (x_i, x_j) functioning in a parallel mode and making more and more steps with each pair as its inputs. As in the case of the input x_1, the machine M, at first, finds the word x_k for which the machine K_X continues forever repeating 1 as its output and then locates a word $x_n > x_k$ for which the machine K_X also continues forever repeating 1 as its output. The machine M can do this because the definability domain of the machine K_X is infinite. When the machine M finds this word x_n, it continues forever repeating x_n as its output for an input x_2. It means $M(x_2) = x_n$ and $x_n > x_k$. Note that $x_2 \leq x_n$ and x_n may be not the least element in the definability domain X of the machine K_X that is larger than x_k.

Given the word x_2 as its input, the machine M performs similar cycles as before but with triples of words (x_i, x_t, x_j) as inputs to the machine K_X, which processes them in a parallel mode. In this case, the machine M, at first, finds the word x_k for which the machine K_X continues forever repeating 1 as its output and then locates a word $x_n > x_k$ for which the machine K_X also continues forever repeating 1 as its output. After this, the machine M finds the word $x_p > x_n$ for which the machine K_X continues forever repeating 1 as its output. The machine M can do this because the definability domain of the machine K_X is infinite. When the machine M finds this word x_p, it continues forever repeating x_p as its output for an input x_3. It means $M(x_3) = x_p$ and $x_p > x_n > x_k$. Note that $x_3 \leq x_p$ and x_p may be not the least element in the definability domain X of the machine K_X that is larger than x_n.

In such a way, the machine M finds results for any input x_i computing a total monotone function. By Lemma 2, the range Z of this function is inductive decidable and by construction, it is infinite.

Theorem is proved.

This result allows us to find additional properties of inductive algorithmic complexity (cf. Section 4).

Let us consider the set $R_M = \{(x, t)$; given the input x, an inductive Turing machine M gives the result in not more than t steps$\}$, i.e., R_M consists of all pairs (x, t), in which x is a word from $\{0, 1\}^*$ and t is a natural number.

Lemma 3.3. The set R_M is inductively decidable.

Proof. We build an inductive Turing machine K that gives 1 as its result for all inputs from R_M and gives 0 as its result for all inputs that does not belong to R_M. It means that K decides the set R_M.

To achieve this goal, we include the machine M as a part (in the form of subroutine) of the machine K and define functioning of K in the following way. When K obtains a word (x, t) as the input x, it starts simulating the machine M for the input x. When the step number n is made the machine K gives the intermediate output 1. Then the machine K makes one more step simulating the machine M for the input x and compares the new intermediate output of the machine M with its previous result. When these outputs coincide, the machine K gives the intermediate output 1. Otherwise the machine K gives the final output 0 and stops.

After each intermediate output 1, the machine K makes one more step simulating the machine M for the input x and compares the new intermediate output of the machine M with its previous result. When these outputs coincide, the machine K gives the intermediate output 1. As the result, the inductive Turing machine K gives 1 when the outputs of M start repeating from the step t and gives 0 as its result otherwise. In such a way, the machine K decides whether an arbitrary word (x, t) belongs to R_M or does not belong.

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Lemma is proved.

Now we find additional relations between inductively computable sets and inductively decidable sets.

Taking a binary relation $R \subseteq \Sigma^* \times \Sigma^*$, it is possible to consider two projections of this relation:

The left projection $\Pr_l R = \{ x;\ \exists y\ ((x, y) \in R) \}$

The right projection $\Pr_r R = \{ y;\ \exists x\ ((x, y) \in R) \}$

Theorem 3.2. A set X is inductively computable if and only if it is the left projection of an inductively decidable binary relation.

Proof. *Necessity*. Let us consider an inductively computable set X. By definition, there is an inductive Turing machine M, which computes X.

Let us consider the set $R_M = \{(x, t)$; given the input x, an inductive Turing machine M gives the result not more than in t steps$\}$, i.e., R_M consists of all pairs (x, t), in which x is a word from $\{0, 1\}^*$ and t is a natural number. By Lemma 3.3, the set R_M is inductively decidable and $\Pr_l R_M = X$ because an element x is computed by M if and only if there is a number t such that given the input x, an inductive Turing machine M gives the result not more than in t steps.

Note that $X = \Pr_{lr} R^{\circ}_M$ where $R^{\circ}_M = \{(t, x);\ \{(x, t) \in R_M \}$ and thus, R°_M is inductively decidable

Sufficiency. Let us consider an inductively decidable binary relation $R \subseteq \Sigma^* \times \Sigma^*$ and its left projection $\Pr_l R = \{ x;\ \exists y\ ((x, y) \in R) \}$, which we denote by X. By definition, there is an inductive Turing machine K_R that gives the result 1 for any input (x, y) from R and gives the result 0 for any input (z, u) that does not belong to R.

To show that the set X is inductively computable, we extend the alphabet Σ by adding the new symbol # and build a new inductive Turing machine M, which computes X. The machine M contains the machine K_R as a component (subroutine), a component (subroutine) G, which generates all words x_1, x_2, x_3, … , x_n, … in the alphabet Σ one after another, and a counter C as another component (subroutine) C. The machine M processes information in cycles organized in the following way.

Cycle 1: When the machine M gets a word w as its input, the generator G produces the word x_1 and the machine M gives the pair (w, x_1) to the machine K_R, which starts processing it. At the same time, the counter C counts the number of steps made by K_R. When the machine K_X gives the intermediate output 1, the machine M gives the intermediate output w, which is stored in the memory of M. When the machine K_X gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_X stops processing the pair (w, x_1), the number n_1 of steps made by K_R is stored in the memory of M and the generator G generates the word x_2.

Cycle 2: Then the machine M gives the pair (w, x_2) to the machine K_R, which starts processing it. At the same time, the counter C counts the number of steps made by K_R. When the machine K_R makes less than n_1 steps, the machine M always gives the intermediate output w. After n_1 steps, when the machine K_R gives the intermediate output 1, the machine M gives the intermediate output w. When the machine K_R gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_R stops processing the pair (w, x_2), the number n_2 of steps made by K_R is stored in the memory of M and the machine K_R starts once more processing the pair (w, x_1). At the same time, the counter C counts the number of steps made by K_R.

Cycle 3: When the machine K_R makes less than n_2 steps, the machine M always gives the intermediate output w. After n_2 steps, when the machine K_R gives the intermediate output 1, the machine M gives the intermediate output w. When the machine K_R gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_R stops processing the pair (w, x_1), the number n_3 of steps made by K_R is stored in the memory of M and the machine K_R starts once more processing the pair (w, x_2). At the same time, the counter C counts the number of steps made by K_R.

Cycle 4: When the machine K_R makes less than n_3 steps, the machine M always gives the intermediate output w. After n_2 steps, when the machine K_R gives the intermediate output 1, the machine M gives the intermediate output w. When the machine K_R gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_R stops processing the pair (w, x_2), the number n_4 of steps made by K_R is stored in the memory of M and the generator G generates the word x_3.

Cycle 5: Then the machine M gives pair (w, x_3) to the machine K_R, which starts processing it. At the same time, the counter C counts the number of steps made by K_R. When the machine K_R makes less than n_4 steps, the machine M always gives the intermediate output w. After n_4 steps, when the machine K_R gives the intermediate output 1, the machine M gives the intermediate output w. When the machine K_R gives the intermediate output 0, the machine M gives the intermediate output #, the machine K_R stops processing the pair (w, x_3), the number n_5 of steps made by K_R is stored in the memory of M and the machine K_R starts once more processing the pair (w, x_1) and this process continues, while the counter C counts the number of steps made by K_R.

This process stabilizes if and only if the machine K_R stabilizes processing a pair (w, x) for some x. If it happens, the machine M computes the word w. In this case, $w \in X$. Otherwise, w does not belong to the range of M. In this case, w also does not belong to X. As w is

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an arbitrary word, it means that the machine M computes the set X.
Theorem is proved.

Corollary 3.1. A set X is inductively recognizable if and only if it is the left projection of an inductively decidable binary relation.

If R is a binary relation, then $R^{o} = \{(y, x); (x, y) \in R\}$ is the involution of R, also called the inverse of R. Definitions imply the following results.

Lemma 3.4. $\mathrm{Pr}_l R = \mathrm{Pr}_r R^{o}$ and $\mathrm{Pr}_r R = \mathrm{Pr}_l R^{o}$.

Lemma 3.5. A relation R is inductively computable (inductively decidable) if and only if the relation R^{o} is inductively computable (inductively decidable).

Theorem 3.2 and Lemma 3.5 and 3.4 give us the following results.

Corollary 3.2. A set X is inductively computable if and only if it is the right projection of an inductively decidable binary relation.

Corollary 3.3. A set X is inductively recognizable if and only if it is the right projection of an inductively decidable binary relation.

IV. Inductive Algorithmic Complexity

Here we study inductive algorithmic complexity for finite objects such as natural numbers or words in a finite alphabet. Usually, it is the binary alphabet $\{0, 1\}$.

Definition 4.1. The *algorithmic complexity* $\mathrm{IC}_M(x)$ of an object (word) x with respect to an inductive Turing machine M is defined as

$$\mathrm{AC}_M(x) = \begin{cases} \min\{\, l(p);\ M(p) = x\} & \text{when there is } p \text{ such that } M(p) = x \\ \text{undefined} & \text{when there is no } p \text{ such that } M(p) = x \end{cases}$$

Note that if M is a Turing machine, then algorithmic complexity $\mathrm{AC}_M(x)$ with respect to M coincides with Kolmogorov complexity $\mathrm{C}_M(x)$ with respect to M. If M is a prefix Turing machine, then the algorithmic complexity $\mathrm{IC}_M(x)$ is the prefix Kolmogorov complexity $\mathrm{K}_M(x)$.

However, as in the case of conventional Kolmogorov complexity, we need an invariant complexity of objects. This is achieved by using a universal simple inductive Turing machine (Burgin, 2004; 2005).

Definition 4.2. The *inductive algorithmic complexity* $\mathrm{IC}(x)$ of an object (word) x is defined as

$$\mathrm{IC}(x) = \begin{cases} \min\{\, l(p);\ U(p) = x\} & \text{when there is } p \text{ such that } U(p) = x \\ \text{undefined} & \text{when there is no } p \text{ such that } U(p) = x \end{cases}$$

where $l(p)$ is the length of the word p and U is a universal simple inductive Turing machine.

Note that inductive complexity is a special case of generalized Kolmogorov complexity (Burgin, 1990), which in turn, is a kind of axiomatic dual complexity measures (Burgin, 2005).

The prefix inductive complexity $\mathrm{IK}(x)$ is optimal in the class of prefix inductive complexities $\mathrm{IK}_T(x)$.

Optimality is based on the relation $\preccurlyeq$ defined for functions $f(n)$ and $g(n)$, which take values in natural numbers:

$f(n) \preccurlyeq g(n)$ if there is a real number c such that $f(n) \leq g(n) + c$ for almost all $n \in \boldsymbol{N}$

Let us consider a class $\mathbf{H}$ of functions that take values in natural numbers. Then a function $f(n)$ is called *optimal* for $\mathbf{H}$ if $f(n) \preccurlyeq g(n)$ for any function $g(n)$ from $\mathbf{H}$. In the context of the axiomatic theory of dual complexities, such a function $f(n)$ is called *additively optimal* for the class $\mathbf{H}$.

Results from the axiomatic theory of dual complexities (Burgin, 1990; 2010) imply the following theorem.

Theorem 4.1. The function $\mathrm{IC}(x)$ is optimal in the class of all prefix inductive complexities $\mathrm{IK}_T(x)$ with respect to a prefix simple inductive Turing machine T.

As there is a simple inductive Turing machine M such that $M(x) = x$ for all words x in the alphabet $\{1, 0\}$, we have the following result.

Proposition 4.1. $\mathrm{IC}(x)$ is a total function.

Let us assume for simplicity that inductive Turing machines are working with words in some finite alphabet and that all these words are well ordered, that is, any set of words contains the least element. It is possible to find such orderings, for example, in (Li and Vitaniy, 1997).

Theorem 4.1. If h is an increasing inductively computable function that is defined in an infinite inductively computable set W and tends to infinity when $l(x) \to \infty$, then for infinitely many elements x from W, we have $h(x) > \mathrm{IC}(x)$.

Proof. Let us consider an increasing inductively computable function f that is defined in an infinite inductively computable set W and tends to infinity when $l(x) \to \infty$. Then by Theorem X1, W contains an infinite inductively decidable subset V. Because the set V is infinite, the restriction h of the function f on the set V tends to infinity when $l(x) \to \infty$.

By Theorem 5.3.12 from (Burgin, 2005), for infinitely many elements x from V, we have $h(x) > \mathrm{IC}(x)$. As V is a subset of W, for infinitely many elements x from W, we have $h(x) > \mathrm{IC}(x)$.
Theorem is proved.

Since the composition of two increasing functions is an increasing function and the composition of a recursive function and an inductively computable

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function is an inductively computable function, we have the following result.

Corollary 4.1. If $h(x)$ and $g(x)$ are increasing functions, $h(x)$ is inductively computable and defined in an infinite inductively computable set W, $g(x)$ is a recursive function, and they both tend to infinity when $l(x) \to \infty$, then for infinitely many elements x from W, we have $g(h(x)) > \mathrm{IC}(x)$.

Corollary 4.2. The function $\mathrm{IC}(x)$ is not inductively computable. Moreover, no inductively computable function $f(x)$ defined for an infinite inductively computable set of numbers can coincide with $\mathrm{IC}(x)$ in the whole of its domain of definition.

As Kolmogorov complexity $C(x)$ is inductively computable (Burgin, 2005), Theorem X3 implies the following result.

Theorem 4.2. For any increasing recursive function $h(x)$ that tends to infinity when $l(x) \to \infty$ and any inductively computable set W, there are infinitely many elements x from W for which $h(C(x)) > \mathrm{IC}(x)$.

Corollary 4.3. In any inductively computable set W, there are infinitely many elements x for which $C(x) > \mathrm{IC}(x)$.

Corollary 4.4. For any natural number a and in any inductively computable set W, there are infinitely many elements x for which $\ln_a(C(x)) > \mathrm{IC}(x)$.

Corollary 4.5. In any inductively computable set W, there are infinitely many elements x for which $\ln_2(C(x)) > \mathrm{IC}(x)$. If $\ln_2(C(x)) > \mathrm{IC}(x)$, then $C(x) > 2^{\mathrm{IC}(x)}$. At the same time, for any natural number k, the inequality $2^n > k \cdot n$ is true almost everywhere. This and Corollary X7 imply the following result.

Corollary 4.6. For any natural number k and in any inductively computable set W, there are infinitely many elements x for which $C(x) > k \cdot \mathrm{IC}(x)$.

Corollary 4.7. In any inductively computable set W, there are infinitely many elements x for which $C(x) > 2^{\mathrm{IC}(x)}$.

Corollary 4.8. For any natural number a and in any inductively computable set W, there are infinitely many elements x for which $C(x) > a^{\mathrm{IC}(x)}$.

In addition, it is possible to apply obtained results to inductive algorithmic complexity of inductively computable functions, which are infinite objects but have a finite representation when they are enumerated.

V. Conclusion

We have found some basic properties of inductively computable, recognizable and decidable sets, as well as of inductively computable functions for computations, recognition and decision are performed by simple inductive Turing machines. These results show that inductive Turing machines form a natural extension of Turing machines allowing essentially increase power computations and decision-making.

We also applied the obtained results to algorithmic information theory demonstrating how inductive Turing machines allow obtaining more information for essentially decreasing complexity in comparison with Turing machines. The results obtained in this paper extend and improve similar results from (Burgin, 2004; 2005).

At the same time, simple inductive Turing machines form only the first level of the constructive hierarchy of inductive Turing machines (Burgin, 2005). Thus, it would be interesting to study similar properties arising in the higher levels of the constructive hierarchy. Besides, it would be useful to consider these problems in the axiomatic theory of algorithms (Burgin, 2010b).

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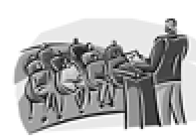

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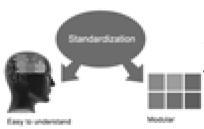

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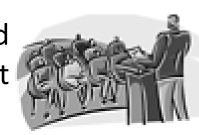

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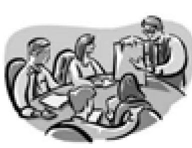

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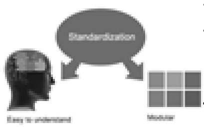

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Note :

"

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"

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2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript’s Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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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.

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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.

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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

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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
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- 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.
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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
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- 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.

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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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