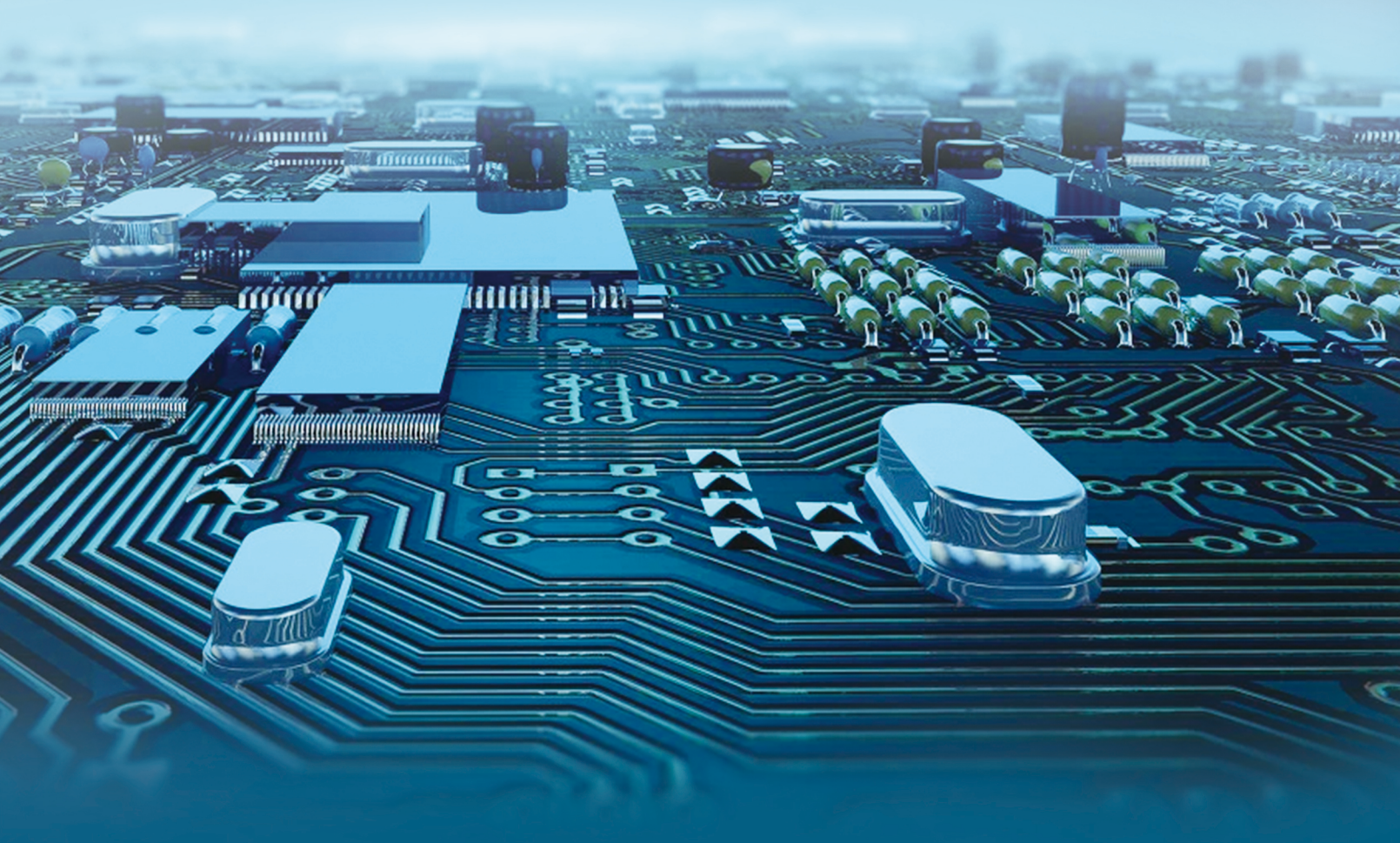




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ARTICLE**Basic Unit: As a Common Module of Neural Networks****Seisuke Yanagawa***

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ABSTRACT

In this paper, the logic is developed assuming that all parts of the brain are composed of a combination of modules that basically have the same structure. The feeding behavior of searching for food while avoiding the dangers of animals in the early stages of evolution is regarded as the basis of time series data processing. The module that performs the processing is presented by a neural network equipped with a learning function based on Hebb's rule, and is called a basic unit. The basic units are arranged in layers, and the information between the layers is bidirectional. This new neural network is an extension of the traditional neural network that has evolved from pattern recognition. The biggest feature is that in the processing of time series data, the activated part changes according to the context structure inherent in the data, and can be mathematically expressed the method of predicting events from the context of learned behavior and utilizing it in best action.

1. Introduction

No animal has wheels, but we have incorporated rotating mechanisms in various mechanical devices to run faster than horses and powerful than cows. In addition, since computers have speeds and processing amounts that are incomparable to actual neural circuits, pattern recognition technology using neural networks originating from Perceptron can instantly judge huge amounts of data, large commercial outcome have been taken. However, these progress does not always lead to a deep understanding of the intellectual functions of living organisms.

In the next chapter, I will consider the feeding behavior of seeking food while avoiding the dangers that animals in the early stages of evolution have as essential time-series processing. The processing will be realized by combining elemental circuits with the same structure. A neural net-

work that has the essential function is presented basing Hebb's law and called Basic Unit^[1]. A Basic Unit is a collection of circuits that process time-series data and operates as a component of the whole^{[2],[3]}. The Basic Units are arranged in layers, and the information between the layers is bidirectional. When the length of time series data is 1, it is equivalent to a conventional neural network whose main function is pattern recognition. This new neural network can be said to be a neural network whose functions have been extended from pattern recognition to behavior recognition, learning and generation.

The biggest feature is that in the processing of time series data, the activated part changes according to the context structure inherent in the data, and can be mathematically expressed the method of predicting events from the context of learned behavior and utilizing it in best action.

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2. Basic Units and those Layers

Even animals in the early stages of evolution move in the direction of light and smell in order to survive, prey on them if they judge that they are food, and fight or avoid them if they are dangerous. This level of behavior could be mimicked by junior high school level electronics by combining sensors and logic ICs, and the number of logic elements used may not be much different from the total number of insects or zooplankton neurons. In more evolved animals, even predatory behavior consists of a time series of multiple behaviors. That is, the process is to extend the arm toward the goal, open the palm when approaching the goal, close the palm when touching the goal, grab the goal and bring it closer to one's mouth. This operation can be realized with a circuit that is a slightly developed version of "electronic work at the junior high school level". For example, Figure 1 is a circuit in which the AND gates are connected in series. The four actuators are connected by rotation axis and show the shoulder, upper arm, lower arm, palm, finger muscles and joints from the left. The gate corresponding to the shoulder receives start signal and signal regarding the angle and load from the rotation axis. If the conditions are met, it drives the actuator and sends a signal to the gate corresponding to the upper arm. It continues until the operation of the actuator corresponding to the finger is completed.

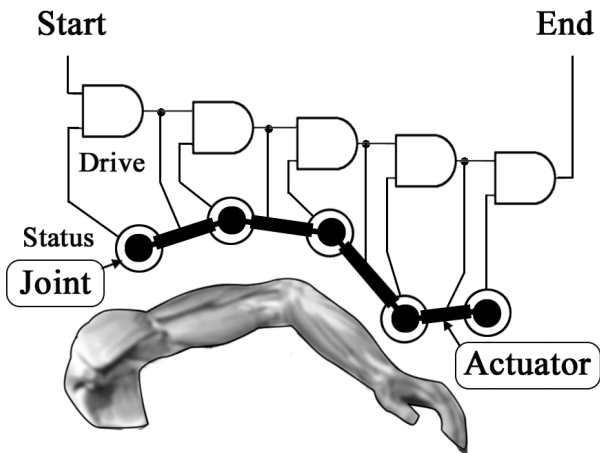


Figure 1. Concept of a circuit that moves the arm

The movement of the arm has various functions such as grasping, hitting, and throwing. Figure 2 shows the circuits arranged by function. It can be said that it is a judgment like choosing a brush that draws the desired picture from the brush stand. It is impossible to develop such a model into a neural network that accepts and generates time series data.

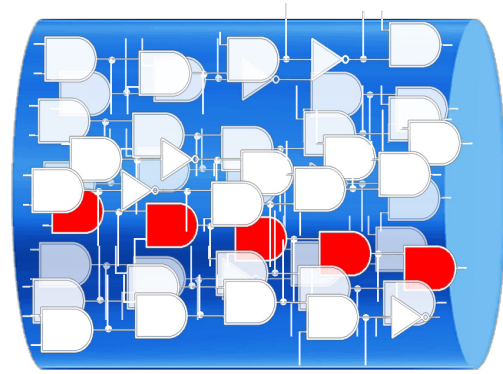


Figure 2. Electronic circuits collected in a bundle

Commercial results may be obtained if calculations based on the similarity of time series data or Markov processes are performed at high speed and in large quantities, but it is far from elucidating the functions of nerve cells in living organisms. Let's think about realizing the function with a model that uses elements that are more familiar with the function of nerve cells, specifically, that have another characteristic according to the Hebb rule.

First, it is shown in Figure 3 that time series data composed of finite type elements can be divided into a plurality of subsequences in which the same element does not occur multiple times. Since the divided subsequences is considered an element of the new time series data in the upper hierarchy, it can be said that every time series data contains a hierarchical context.

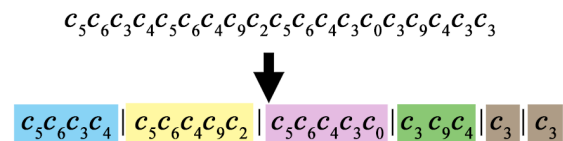


Figure 3. Any string can be split into subsequences

Consider a set U of elements equivalent to an AND gate as shown in Figure 4 left. Each element is randomly connected and receives the elements of time series data c_0 , c_1 , c_2 and c_3 from below. U_0 is a set of elements activated by receiving the signal c_0 as the start of a series of operations. Next, c_1 is received following c_0 , the element with high activity is the set of elements that are already activated by the reception of c_0 . That is, U_1 accepts c_0c_1 . Similarly the set of highly active elements is narrowed until the last data c_3 is received, and the last remaining set of elements U_3 becomes a pattern showing the time series data $c_0c_1c_2c_3$. Figure 4 Right is an image of a basic unit that processes time series data starting with c_0 , and this structure may be not so different to the structure of a hypothetical module called mini- and macro-columns, barrels, stripes, or blobs in neuroscience^[1]. All time-series data can be processed by arranging basic units for the number of elements that

appear at the beginning of the time-series data and regarding their output as the upper-layer time-series data.

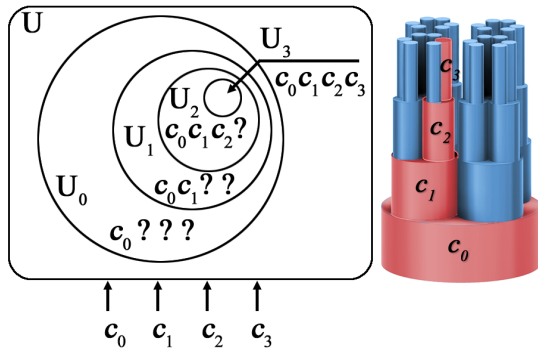


Figure 4. Operation diagram and image of Basic Unit

3. Conclusions

The neural network not only controls the current input/output movement as the hierarchy is added to the upper level, but also stores the history as longer time series data. The context of time series data is represented by a tree-structured graph.

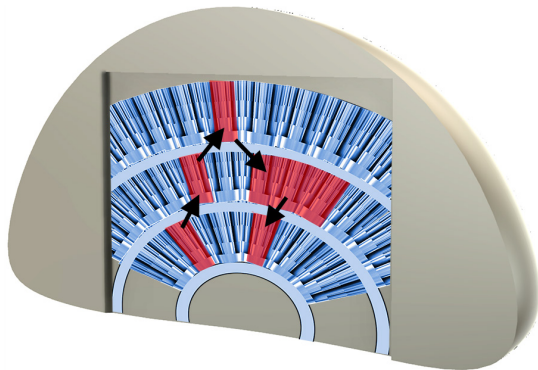


Figure 5. State changing of Basic Units arranged in hierarchical

While the time series data are processing, the activity of the Basic Unit changes along the tree. The next possible states of the Basic Unit located on the leaves of the tree that is connected to the sensory and motor organs follow the tree toward the root, calculate the state of the next activated Basic Unit according to the context. It is obtained by reverse transmission in the tree. In other words, the optimal policy to be taken can be obtained from the calculation by determining in which context the current situation is in the stored time series data. The next evolution of animal intelligence seems to be the acquisition of imitation and symbolization functions^{[4],[5]}. The former leads to sociality in a group, and the latter leads to the acquisition of language as a means of communicating information. I hope that this paper will serve as a basis for treating these themes as mathematical objects^[6].

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ARTICLE

Design and Realization of Automatic Warehouse Based on S7-1500PLC

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ABSTRACT

In order to improve the efficiency of automatic warehouse control system, the experimental platform of stereoscopic warehouse with s7-1500plc is designed. The manipulator is driven by stepper motor and servo motor to realize x, y and Z three-axis space motion. The material transmission system is built by general-purpose G120 inverter. HMI KTP700 realizes control and status monitoring. The materials are identified and classified by RFID sensor and other sensors. TIAV15 software build PROFINET communication and PROFIBUS communication network. Using the GRAPH language programming can improve the visualization degree of application and solve the complex problems of program design and debugging of the warehouse control system. Through the design of hardware and software, a set of complete control system design scheme is formed, which has high practical value and provides an excellent teaching and experiment platform for the intelligent storage system.

1. Introduction

With the rapid development of the logistics industry and the popularization of automated production lines, the production cycle of products has been greatly shortened. Traditional warehouses can no longer meet the requirements. Intelligent warehousing systems can effectively coordinate the production process to achieve accurate and efficient handling and storage of items, which is smart manufacturing.^[1]

RFID is an automatic identification system, which can identify the target and collect data through the non-contact RF signal of the electronic tag. It can support fast reading and writing, non visual identification, mobile identification, multi-target identification, and has the function of encrypted communication. RFID has great advantages because of its high data transmission rate and long-distance reading. It can adapt to the harsh industrial environment

and is widely used in logistics, production, retail, transportation and other industries. It has gradually become an indispensable technical means for enterprises to improve the level of material supply chain management, reduce costs and realize enterprise management informatization^[2].

In this paper, based on s7-1500 PLC, according to the characteristics of automated warehouse, the system hardware and software design is completed. In the hardware design, the reasonable selection of PLC, inverter and so on, draws the corresponding hardware connection diagram and wiring diagram. In the software design, a complete set of stereoscopic warehouse control system is designed, and the program is designed to improve the storage efficiency of the warehouse.

2. Hardware Design of the System

The automatic warehouse system is composed of

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control management unit, material transmission unit and classified storage unit. The system structure is shown in Figure 1.

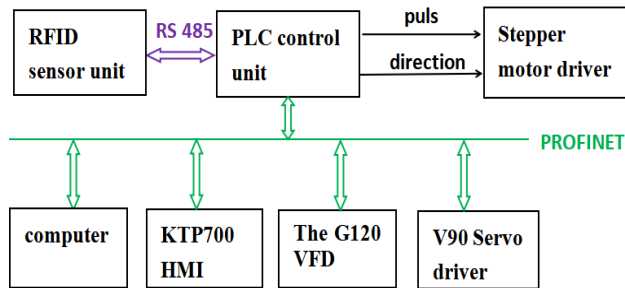


Figure 1. system composition diagram

2.1 Control Management Unit

The control system is controlled by PLC, because PLC has good anti-interference ability, stability and communication ability. The programming system is simple and intuitive, which provides a guarantee for the realization of three-dimensional warehouse. The system selects Siemens 1500 series PLC, the model is 1516-3PN / DP, the advantages of this model are: PLC integration has three PN interfaces, a DP interface, can be directly inserted into the communication cable to achieve PROFINET and PROFIBUS communication, do not need to build external communication module. By carrying the process module TM PTO4 with four-channel high-speed pulses, the stepper motor can be controlled; the GRAPH language inside the 1500 series PLC makes the programming of process control more intuitive and convenient for monitoring and debugging. Profinet communication can realize real-time data interaction and interconnection with the Internet. The system network is simple, compatible and extensible. It can use shielded industrial Ethernet cable improves the stability of the system. The communication between S7-1500 and the RFID sensor adopts the RS485-based PROFIBUS DP protocol, which has good system stability and strong expansion capability. It can read and write electronic tags through the industrial identification instructions in Siemens S7-1500.

The man-machine interface selects KTP700 Basic, 7-inch touch screen, 1×PROFINET interface, 1×USB interface, to meet the control and monitoring requirements of the system. The operator sends commands through the touch screen and sends it to the PLC. The PLC reads the position information of the servo and stepper motors through the sensor signal and sends it to the touch screen. It can display the current position and movement status of the handling manipulator, and read the color attributes of the current material, etc.



Figure 2. 1516-3pn / DP series PLC

2.2 Material Transfer Unit

The material conveying unit uses a squirrel-cage three-phase asynchronous motor to drive the conveyor belt, and the Siemens G120 series inverter is used to control the high and low speed operation of the material conveying motor, which can realize accurate parking, and has high safety during operation, and can achieve long distances. Distance control, with strong communication function. The three-phase asynchronous motor of the conveyor belt is directly connected to the G120 inverter, where R. S. T are connected to the three-phase power supply, PE is grounded, U. V. and W are connected to the three-phase input of the motor, and the inverter is connected to the CPU of the PLC through PROFINET. The CPU controls the speed of the conveyor motor by sending the control word of the inverter, and reads the speed of the motor by receiving the status word.

2.3 Handling and Storage Unit

2.3.1 Composition of Handling Storage Unit

The handling and storage unit is composed of three-dimensional shelves and three degree of freedom manipulator, which realizes the handling and classification of materials. The shelves are designed as two 90° three-layer shelves. Each layer stores the same material and the same color of materials, realizing the storage of materials in and out of the warehouse. The manipulator can realize the spatial movement of X, y and Z axes, in which the movement of X and Y axes is controlled by stepper motor, and the movement of Z axis is controlled by servo motor. The three axes drive the worktable to do three-dimensional movement on the guide rail by using the lead screw, and the clamping part is pneumatic manipulator, so as to realize the storage and delivery of products. A color sensor and an RFID sensor are installed on the upper end of the

manipulator to identify the material information. RFID system consists of PROFIBUS communication module asm456, electronic tag, reader and antenna.^[3] In order to improve the reliability of RFID reading information in metal shelves, the most commonly used method is to paste a layer of magnetic absorbing material behind the RFID tag. The high-frequency anti-metal tag is selected, which is an electronic tag packaged with anti-magnetic absorbing material. The warehouse design is based on the storage and delivery of the production process, and realizes the transportation of materials from shelf 1 to shelf 2. The middle part is the transportation mechanism, and the status of shelf 1 and shelf 2 can be observed on the outside of the warehouse. The 3D concept photo and real photo are shown in Figure 3.

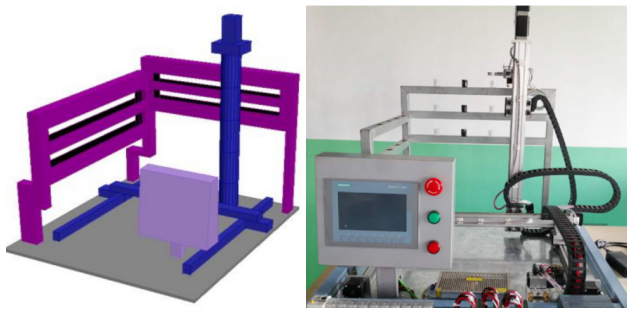


Figure 3. The 3D concept photos and real photos

2.3.2 Handling Mechanism Wiring

The 1500 series PLC does not have its own high-speed pulse port, it needs to configure the pulse / direction interface process module tmpt04. With this process module, at most four stepper motor shafts can be connected for a s7-1500 system. The module is connected to the process object through profidrive frame 3, and forms the driver interface. The pulse / direction interface consists of two signals, in which the frequency of pulse (P) output represents the speed and the number of pulses output represents the travel distance. The direction (d) output is used to define the direction of travel. The wiring diagram of process module and step driver is shown in Figure 4 and Figure 5.

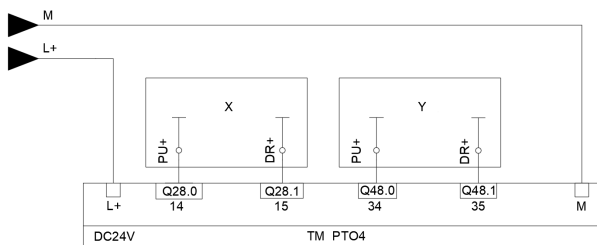


Figure 4. Module TM pto4 wiring diagram

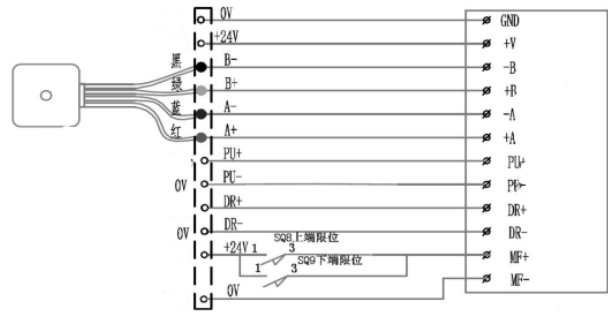


Figure 5. wiring diagram of stepping driver

The servo driver V90 communicates with s7-1500 through profinet.

SINAMICS-V90-PN is configured in TIA V15 software to configure the address range of message and input address I and Q. The SINAMICS-V90 wiring is shown in Figure 6.

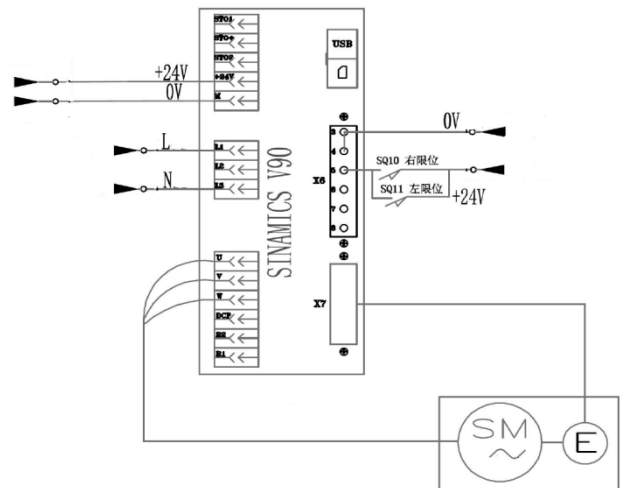


Figure 6. Wiring diagram of SINAMICS-V90 servo drive

3. Design of Control System of Stereoscopic Warehouse

According to the functions of automated warehouse, there are mainly the following aspects: communication function; action control: horizontal and vertical movement. Position control: positioning in the reclaiming position, storage position, etc. ; Speed control ;human machine interface.

3.1 PLC Control System Configuration

The control system consists of profinet communication and RS485 bus protocol communication. S7-1500plc communicates with inverter, servo driver and touch screen through profinet. 485 communication protocol is used

with RFID sensor. It is linked with RFID reader through profibus communication module asm456. Through TIA software v15.1, the configuration diagram is shown in Figure 7.

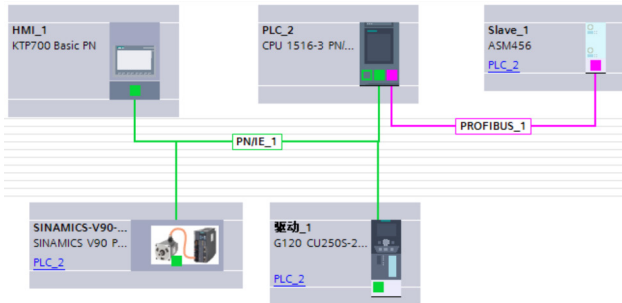


Figure 7. the configuration diagram

3.2 PLC Program Design

3.2.1 Program Flow Chart

The work flow chart of stereoscopic warehouse system is shown in the Figure 8. Using graph language in s7-1500 to write the sequence control program according to the flow chart can directly reflect the working process of the system. The graphical programming interface facilitates the debugging of the program and improves the programming efficiency and accuracy^[4].

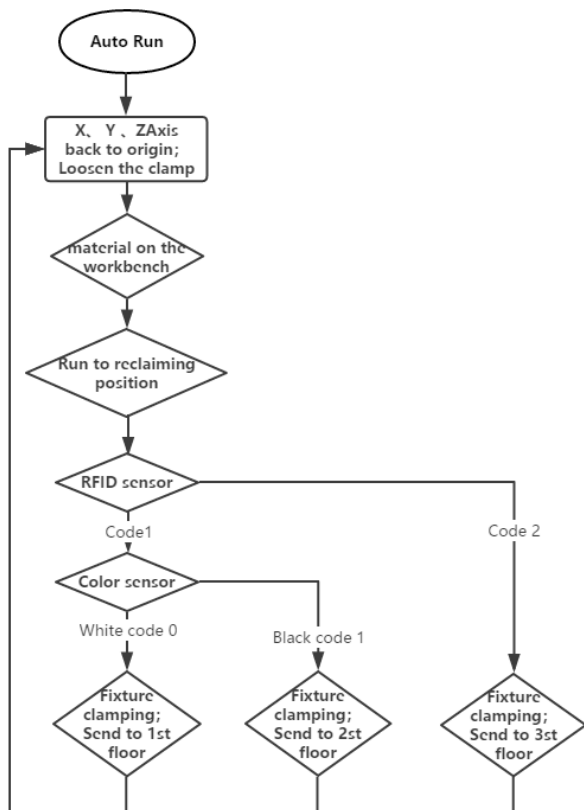


Figure 8. Auto mode program flow chart

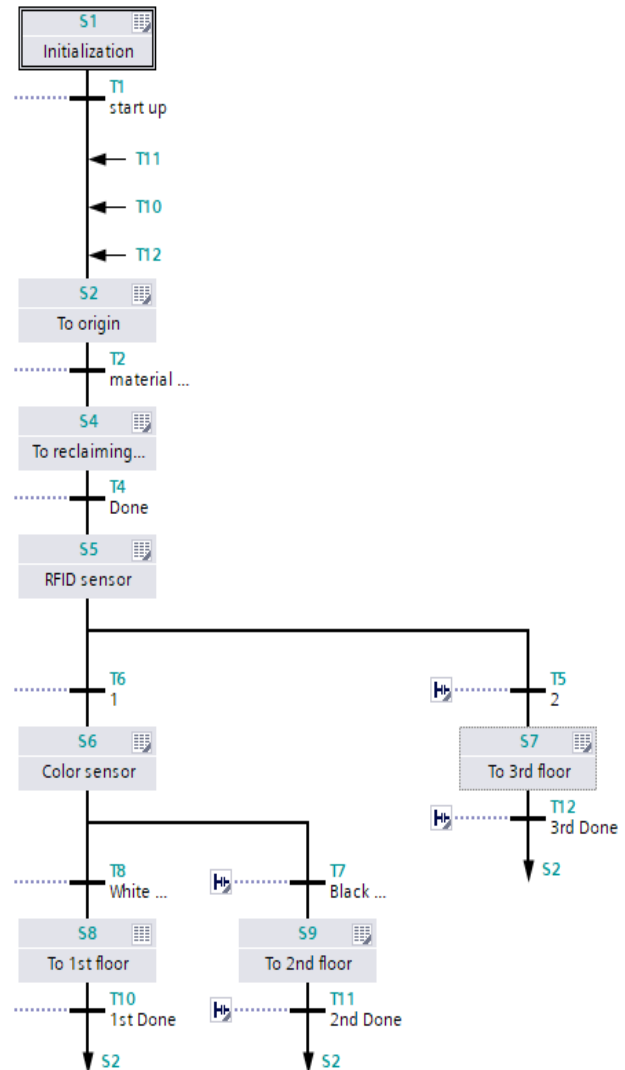


Figure 9. Auto mode GRAPH program

3.2.2 Program Design

Take sending materials to the first floor of the warehouse as an example to analyze the program. Create a new FC block named sent to the first floor, and program in the block. After writing, you can drag FC blocks into step S8, S9, S7. The FC block can be called twice or three times to reduce the workload of programming. This paper introduces the functions of some programs in FC block, using the motion control instruction "MC". The axis can be moved to an absolute position, the position relative to the origin is defined by the parameter "position", and the dynamic behavior of motion control is defined by "velocity", "jerk", "acceleration" and "deceleration". The X axis determines position control program is shown in the Figure 10.

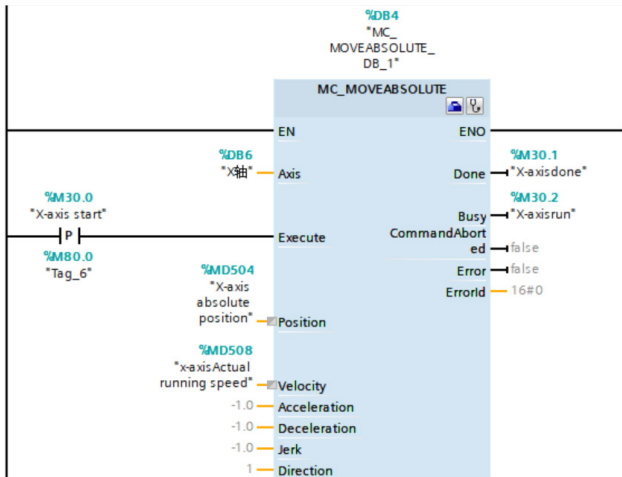


Figure 10. X axis determines position control program

Because the space between rows and columns of the three-dimensional shelf is fixed, after determining the spatial coordinates of the first row, the subsequent position can be determined by using the automatic address recognition algorithm to determine the coordinates of other rows and columns. Take the first action of putting materials into the stereoscopic warehouse as an example. The z-axis coordinate and y-axis coordinate have been fixed. Only the x-axis coordinate changes according to the different bin level. The x-axis coordinate of each bin level is:

$$L_x = X_1 + (N_x - 1) L_1$$

X_1 represents the x-axis coordinates of the first bin in the first row, N_x represents the bin number, and L_1 represents the x-axis spacing of each bin. The positioning method of Z-axis and y-axis is the same.

In order to improve the operation efficiency of three-dimensional warehouse, due to the different positions of different bin material level from the reclaiming point, if the fixed speed is used, the storage and delivery time of the distant bin material level is longer, which leads to the low efficiency of storage. Through experiments, the storage and delivery time of each bin is set as 5S, the maximum speed V_{max} and the minimum speed V_{min} are set, and the absolute position coordinate is divided by the operation time. If the speed is within the effective range, it means that the speed value is effective [5]. The X axis speed setting program is shown in the Figure 11.

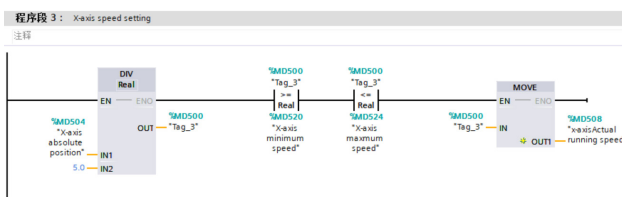


Figure 11. The X axis speed setting program

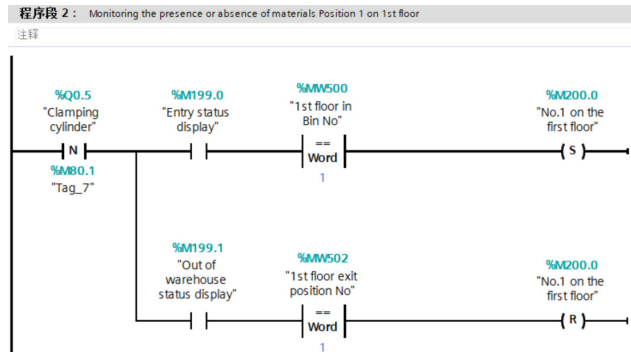


Figure 12. Monitoring the presence or absence of materials on Position 1on 1st floor

3.4 HMI Design

According to the system control requirements, the automatic and manual control interface is developed. The screen can realize the system start, stop and other functions. At the same time, it can monitor the real-time position and speed of the manipulator, and display the material number, color and storage status. The manual operation interface is shown in the Figure 13, and the automatic operation interface is shown in the Figure 14.

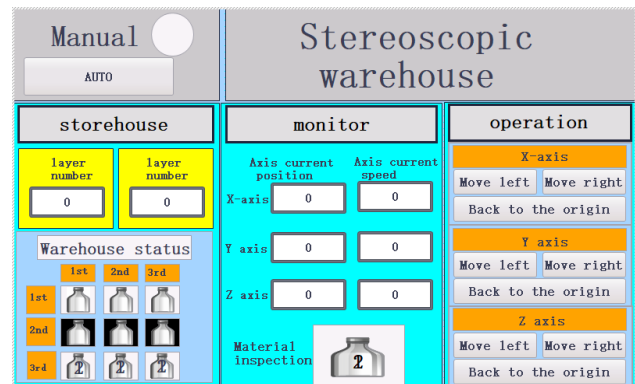


Figure 13. manual operation interface

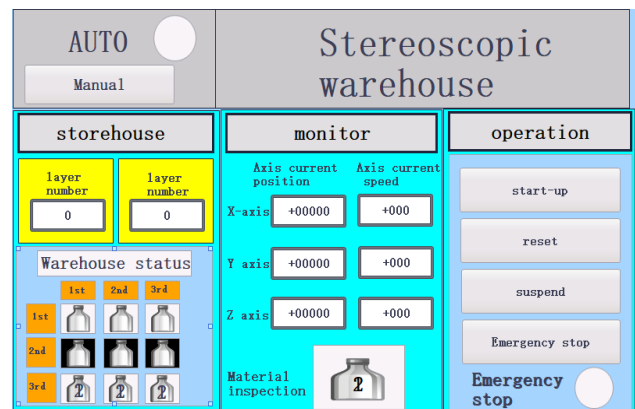


Figure 14. automatic operation interface

Not only need to pay attention to the safety of PLC and

host computer software, the safety of HMI should also be valued. Once the attacker has successfully compromised the HMI device, he can read or even maliciously modify the data variables in the industrial field. Use a password to restrict access to the HMI local setup menu. Uploading or downloading new projects to the HMI can be protected by a password, and the data stored in the HMI can be retrieved. Access from connected devices (eg PC, PLC) is also password protected. KTP700HMI has two Ethernet ports. These ports provide physical isolation between the local network and the Web.

4. Conclusions

The test of the three-dimensional warehouse can meet the design requirements. Based on S7-1500, this article uses frequency conversion technology and stepping servo drive control to realize the three-dimensional warehouse control system. The hardware selection, network construction and program design of the automated three-dimensional warehouse have been completed, and materials can be sorted and stored according to their numbers and

colors. The operation mode is efficient, and the control accuracy is high, which is convenient for maintenance and expansion.

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ARTICLE

A New Model for Automatic Text Classification

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ABSTRACT

In this paper, a new method for automatic classification of texts is presented. This system includes two phases; text processing and text categorization. In the first phase, various indexing criteria such as bigram, trigram and quad-gram are presented to extract the properties. Then, in the second phase, the W-SMO machine learning algorithm is used to train the system. In order to evaluate and compare the results of the two criteria of accuracy and readability, Macro-F1 and Micro-F1 have been calculated for different indexing methods. The results of experiments performed on 7676 standard text documents of Reuters showed that the best performance is related to w-smo bigram criteria with accuracy of 95.17 micro and 79.86 macro. Also, the results indicated that our proposed method has the best performance compared to the W-j48, Naïve Bayes, K-NN and Decision Tree algorithms.

1. Introduction

We live in a world that the information has much value for us. With increasing the amount of information available on Internet, the tools are needed very much to help searching, filtering and managing the resources.

Text classification is referred to the thematic indexing practice of natural language texts based on a predetermined set. Now, text classification is applied to many of the fields from text indexing based on a controlled dictionary to text filtering, automatic production of the meta-data, word sense disambiguation, production of hierarchical catalogues of web resources and generally in any application requiring documentation organization or special selective and comparative distribution of documentation ^[1]. The other applications of text classification may be included the automatic systems

of responding to the questions, information filtering, identifying the data themes, worthlessness of electronic mails, identifying the title and the other related fields ^[2]. The main challenge of documents classification is the bigness of the features space in this type of matters. In many of the present algorithms such this one, a large space causes that the classifier becomes much slow and inefficient. Moreover, there are the features that not only cause no better documents classification but also lower the precision of classification ^[3].

A text may not be interpreted directly by a classifier or a classifier algorithm but using an indexing process it is mapped to an array that its contents are stated by the dimensions. This practice helps to provide the necessary consistency and homogeneity for the texts of training and trial set sand validation ^[1].

In this paper, for automatic text classification three in-

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dexing methods including “bigram, trigram and qudgram” are used and machine learning algorithm W – SMO also utilized. The results show that the best method of text indexing is bigram. To classify the text, the 7676 - paper dataset of Reuters news agency has been used. This dataset has been collected titled as Reuters – 21578 that the constructing method and statistical information of this dataset explained in [4].

Of the selected documents regarding their contents classified in 8 groups, 70% have been considered as learning sets and 30% of documents placed in the test set on which the automatic classification is performed.

The rest of the paper is organized as the following. In the second section a review of text classification is given. Then in the third section the details of proposed method studied completely and finally in the fourth section the results and evaluation of proposed method given.

2. Review of Text Classification

With respect to the extension of electronic text information size being available through Internet and the other resources if no suitable indexing and classification is present, the practice of retaining and processing unclassified text information will be exposed to many problems. Text classification has lots of applications including documents pursuit, document management, document extension and lowered information size. A lot of machine learning methods have been used about text classification during the recent years including neural networks [5], K – nearest neighbor (K – NN) [6], Naïve Bayes networks [7], and decision tree [8] that each of these methods has different calculations and precision.

In [9], text classification in Turkish language using n – gram has been studied. In this research using unigram, bigram, trigram and qudgram, the text has been classified.

The tests in this paper have been conducted on 600 documents allocated to six sets and the efficiency of this research reported 95/83%. In [10], text classification has been given using an integrated algorithm that is composed of SVM and K – NN algorithms. The results of this research performed on dataset of Reuters news agency show that at the best state the efficiency of this integrated method is 81/48% and at the worst state 54/55%.

3. Phases of Proposed Method

In Figure 1, the general phases of the proposed method have been shown that in the following each of the phases described and the obtained results explained.

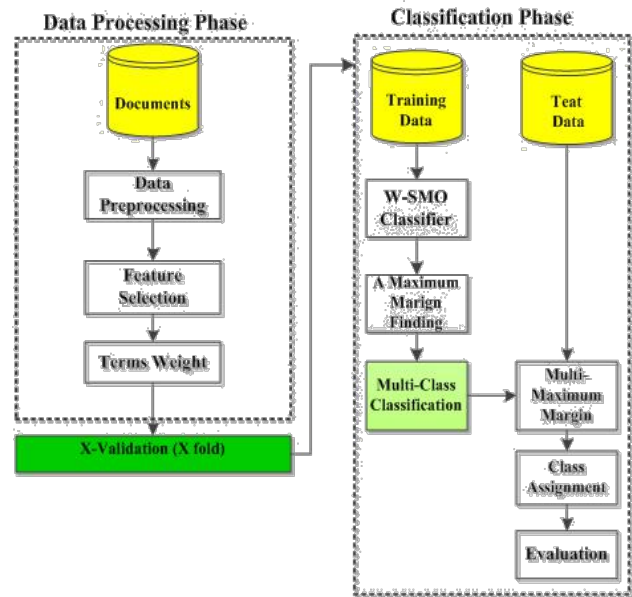


Figure 1. Proposed method for text classification

3.1 Data Processing Phase

A set of operations resulted in producing a set of refined data in order to achieve suitable features of text is namely called text processing. This operation includes the phases of text preparation, documentation indexing and indices weighting described in the following.

The phase of text preparation

In the phase of text preparation, the text including sequential characters is changed to a display suitable for learning algorithms and classification.

This phase in our proposed method is usually included the following cases:

- Obtaining the word root
- Omitting prefixes and suffixes
- Omitting Stop Words and writing symbols

Indexing phase

In this phase, a d_j text is shown by a vector of its phrases weight. In other words, $d_j = \langle w_{1j}, w_{2j}, \dots, w_{|T|j} \rangle$ where T is the set of phrases brought at least once over the throughout training set (sometimes also called features) and $0 \leq w_{kj} \leq 1$. The difference of approach is usually due to one of the following reasons in this case:

- Different definitions of a thing named “ phrase “.
- Different ways of calculating the weight of terms.

In this paper, text indexing method has been used as simple words and N – gram (qudgram, trigram, bigram) method that N - gram method explained in the following.

N – gram method

In this method, indexing is as sequential from N letters successively. A word of text as a set of N – grams overlapping each other has been shown ^[11]. For example, word “TEXT” is composed of the following N – grams:

Bigram : _T, TE, EX, XT, T_

Trigram : _TE, TEX, EXT, XT_, T__

Quadgram : _TEX, TEXT, EXT_, XT__, T___

Where “_” is an indicator of distance. The advantage of N – gram is its nature. Since any strain is composed of a few words, the errors are not dispersed and effect on a few numbers s of strains.

Weighting phase

To weight the features, different approaches may be utilized. The simplest of this weighting state may be done as binary.

Another selection of weighting on each word is with respect to the number of repeating each word. But, one of the suitable and considerable techniques is to use *tf-idf*^[15]. is the frequency product of each word at inverse of document frequency usually defined as the following:

$$tf-idf(t_k, d_j) = tf(t_k, d_j) \times \log \frac{|N|}{N(t_k)} \quad (1)$$

Where: N is the candidate of the total number of documents, t_k is the number of documents from training set in which the word t_k has occurred at least once $tf(t_k, d_j)$ indicates to the number of replications of kth word at j^{th} document. Therefore, more occurrence of a word is effective in its increased weight if it has not been replicated in all of the other texts. Regarding that this method is reflexive and its other dimensions have been used in many practices and its good efficiency approved on different datasets, this reflective method selected in this paper.

3.2 Classification Phase

This phase includes two learning and test phases that each of them are described in the following.

Learning phase: Automatic text classification algorithm

In this paper, W – SMO algorithm ^[12,13] has been applied. Using support vector machine algorithms in text classification problems is a new approach attracted much attention within the recent years. In learning phase, W – SMO approach tries to select the margin of decision such a way that it maximizes its least distance with any of desired sets. This type of selection causes that our decision tolerates noise conditions in practice well and also responds appropriately. This type of mar-

gin selection is done based on the points named support vectors.

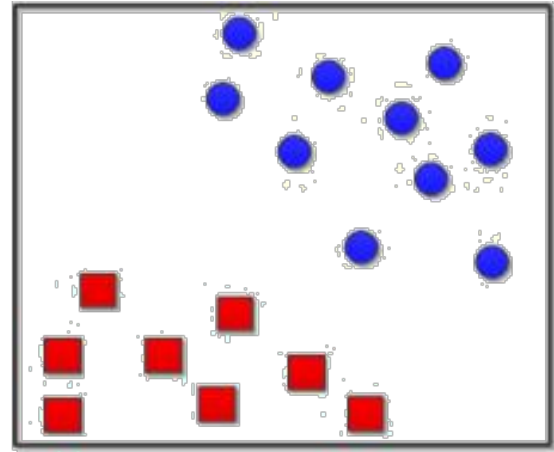


Figure 2. The set of points related to two sets

Figure 2 shows the set of records related to two sets in a problem of binary classification. Respecting this figure, it is identified that there is the possibility of separating these two sets using various linear classification. Now, suppose that we have two lines b_1 and b_2 drawn in Figure 3. The aim is to find the best line among these two drawn lines. The best line is simply recognizable using the algorithm of support vector machines.

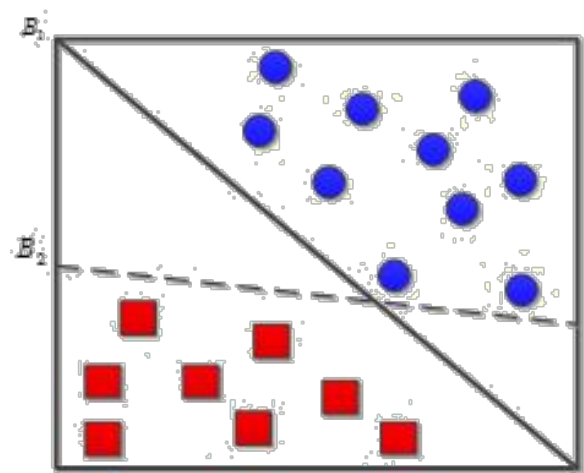


Figure 3. Classification lines of the sample

The algorithms based on support vector machines are algorithms trying to maximize a margin. These algorithms, to find the line of separating the sets, begin from two parallel lines and move these lines in opposite direction of each other until each of the lines reaches a sample of a special set at its side. After doing this phase, a band or margin is formed between two parallel lines. Whatever the width of this band is more, it means that the algorithm could maximize the margin and the aim is also at maximizing this margin. In fact, our aim is at selecting the

most possible value for this margin. In the center of image margin, the line separating the sets, that is, central line is placed. Now, among the lines drawn the algorithm selects a line with the maximum side margin as the separator of the sets. The margin related to two lines b_1 and b_2 is shown in Figure 4.

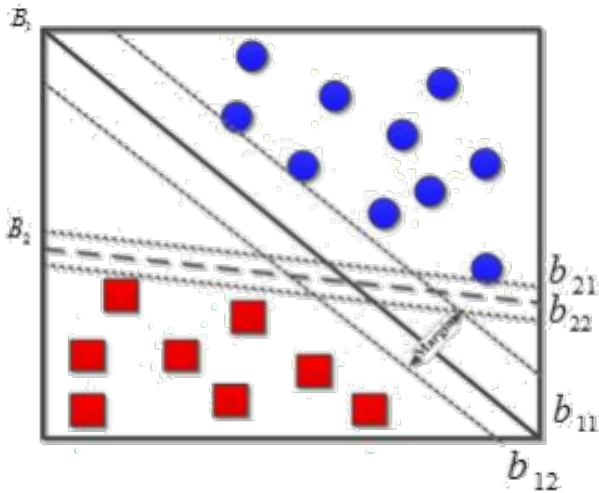


Figure 4. Classification lines margin of the sample

The relation of calculating the margin is as relation (2):

$$\text{Margin} = \frac{2}{\|\vec{w}\|^2} \quad (2)$$

Consequently, after calculating the margin, the algorithm selects B_1 line as a separator line because the side margin of this line is more than that of B_2 . After selecting the separator line, the algorithm calculates a function for calculating the classification of new records based on the equations set of separating line and equations set of parallel line. The equations set of separating line B_1 and equations set of parallel line are shown in Figure 5. In this figure $\vec{w} \times \vec{x}_1 + b = 1$ is the equation of line b_{11} . Consequently, $\vec{w} \times \vec{x}_1 + b \geq 1$ refers to the right side of this line and in fact refers to the zones in which the records from the type of circle set are located on it. When the algorithm reaches the relation $\vec{w} \times \vec{x}_1 + b \geq 1$ after placing the values of the new record features in function, it will return the value of 1 meaning that the new record is related to the circle set. In Figure 5, $\vec{w} \times \vec{x}_1 + b = -1$ is the line equation of b_{12} . Consequently, $\vec{w} \times \vec{x}_1 + b \leq -1$ refers to the left side of this line and in fact refers to the zones on which the records from the type of square set are located on it. When the algorithm reaches the relation $\vec{w} \times \vec{x}_1 + b \leq -1$ after placing the values of new record features in function, it will return the value of -1 meaning that the new records belong to the square set.

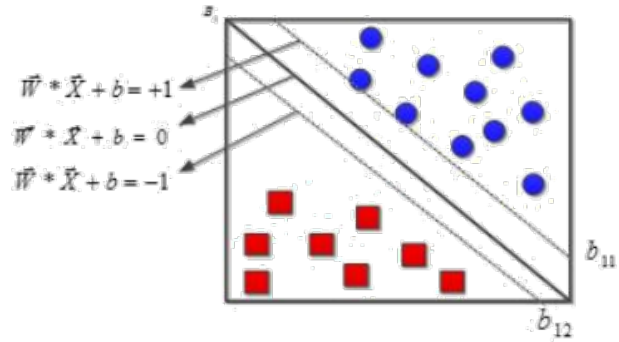


Figure 5. Minimizing margin of classifier line in support vector machine

In this section, at first the data set applied to test the classifier and learning are defined and then the implementation details are given.

3.3 Data Set

The documents used as the dataset have been collected from Reuters news agency. The dataset includes 7676 text documents with different sizes classified into 8 classes. Each document is labeled based on the contents and zones in which it found and placed in an individual file describing a set or a set collection marked by a label. Table 1 shows a list of the dataset from Reuters news agency for test phase.

To separate the test and training collections, X – validation has been used. The number of subsets for this practice is 5 and number of documents has been divided into 5 equal subsets. Each time, one subset has been regarded as the test set and the other four subsets as learning set. Finally, the mean of obtained results has been calculated.

Table 1. Document's list of test phase for data set Reuters – 21578

Sets	Trial phase	Test set	Sum
Acq	1596	696	2292
Trade	251	75	326
Ship	108	36	144
Interest	190	81	271
Grain	41	10	51
Crude	253	121	374
Earn	2841	1083	3924
Money-fx	206	87	293

3.4 Evaluation Criteria

In problems of text classification, recall, precision and F1 criterion are usually used as following formulas:

$$\text{Recall} = \frac{TP}{TP + FN} \quad (3)$$

$$\text{Precision} = \frac{TP}{TP + FP} \quad (4)$$

$$F1 = 2 \times \frac{\text{Recall} \times \text{Precision}}{\text{Recall} + \text{Precision}} \quad (5)$$

TP: Number of texts truly attributed to a class.

FN: Number of texts wrongly attributed to a class.

FP: Number of texts wrongly rejected from a class.

At last, to evaluate the efficiency on the total classes, mean taking method has been used. In macro mean- taking, the precision and recall rates of total classes are calculated. In this method, the total classes are given equal weight.

After obtaining the precision, recall and F1 for each set, two methods are applied to calculate the mean of these criteria ^[14]. In formulas (6) and (7), macro-precision is shown by π^M and micro-precision π^μ .

$$\pi^M = \frac{\sum_{i=1}^{|c|} \pi_i}{|c|} \quad (6)$$

$$\pi^\mu = \frac{\sum_{i=1}^{|c|} TP_i}{\sum_{i=1}^{|c|} (TP_i + FP_i)} \quad (7)$$

At each of two above formulas, $|c|$ means the number of sets that is 8 in our trial.

4. Results and Evaluation

To evaluate the proposed method, Rapid Miner simulator software and a system with Intel processor 2,3GHZ, memory 4GB and operation system 7 have been used. In this paper, to automatic classification of the texts three indexing methods bigram, trigram and qudgram and also machine learning algorithm W – SMO have been applied. To classify the texts, 7676 text documents from Reuters news agency have been used. This dataset has been collected titled as Reuters – 21578. Of the selected documents regarding their contents classified in 8 sets, 70% have been considered as learning sets and 30% of documents placed in the test set on which the automatic classification is performed.

The results of evaluating classifier using indexing methods are shown in Figure 6 in which bigram indexing method from two criteria of Micro – F1 & Macro – F1 has a better efficiency to the methods of trigram and qudgram.

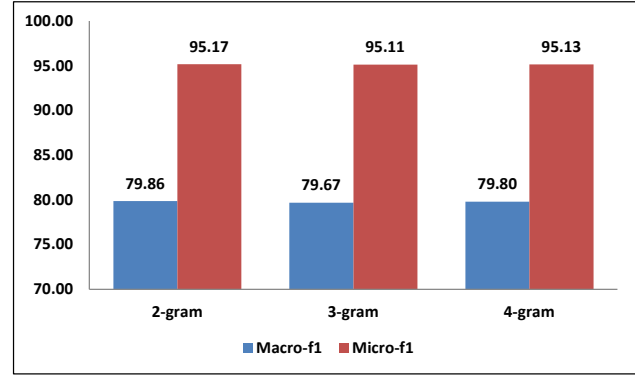


Figure 6. Obtained results for indexing methods

In addition, for each one of the news set the precision and recall criteria have been evaluated and obtained results in Table 2 show that the best efficiency of proposed algorithm is related to Earn set with precision 98.73% and recall 99.26%.

Table 2. Details of proposed algorithm results for each set

Set	Precision	Recall
Acq	94.06%	96.26%
Trade	92.31%	90.67%
Ship	70.00%	61.11%
Interest	87.43%	82.72%
Grain	56.52%	40.00%
Crude	93.42%	88.43%
Earn	98.73%	99.26%
Money-fx	83.94%	80.64%

Also, we have evaluated our proposed method with machine learning algorithm like W – j48, Naïve Bayes, K – NN, Decision Tree that the results of this evaluation shown in Figure 7. The results show that classification efficiency using W – SMO and bigram combination is more than that the other combinations. The precision of classification reaches 95.17% of Micro – F1 precision at the best state and 79.86% of Macro – F1 precision.

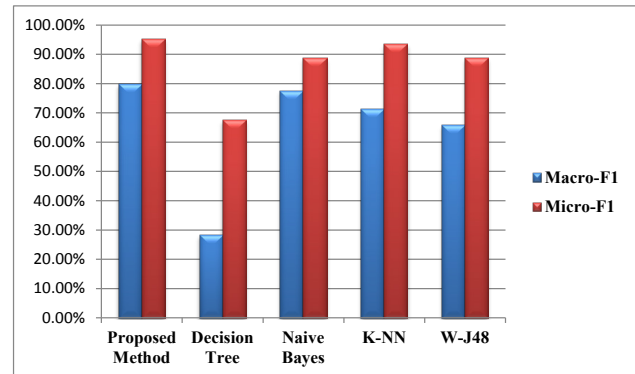


Figure 7. Obtained results based on two criteria Micro – F1 & Macro – F1 of our proposed method with W – j48 , Naïve Bayes , K – NN , Decision Tree methods

5. Conclusions

In this paper, a method has been presented for automatic text classification. This method has been evaluated with the standard dataset of Reuters news agency including 7676 documents classified within 8 different sets. Using different tests performed on indexing methods, combination of bigram method and learning algorithm W – SMO had the best efficiency. In addition, our proposed method was evaluated with machine learning algorithm W – j48, Naïve Bayes, K – NN, Decision Tree. The results of evaluation showed that our proposed method for this dataset has the best efficiency to these algorithms. Finally, our proposed method reached Micro – F1 & Macro – F1 criteria to 79.86%, 95.17% for this dataset, respectively.

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ARTICLE

Communication of Internal Speech with Communicative Associative Robot via Spectral Neurointerface

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ABSTRACT

Thought communications with an associative-communicative robot are carried out through the spectral neurointerface of internal speech. Internal speech is an energy physiological process. Internal speech is vibration from the mental vibration of thought. Mental vibration of thought is a process in the mental ethereal field. The vibrations of thoughts are reflected and observed by the mind in the form of semantic sensual images. Vibrations of semantic sensual images generate vibrations of internal speech action (internal speech) in the form of language communicative and associative stereotypes which are perceived by a touch zone of a brain of Wernicke. Internal speech is a linguistic mental vibration. It is felt and becomes internally audible and drawn to attention. The perception of vibrations of internal speech is carried out through energy channels, such as the internal posterior median canal of the spine. The spectral neurointerface perceives these vibrations. Neocortex makes us a reasonable person - allows us to think and talk. The spectral neurointerface is based on the principles of biosensors, bioenergy detectors, spectral analyzers and electrocorticography for neuroimaging parts of the brain that record vibrations of internal speech, such as the lower frontal gyrus, the upper and middle temporal gyrus, the medial prefrontal cortex, the hind parts of the wedge and preline and the dark temporal region, including the posterior. Internal speech activity is associated with the semantic memory of the neocortex.

1. Introduction

Neurointerface is a system for the exchange of information between the human brain and an electronic device. The brain processes incoming sensory stimuli, for example - sound, smell, taste, controls the life and movements of the body. He is also responsible for thinking, memory, emotions and the like. It is noteworthy that these powerful but exquisitely subtle abilities arise from electrical and chemical interactions between the approximately 100 billion cells of which it consists. Each such interaction is reflected in

the recorded brain activity, and the neurointerface registers this activity in various regions of the brain and transfers it to external device control commands or vice versa transfers external commands to brain electrical activity. A computer with a specialized program always acts as a translator and simultaneously as an information analyzer in the neurointerface. All brains of each person have common anatomical schemes and synoptic interactions, but the exact sample of connections and interactions varies greatly from person to person, so the program should be able to adjust to the pecu-

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liarities of each user's brain. In this case, the program in the computer can process the signal, can be trained, adapting both to the task and to a particular person. For such training, feedback is needed - the program must receive information about whether it correctly interpreted the received signals, whether it "understood" correctly the particular brain with which it works. At the same time, the program can partly manage the patient, orienting him to work with those situations that she recognizes less successfully. We can even say that the brain interface - a computer uses artificial intelligence to recognize the types of brain activity.

Neurointerfaces are unidirectional and bidirectional. The former either receives signals from the brain or sends them to him. The second ones may send and receive signals simultaneously. Neurointerfaces differ in type:

- invasive, sensors are placed directly in the cerebral cortex.
- non-invasive, sensors are placed on the head.

A key feature of the neurointerface is that it allows you to connect to the brain directly. In modern interfaces, brain activity is recorded using electroencephalograms (EEG), magnetoencephalograms (MEG), near infrared spectroscopy (NIRS). MEG allows the measurement of weak magnetic fields generated by ion currents in brain neurons. Superconducting quantum interferometers, or SQUID sensors, are used to detect very weak magnetic fields. Recently, near-infrared spectroscopy (NIRS) has been increasingly used to record brain activity. This is a small device in the form of a hat that is worn on the head. Infrared radiation penetrates through the bones of the skull and adjacent tissues into the frontal and occipital cortex of the brain and allows you to evaluate the oxidation state of hemoglobin, that is, the brain's oxygen consumption. Here, unlike EEG and MEG, a signal of optical nature is recorded - absorption of infrared radiation for recording in the motor and prefrontal cortex signals generated by mental score and logical tasks, musical and visual images.

Now the technical problem is measurement accuracy. In non-invasive neurointerfaces - the skull, skin and other layers separating nerve cells from electrodes distort information about the signal. In order to translate electrical activity into understandable commands, the program must be able to: separate the signals it needs and clear them from background noises, adjust to the features of the human brain and translate any information with high accuracy. The brain circuitry is too complex for our analytical and computational capabilities, so at the moment high accuracy is too difficult.

The operation of the interface is based on the analysis of information coming from the patient through four channels. These are the electrical pulses of neurons, their magnetic activity, the flow rate of blood inside the vessels and the

change in metabolism.

Many neurointerfaces can be divided into three groups: active, reactive and passive interfaces. The active interface uses changes in brain activity, which is directly and consciously controlled by humans. The reactive interface generates control commands by studying the brain's response to an external signal, such as light or sound. The passive interface analyzes the current activity of the brain, which occurs on its own, in the process of human life. Such interfaces can be useful for creating monitoring systems that monitor the emotional state, detect a decrease in concentration, or a loss of control over the system.

If the neurocomputer interface is connected, for example, with augmented reality glasses, then a person will be able to look at the lighting in the room, switch TV channels and even communicate with a doctor. One of the capabilities of the neurocomputer interface is the transmission of visual information to the brain. Thanks to this, a person can print using a look - however, not very quickly. One of the most famous non-invasive interfaces of this type, it is called R300 speller, allows its owner to dial five characters per minute, the information transfer rate is about 0.5 bits per second. Tianjin University employee Wei Xiwen at the World Robot Conference in China set a record for the speed of typing using neurointerface. Syven's neurointerface spent 0.413 seconds to determine the desired English letter with 100% accuracy. A group of Chinese and American researchers led by Xiaogan Chen of Tsinghua University have developed a non-invasive neurocomputer interface that allows a person to print a look at a rate of 50 to 60 characters per minute.

An international group of scientists has created a system based on functional spectroscopy in the near infrared region, which allows people with "locked man" syndrome to answer yes or no to a question asked. The Australian company Emotiv develops electronics for neurointerfaces based on EEG. In 2017, American scientists in their study used one of the company's products - the EPOC + helmet, which recognizes waves of electrical brain activity and determines the emotional state of a person.

In 2020, engineers at St. Petersburg Polytechnic University developed Russia's first platform for creating neurotrainers and neurointerfaces, which includes a headset that measures brain activity signals and will allow users to learn how to develop robot control systems using brain signals.

Laboratory of Neurophysiology and Neurointerfaces of Lomonosov Moscow State University. The Neurochat technology is based on the achievements of its employees, which allows people with disabilities to communicate normally with each other and with the world in general.

According to the creators, "the headset registers the neurophysiological indicators of the patient and transforms his mental efforts into certain commands for the keyboard of the computer or other actuators. By translating a mental choice of a character into a real set of these characters on the screen, a person letter by letter can type text without the effort of voice and movement. In February of this year, Neurochat was first used in a transcontinental communication session between patients with severe speech and movement disorders. Moreover, each of them "spoke" in his own language, and the neurointerface translated messages to the interlocutor into his native language.

Ideally, neurointerfaces guide the control of the technique by the power of thought. Neurophysiologists and engineers have not yet been able to read thoughts. Not a single device is yet capable of reading human thoughts. The hope that technology will reach such heights is facilitated by the fact that more projects, developments, scientific research in this area, research groups and commercial companies, including large ones that are engaged in the development and development of neurointerfaces, are emerging. There are more than a hundred research groups alone. The largest companies in this area are Neuralink, Mind Technologies, Covidien, Compumedics, Natus Medical, Nihon Kohden, Integra Life Sciences, CAS Medical Systems and Advanced Brain Monitoring. Even large firms such as Nissan and Facebook have long announced their intentions to create neurointerfaces.

Elon Musk created Neuralink, with the goal of developing a neurointerface that will allow people to communicate telepathically. In April 2021, Ilona Mask's neurotechnological startup Neuralink published a video with a macaque that plays ping pong on a computer, controlling a virtual racket with the power of thought. Chips were also injected into her brain. According to the developers, using Bluetooth they can be associated with any gadget. First, the monkey was taught to play a video game using a joystick. Her successes were supported by an award in the form of banana puree. At this time, chips recorded macaque brain activity and transmitted data to a computer. There they were processed by a program that learned to recognize the actions of a monkey. After some time, the researchers disconnected the joystick from the computer and watched as the monkey controlled the game with the power of thought, continuing to twist the disconnected controller with his paw. Subsequently, they removed him, and the primate began to play without a single movement of the limbs. Elon Musk said: "We will be able to surpass the power of the human brain by 2030".

Neurointerfaces are used in various spheres of life. The new neuroscience of connecting brains with machines change our lives ^[1]. Neurointerfaces of interaction ^[2]. Hu-

man brain cloud interface ^[3]. High resolution passive speech ^[4]. Technological diagnostics of human condition according to spectral analysis of biofield ^[5]. Implementation of international telemedicine network with rapid coronavirus registration by resonant technology to neutralize the pandemic ^[6]. Neuro - processing for the development of neurointerfaces ^[7]. On-chip tao_x -based non-volatile resistive memory for in vitro neurointerfaces ^[8]. Functional and harmonious self-organization of large intellectual agent ensembles with smart hybrid competencies ^[9].

Neurointerfaces also find use in robot control. The article discusses the control of an associative-communicative robot through the spectral energy interface of internal speech.

2. Aspects of Thinking

The process of cognitive thinking of an individual, characterized by a generalized and mediated reflection of reality. Objects and phenomena of reality have properties and relationships that can be learned directly, through sensations and perceptions. The first feature of thinking is its mediated nature. Directly, he learns what the person can't learn directly indirectly, indirectly: some properties through other, unknown entities through known. Thinking always relies on sensations, perceptions, representations and previously acquired theoretical knowledge. Indirect cognition is mediated cognition. The second feature of thinking is its generality. Generalization as a knowledge of general and essential in reality objects is possible because all the properties of these objects are connected to each other. The general exists and manifests itself only in a separate, specific one. The results of cognitive activity of people are recorded in the form of concepts. The concept is a reflection of the essential features of the subject. The concept of a subject arises from research.

Human thinking proceeds in the form of judgments and conclusions. Judgment is a form of thinking that reflects the objects of reality in their connections and relationships. Each judgment is a separate thought of something. The sequential logical connection of several judgments, necessary to solve any mental problem, to understand something, to find the answer to a question, is called reasoning. Reasoning makes practical sense only when it leads to a certain conclusion, conclusion. The conclusion is a conclusion from several judgments, giving us new knowledge about the objects and phenomena of the objective world. Inferences are inductive, deductive and by analogy.

System forms of judgment are analysis and synthesis, comparison, abstraction, concretization, generalization, classification. Thinking acts mainly as a solution to problems, questions, problems that are constantly put forward to people in life. Solving problems should always give a

person something new, new knowledge. The search for solutions is sometimes very difficult, so mental activity, as a rule, is an active activity that requires focused attention and patience. The real process of thought is always a process not only cognitive, but also emotionally strong-willed.

For human thinking, the relationship is more significant not with sensual cognition, but with internal speech and language. In a more rigorous sense, internal speech is a language-mediated communication process. If language is an objective, historically established system of codes and the subject of special science - linguistics, then internal speech is a psychological process of formulating and transmitting thought by means of language. Thinking relies on sensations and perceptions. The transition from feeling to thought is a complex process, which consists, first of all, in the isolation and separation of an object or a sign of it, in distraction from a specific, single one and the establishment of a significant common for many objects. Thinking operates with a sense of knowledge. Thinking, as a mental process, models the laws of the surrounding world based on axiomatic positions, establishes connections between objects or phenomena of the surrounding world, reflects the essential properties of objects, which leads to the appearance of ideas about objective reality. Thinking is characterized by the ability of a person to reason, analyze, compare, generalize and draw conclusions.

When an Englishman or an Indian thinks about the same object, the figurative vibration of thought is the same, caused by the object itself or the pronunciation of its name. For this reason, a mind reader whose brain center is in connection with a person's su center can read a hidden figurative. The thought of whose spoken speech he cannot understand. The figurative mental vibration of thought is the same in all people, and its expression as a mental sound vibration is the same in people who speak the same language. If the mental language vibrations that encircle thought in the form of speech were the same for all people, then the language would be the same.

Consciousness takes a general undifferentiated movement of figurative thought, and continues as a differentiated movement, manifested further in the form of internal speech of the process of thinking. Thinking manifests itself, firstly, as a subject in the subtle form of the mind and its contents, generated by figurative vibrations of thought and, secondly, in the form of linguistic internal speech, as an expression of thought that projects into the world of sensual experience so that they are the source of the impressions of individual experience within it. The mental language vibrations of internal speech are the same for people who speak the same language. This allows you to solve the problem of recognizing the internal speech of any specialist through

the spectral neurointerface.

3. Spectral Neurointerface

Different parts of the brain consisting of neurons are responsible for different physiological functions (Figure 1). Neuronal activity can be traced by electrocorticography.

In the context of neurointerfaces, we will understand them as an external high-tech device connected to our brain and designed to study its abilities, in our case internal speech.

Spectral neurointerface translates brain activity in internal speech into text. Its functioning is based on the work of neural networks with long short-term memory and an open decoder. It is trained and controlled on spectral electrocorticography data obtained from the internal speech of participating professionals. First, the spectral electrocorticogram data obtained when reading the text are taken: the temporal, spatial and frequency characteristics of vibrations are distinguished. The internal speech vibrations are decoded into text using an open deep learning algorithm. The encoder, which recreates the characteristics of the text from the activity of the brain of internal speech, in turn, is based on the work of two bidirectional recurved neural networks with long short-term memory.

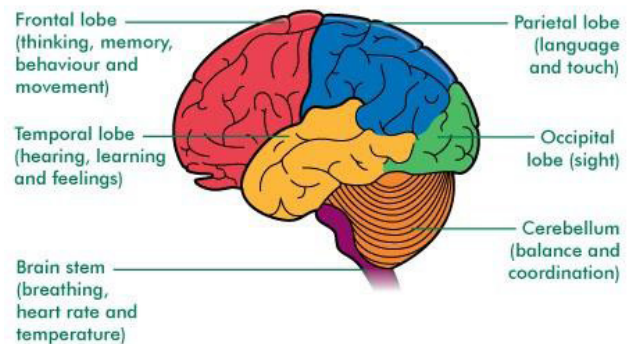


Figure 1. Brain functions.

It is advisable to supply the spectral neurointerface with a regulatory network that allows cleaning the spectral electrocorticogram based on internal speech data of various professionals. This saves the spectral electrocorticogram from artifacts.

Thus, it is possible to achieve high-quality work of the spectral neurointerface in translating the brain activity of internal speech into language speech. At the same time, sufficient performance of the spectral neurointerface is achieved for dialogue in sonorous speech production. Spectral neurointerface can be used for silent people, as well as for telepathic dialogue by internal speech of various spe-

cialists.

Spectral neurointerfaces can be widely used for dialogue and control with communicative associative robots over long distances using high-tech wireless communication means for receiving and transmitting messages.

4. Robot with Communicative Associative Thinking

Mental communication with a communicative associative robot is carried out through its intelligent communicator agent. A team of professionals with different voices communicate with a communicative associative robot using a spectral energy interface. The communicative robot receives the mental language thoughts of each professional by his internal speech through the spectral energy interface.

The system of communicative associative robot of recognition of internal speech vibrations based on syllable resonators automatically converts syllables into words, and words into messages (Figure 2).

A communicative associative robot perceives words by syllables. It has resonated filters for each syllable and recognizers of syllable morphemes by communicative vibration signals by analogy with the auditory snail. The communication robot has a syllable and punctuation decryptor which sequentially puts text codes of the current syllable or punctuation mark from its memory into the common memory and dampens the resonating filter or recognizer of the previous syllable. The communication robot recognizes syllables and punctuation marks by the decoder and through the neural network structure formats the message, in accordance with the sign markup, and transmits it to the control intelligent system of the robot.

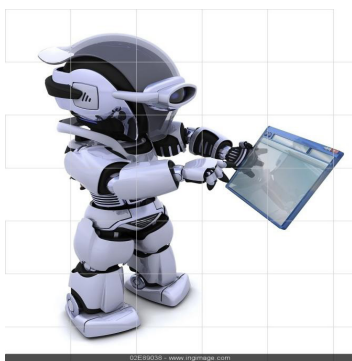


Figure 2. Communicative associative robot

The use of robots with communicative associative technologically intelligent thinking logic through spectral neurointerfaces is in demand in various spheres of life. Cognitive robots with imitative thinking for digital libraries, banks, universities and smart factories^[10]. Robots with artificial intelligence and spectroscopic sight in hi-tech labor

market^[11]. Robots for communication in public in high-tech industry life and space^[12]. System retraining to professional competences of cognitive robots on basis of communicative associative logic of technological thinking^[13]. Increase of safety use robots in industry 4.0 by developing sensitivity and professional behavioral skills^[14]. Robotization of service with goods and products via automatic cabinet^[15].

5. Communicative Associative Logic of Technological Intellectual Thinking

Human thoughts are the essence of reason. The mind knows everything in comparison. He compares heard and written thoughts, opinions and worldviews of other people. If your own thoughts, opinions, images and worldviews coincide with other people, then consent comes. If the mind does not agree with the thoughts, opinions, images and worldviews of other people, then the mind forms its own thoughts, opinions, images and worldviews.

Technological intelligent artificial intelligence can compare thoughts, opinions, images and worldviews according to utility criteria. Technological intelligent artificial intelligence can choose thoughts, opinions, images and worldviews according to the criterion of preference. Technological smart artificial intelligence can detect novelty on the principle of opposite (optimal - not optimal; effective - not effective; dangerous - safe, etc.) method from nasty based on objective conditions.

The semantic basis of communicative associative logic is an essential dictionary of lexical meanings of representatives of reality.

5.1 Entity Dictionary

Let S be a spelling dictionary, where $S = \{Si\}$, Si is a morphological word. The word Si refers to the Qij feature of the Mij representative from the Mi set, where $Mi = \{Mij\}$. Denote the lexical meaning of the word Si via $\{Mij, Qij, Si\}$. The relationship of the lexical values of words $\{Si\}$ with elements of the set Mi is given by the set of feature relations Qi , where $Qi = \{Qij, (Mi, Mij)\}$.

A set of lexical values associated with a set of characteristic relations with representatives is an essential dictionary. Words in the dictionary are supplied with characteristic indexes according to their characteristic relationships with representatives. The entity dictionary captures the characteristic entities of representatives. The dictionary helps to use words with its lexical meaning and distinguish between representatives whom they call on a symbolic level.

Words are used based on characteristic indices. Each feature has three indexes. One index indicates the subject area of knowledge, the second indicates the situation, the third

indicates the situational moment. Words with multiple lexical meanings have multiple sets of indexes. For example, torment (muka) and muka (flour). The word field is used in various subject areas. Each set of indexes defines a lexical word value.

5.2 Information Needs Technology

The information demand implementation system uses a knowledge base and a skill base. The implementation of the information demand is taken either from the knowledge base, or is developed by a typical procedure for implementing the skills base according to the current information demand, or a network of element-by-element implementation according to the combined information demand is formed. Schemes for implementing information needs are obtained from a study of educational practices in the formation of imitative thinking. The diagrams are shown in Figures 3-4.

After implementation, the new information need is entered into the knowledge base and associated with the knowledge element, which is its implementation. The variation of such information need is carried out in a variable part, which are implemented by standard procedures common to them.

The realization of combined information need is developed by the investment, variation and combination of implementations of information need, which are located in the knowledge base of the system. New information need is built either by sequentially merging existing need from implementations, by investing one in another, or by merging and investing at the same time.

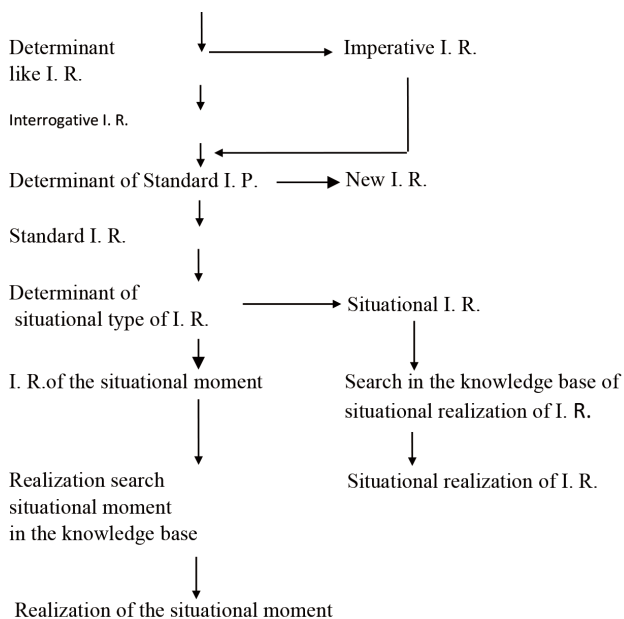


Figure 3. Realization of standard information requirement (I. R.)

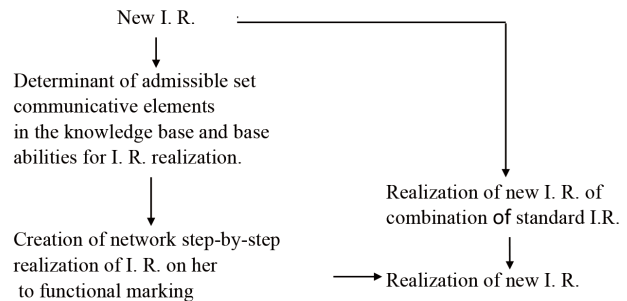


Figure 4. Realization of new information requirement (I. R.)

Retraining system is used to work with the new concepts (Figure 5).

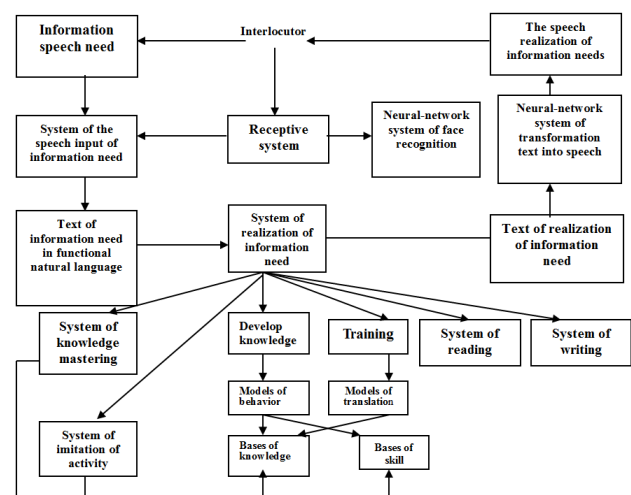


Figure 5. Retraining system.

6. Conclusions

On the way to create an ideal neurointerface that can convey and translate thoughts with high accuracy between the brain and computer, and will also have many areas of use and huge distribution among the population, there are several obstacles. Basically, these obstacles represent a number of modern technical, ethical and legal restrictions. Already, large corporations own our personal information, and with the development of neurointerfaces they will be able to read our thoughts, few will like it, but this is not the worst. The scary thing is that using the brain-computer interface, if necessary, it will be possible to change a person's personality or completely intercept control over his body. No matter how high the hacking protection is. Neurointerfaces will be susceptible to computer viruses and attackers. For this reason, developers will have to provide an appropriate level of security.

Neurointerfaces are progressing, not stopping it. Attracting intellectual resources greatly contributes to the development of technology, and once again convinces that

neurointerfaces are approaching at incredible speed and people should be ready to meet them.

The use of robots with communicative associative technologically intelligent thinking logic through spectral neurointerfaces is already in demand in various spheres of life.

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ARTICLE

Effective Bandwidth Estimation in Data Networks: An Analysis for Two Traffic Characterizations

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ABSTRACT

The Generalized Markov Fluid Model (GMFM) is assumed for modeling sources in the network because it is versatile to describe the traffic fluctuations. In order to estimate resources allocations or in other words the channel occupation of each source, the concept of effective bandwidth (EB) proposed by Kelly is used. In this paper we use an expression to determine the EB for this model which is of particular interest because it allows expressing said magnitude depending on the parameters of the model. This paper provides EB estimates for this model applying Kernel Estimation techniques in data networking. In particular we will study two differentiated cases: dispatches following a Gaussian and Exponential distribution. The performance of the proposed method is analyzed using simulated traffic traces generated by Monte Carlo Markov Chain algorithms. The estimation process worked much better in the Gaussian distribution case than in the Exponential one.

1. Introduction

The need to aggregate several services in a telecommunication network leads to the emergence of the concept of integrated services digital network. Integration means that the network is able to transport many kinds of information as voice, video, data, all of them in digital form, using a single infrastructure. Therefore, the technical problem that motivates this work is the question of working in an environment of shared resources.

Variable Bit Rate (VBR) font multiplexing poses a mathematical and statistical problem: estimating the resource requirements of a font or set of fonts and, as sources are variable, statistical gain is to be expected. Through statistical multiplexing, the different requirements of each service can be explored during the connection. The

development of statistical tools for studying the behavior of a network link arises with greater force from the notion of effective bandwidth introduced by Kelly in 1996^[5], which allows finding expressions to estimate the probability of loss in a link. The EB concept can be applied to sources or to aggregated traffic, as it can be the networks core link, but also it can be used for any shared resource models.

The price to pay for multiplexing sources is that the probability that many sources decide to dispatch the maximum rate, in which case there would be an overflow, is not zero. To minimize the effects of data loss and maintain quality of service (QoS) for both, current and future sources, it is necessary to have mechanisms of admission control that can decide whether to accept a new connection.

For this we need mathematical models to describe the behavior of the sources. Making models traffic carried by

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the network services is a necessary goal for dimensioning of its components and to evaluate its performance. Through traffic models, the appropriate descriptors can be found that characterize the service and facilitate management tasks such as establishing admission control criteria (CAC).

This paper is structured as follows. Section 2 introduces the Generalized Markov Fluid Model, and provides an expression to determine the EB for this model, a tool that will be used to measure the channel occupancy of each source. Section 3 studies the kernel estimation technique, its scope and properties, with the objective of using this tool to estimate the EB for our model. Section 4 presents the parameters of the simulated model and provides kernel estimates of the EB of the GMFM from traces, for two different cases: dispatches following a Gaussian and Exponential distribution. Conclusions are drawn in Section 5, together with some considerations on future work.

2. Mathematical Model and Calculation of the EB

2.1 Model

Within the most user-friendly source models, Markov models are used as they capture temporal correlation. These processes are characterized by a set of states, which form a Markov chain, and the transition times between them. In our case we use the Generalized Markov Fluid Model, introduced in ^[1].

This model is modulated by a continuous time, homogeneous and irreducible Markov chain, and in each state of the chain, the generation rate is a random variable, distributed according to a probability law f_i , that do not change during the time interval in which the Markov chain is in that state.

To interpret the model, we could think that each state in the chain is interpreted as the activity performed by a user, like chat or video conferences, so an abrupt change in the transfer speed report a change of state in the chain. Within a state, the speed data transfer assumes values that depend specifically for such activity, according to some probability distribution.

2.2 Effective Bandwidth

When variable rate sources are multiplexed on a link, a capacity greater than the average rate but less than the maximum transmission rate is reserved for each one. Indeed, the mean rate would be a too optimistic estimation, that would cause frequent losses, and on the other side, the peak rate would be too pessimistic and would lead to a resource waste. Effective bandwidth defined by F. Kelly in ^[5]

is a measure, useful and realistic, of channel occupancy.

In order to estimate EB for a given GMFM, formulas of the type obtained by Kesidis, Walrand and Chang ^[6] were obtained. The advantage of this type of formula is that its parameters can be estimated from traffic traces.

Let us consider $\{X_t\}_{t \geq 0}$ a GMFM, then the effective bandwidth has the following expression:

$$\alpha(s, t) = \frac{1}{st} \log \{ \pi \exp[(Q + sH)t] 1 \} \quad (1)$$

where 1 is a column vector with all entries equal to 1 , π is the invariant distribution, Q the infinitesimal generator for the modulating chain and H is a diagonal matrix of dimension k , whose non-zero elements are the first moments, μ_i , of the law governing the generation rate in state i .

The importance of this result is that provides an expression for the EB that depends on elements that can be estimated with traffic traces, like the infinitesimal generator of the modulating chain, its invariant distribution and the average transfer rate. The properties of this estimator can be seen in ^[1].

3. Invariant Distribution Estimation

In this section the estimators \hat{Q} , \hat{H} and $\hat{\pi}$ of the parameters in (1) are calculated using kernel methods techniques.

3.1 Kernel Density Estimation Methods

Given a simple random sample X_1, \dots, X_n of the random variable of interest with density, the most common method in nonparametric density estimation is the so-called kernel-type estimator, used since the 1960s and whose expression is as follows:

$$\hat{f}(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x - X_i}{h}\right) \quad (2)$$

where $h > 0$ is the window (or smoothing parameter), and K is a kernel function, i.e., a non-negative bounded and real-valued integrable function with $\int K = 1$, unimodal and symmetric around 0 .

The estimator (2) has two unknown elements. On the one hand, the parameter usually referred to as bandwidth, but which in this paper we will call it window size to avoid confusion, whose choice will significantly affect the estimated curve. In addition, this smoothing parameter must verify that it tends to zero "slowly", i.e., $h \rightarrow 0$, $nh \rightarrow \infty$ to ensure that \hat{f} tends to the true density f . And on the other hand the kernel function K , which there are different types to use and whose selection is usually set by the researcher. More details about kernels are discussed in ^[2].

To assign a density to the value x_0 in (2) where we want to calculate $\hat{f}(x_0)$ we open an interval of length h centered on

x_0 . The more data in that interval $\hat{f}(x_0)$ is higher, but it is not a value directly proportional to the number of data in that interval, rather these are weighted as a function of distance, by the function $K\left(\frac{x-x_i}{h}\right)$. The way $\hat{f}(x_0)$ is constructed ensures that the final curve obtained is a smooth continuous curve.

It is important to note that, this estimation technique is widely used due to its properties, including an asymptotically optimal kernel estimate in L_1 and strong convergence in L_1 for kernel density estimates, which can be appreciated in more detail in [3,4].

3.2 Considerations in the Kernel Density Estimation Implementation

Having into account that GMFM is a process with ergodic properties and time averages and spatial averages converges, if the process evolves enough time, we can analyze the traffic rates. The traffic speeds values can be considered as a random variable with distribution π . Hence we can estimate its probability density function (p.d.f.) by means of kernel methods.

As mentioned above, the window size parameter h is an important aspect of these techniques, its general behavior is that the larger the window, the smoother the p.d.f. estimated. Therefore, a “large” h could lead to joining nearby peaks into one and drawing incorrect conclusions, but a “small” h could show too many peaks leading to false highs.

Using an appropriate window size, we find that this p.d.f. is multimodal, and based on the shape of this distribution we will estimate the ranges and average rates of dispatch. Finally, we estimate the probability π_i of each state, with the area under the p.d.f. within each range. With this information we reconstruct the modulating chain by assigning each instant to the corresponding state, and compute the estimators presented in [1]. This can be done because both, spatial and time behavior converges in the GMFM. Analyzing the minima and maxima we estimate both the elements of H and the range of values associated with each state of the modulating chain.

3.3 Infinitesimal Generator Estimation

To obtain \hat{Q} there are different approaches, the method used in this work is to recover the state of the modulating chain by comparing the trace with the estimated ranges from $\hat{\pi}$. Once the modulating chain is reconstructed, we can estimate the elements in \hat{Q} by the ratio between the number of transitions from state i to state j and the time that the chains remains at time i .

4. Simulation and Numerical Results

In this section we will carry out the analysis with simulated traffic traces generated by simulations to perform the kernel estimations. Simulations were performed in Python 3.7 using sklearn.neighbors library [7] and codes can be provided by asking to the authors.

4.1 Parameters to Simulation

Several traffic simulations were performed according to the presented model were performed where the modulating Markov chain has $k = 9$ states and each state is associated with a data transfer rate interval shown the table below.

To design the infinitesimal generator of the chain we took into account some considerations like that, it is desired that the usual state be that of the highest transfer rate available in the transmission channel, so the most probable state is the ninth. It is also more common in the actual behavior of a transmission channel to jump from one state to the adjacent ones, to the maximum transfer rate, or to the minimum rate of transfer, so

State	Transfer speed (Mbps)
1	(0, 1024]
2	(1024, 2048]
3	(2048, 3072]
4	(3072, 4096]
5	(4096, 5120]
6	(5120, 6144]
7	(6144, 7168]
8	(7168, 8292]
9	(8292, 10240]

$$Q = \begin{pmatrix} -7 & 2 & 0.13 & 0.13 & 0.13 & 0.13 & 0.13 & 0.13 & 4.22 \\ 2 & -7 & 2 & 0.13 & 0.13 & 0.13 & 0.13 & 0.13 & 2.35 \\ 1 & 2 & -7 & 2 & 0.13 & 0.13 & 0.13 & 0.13 & 1.48 \\ 1 & 0.125 & 2 & -7 & 2 & 0.13 & 0.13 & 0.13 & 1.485 \\ 1 & 0.125 & 0.13 & 2 & -7 & 2 & 0.13 & 0.13 & 1.485 \\ 1 & 0.125 & 0.13 & 0.13 & 2 & -7 & 2 & 0.13 & 1.485 \\ 1 & 0.125 & 0.13 & 0.13 & 0.13 & 2 & -7 & 2 & 1.485 \\ 2 & 0.20 & 0.20 & 0.20 & 0.20 & 0.20 & 0.20 & -8 & 4.8 \\ 2 & 0.30 & 0.30 & 0.30 & 0.30 & 0.30 & 0.30 & 5 & -8.8 \end{pmatrix}$$

Within each of these intervals, how much is actually dispatched is drawn by means of a probability distribution, in the first case by a Gaussian distribution and in the second case by an Exponential.

The simulated trace is a succession of pairs $(v_i; t_i)$, with i from 0 to 20000, where v_i is the transfer speed, t_i is the moment when the chain jumps to another state and 20000 is the number of jumps in the chain, so the link transfers at the speed v_i while $t_{i-1} < t < t_i$.

4.2 Estimations from Traces

4.2.1 Gaussian Distribution Case

Parameters for the modulating chain were introduced in section 4.1. In this case we consider that within each interval the dispatched is drawn from a Gaussian

distribution centered to its midpoint and deviation equal to one sixth of the length of the interval.

Figure 1 shows the first 150 jumps of a trace as an example, to visualize with which data we are going to work.

For each simulated trace we estimate the EB through the following steps:

(1) Apply a Gaussian kernel to all v_i $0 \leq i \leq 20000$, with $h = 200$, to obtain $\hat{\pi}(x)$ for $0 < x < 10240$. This is possible because GMFM are ergodic, and time and spaces averages converge. See Figure 2.

(2) Find minima for $\hat{\pi}(x)$. These minima are an estimate for the extremes of the dispatch ranges, which in turn allow us to determine the state of the modulating chain. As Gaussian distribution is symmetric, we determine rate averages using the estimated rank middle points. Finally, area under $\hat{\pi}(x)$ between two consecutive minima estimates $\hat{\pi}_i$.

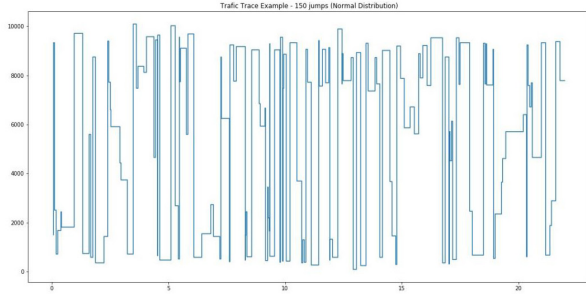


Figure 1. Gaussian distribution traces examples.

(3) Go through the trace comparing each v_i with the rank estimated to assign the corresponding state, to obtain the estimated chain (\hat{c}_i, t_i) , $0 \leq i \leq 20000$.

(4) Estimate infinitesimal generator from (\hat{c}_i, t_i) where t_i are cumulative so first order difference of t_i gives permanence time in state c_i .

(5) Calculate the estimated EB with \hat{H} , $\hat{\pi}$, and \hat{Q} , as in (1).

The choice over the value of 200 for the width of the kernel window is somewhat heuristically determined.

Table 1. Theoretical and estimated ranges of dispatch using Kernel Estimation techniques.

Theoretical range	0	1024	2048	3072	4096	5120	6144	7168	8192	10240
Estimated range	0	1091.74	2076.63	3083.74	4099.60	5125.89	6152.85	7020.94	8321.57	10240
Error	0	67.74	28.63	11.74	3.6	5.89	8.85	147.06	129.57	0

Table 2. Theoretical and estimated average dispatch rates.

Theoretical Average rates	512	1536	2560	3584	4608	5632	6656	7680	9216
Estimated average rates	516.16	1537.06	2548.88	3585.94	4607.19	5629.44	6653.37	7678.99	9213.89
Error	4.16	1.06	11.12	1.94	0.81	2.56	2.63	1.01	2.11

Smaller values generate an estimated trace with much more local maxima, making this search difficult to automate.

Figure 2 shows the theoretical and estimated density; Table 1 shows the estimated ranges of dispatch and Table 2 the estimated average dispatch rates.

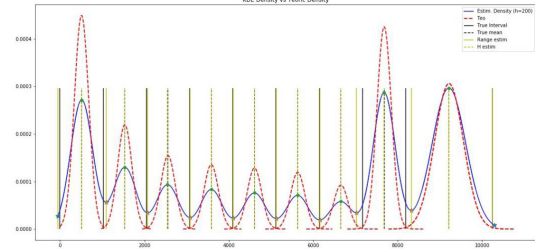


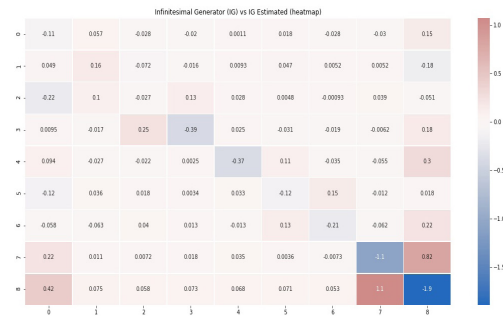
Figure 2. Theoretical and estimated density, using Kernel Estimation techniques.

The estimation of the infinitesimal generator is as follows

$$Q = \begin{pmatrix} -6.8935 & 1.9432 & 0.1578 & 0.1501 & 0.1289 & 0.1116 & 0.1578 & 0.1597 & 0.1597 \\ 1.9513 & -7.1605 & 2.072 & 0.1456 & 0.1207 & 0.0832 & 0.1248 & 0.1248 & 2.5297 \\ 1.2182 & 1.8956 & -6.9733 & 1.8728 & 0.1025 & 0.1252 & 0.1309 & 0.0911 & 1.5313 \\ 0.9905 & 0.1424 & 1.7519 & -6.6115 & 1.9748 & 0.161 & 0.1486 & 0.1362 & 1.3062 \\ 0.9061 & 0.1521 & 0.1521 & 1.9975 & -6.634 & 1.885 & 0.1654 & 0.1852 & 1.1839 \\ 1.1248 & 0.0894 & 0.1117 & 0.1266 & 1.9665 & -6.8754 & 1.8474 & 0.1415 & 1.4675 \\ 1.0581 & 0.1883 & 0.0897 & 0.1166 & 0.1435 & 1.8651 & -6.7879 & 2.0624 & 1.2643 \\ 1.7767 & 0.1891 & 0.1928 & 0.1818 & 0.1655 & 0.1964 & 0.2073 & -6.9357 & 3.977 \\ 1.5757 & 0.2246 & 0.2421 & 0.2269 & 0.2316 & 0.2293 & 0.2468 & 3.9292 & -6.9074 \end{pmatrix}$$

The heat map for the error in the estimation of infinitesimal generator shown in the Table 3, help us to evaluate the performance of the estimator.

Table 3. Heatmap for error estimation in the infinitesimal generator.



In addition, the confusion matrix M that we show below,

allow us to evaluate the performance in the estimation of the states.

$$M = \begin{pmatrix} 3521 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 375 & 1317 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 260 & 952 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 247 & 866 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 224 & 793 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 197 & 739 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 176 & 578 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 789 & 2973 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1330 & 4662 \end{pmatrix}.$$

Rows are the actual states and columns are the predicted or estimated states. For example, the 260 in matrix M at row 3, column 2 indicates that two hundred and sixty times the chain was in state 3 but was estimated to be in state 2.

Figure 3 shows the comparison of the estimated EB for a trace with the theoretical value.

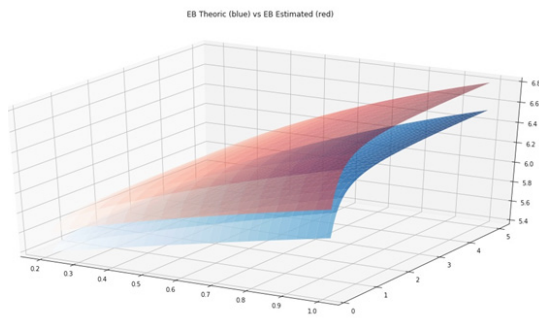


Figure 3. Theoretical bandwidth (blue) vs. Estimated bandwidth (red)

We can see that estimated EB is always above real one. This is not a problem because overflow probability and other QoS estimation, are conservative calculated, i.e., real probability is less than the estimated.

4.2.2 Exponential Distribution Case

Parameters for the modulating chain were introduced in section 4.1, in this case we consider that within each interval the dispatched is drawn from an exponential distribution with mean value is 100 MB from interval

origin. If the interval is [1024, 2048), the exponential mean parameter is at 1124 MB.

Figure 4 shows the first 150 jumps of a trace as an example, to visualize with which data we are going to work.

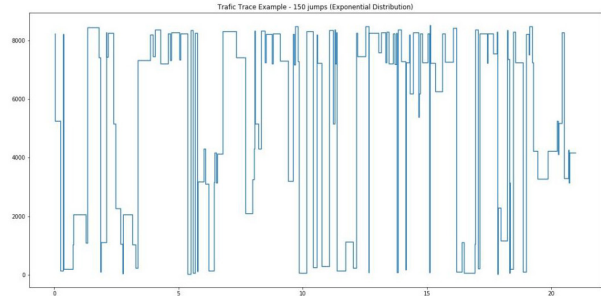


Figure 4. Exponential distribution traces examples.

For each simulated trace we estimate the EB through the following steps:

(1) Apply a Gaussian kernel to all v_i , $0 \leq i \leq 20000$, with $h = 20$, to obtain $\hat{\pi}(x)$ for $0 < x < 1024$. This is possible because GMFM are ergodic, and time and spaces averages converge. See Figure 5.

(2) Find maxima for $\hat{\pi}(x)$. These maxima are an estimate for the extremes of the dispatch ranges, which in turn allow us to determine the state of the modulating chain. Exponential distribution is not symmetric. So, we determine rate averages empirically calculating mean value of all the times that dispatch was within interval determinate by this maximum. Finally, area under $\hat{\pi}(x)$ between two consecutive maxima estimates $\hat{\pi}_i$.

(3) Go through the trace comparing each v_i with the rank estimated to assign the corresponding state, to obtain the estimated chain (\hat{c}_i, t_i) $0 \leq i \leq 20000$.

(4) Estimate infinitesimal generator from (\hat{c}_i, t_i) where t_i are cumulative so first order difference of t_i gives permanence time in state c_i .

(5) Calculate the estimated EB with \hat{H} , $\hat{\pi}$ and \hat{Q} as in (1).

The choice over the value of 20 for the width of the kernel window is somewhat heuristically determined.

Table 4. Theoretical and estimated ranges of dispatch using Kernel Estimation techniques.

Theoretical range	0	1024	2048	3072	4096	5120	6144	7168	8192	10240
Estimated range	0	1052.14	2074.48	3101.50	4124.17	5155.21	6175.87	7198.54	8221.54	10240
Error	0	28.14	26.48	29.50	28.17	35.21	31.87	30.54	29.54	0

Table 5. Theoretical and estimated average dispatch rates.

Average theoretical rates	100	1124	2148	3172	4196	5220	6244	7268	8292
Estimated average rates	200.93	1318.37	2389.62	3418.37	4461.25	5459.18	6839.68	7613.36	8321.96
Error	100.93	194.37	241.62	246.37	265.25	239.18	595.68	345.36	29.96

Bigger values generate an estimated trace with less local maxima, but more “normalized”, so estimation of area under the curve fall far from actual values.

Figure 5 shows the theoretical and estimated density; Table 4 shows the estimated ranges of dispatch and Table 5 the estimated average dispatch rates.

In this case the estimation of the infinitesimal generator is as follows

$$Q = \begin{pmatrix} -6.9393 & 1.4441 & 0.2797 & 0.1416 & 0.1381 & 0.1206 & 0.1311 & 1.0875 & 2.9145 \\ 1.8619 & -6.7947 & 1.3564 & 0.2991 & 0.1053 & 0.1559 & 0.1137 & 0.6445 & 1.5418 \\ 1.4328 & 1.1773 & -6.8974 & 1.3106 & 0.4276 & 0.1499 & 0.1388 & 0.4887 & 1.0329 \\ 0.9056 & 0.4787 & 1.3261 & -6.8505 & 1.2356 & 0.5757 & 0.1423 & 0.4334 & 1.0286 \\ 1.2968 & 0.153 & 0.4881 & 1.2312 & -7.2344 & 1.2822 & 0.4153 & 0.4954 & 1.0928 \\ 1.0977 & 0.1432 & 0.1511 & 0.5648 & 1.2409 & -7.1909 & 1.4477 & 0.692 & 0.9705 \\ 1.4889 & 0.1396 & 0.2047 & 0.1535 & 0.3955 & 0.6281 & -7.1049 & 1.2888 & 2.4288 \\ 1.7487 & 0.1901 & 0.218 & 0.1967 & 0.195 & 0.2065 & 0.5425 & -7.0048 & 2.0405 \\ 1.6385 & 0.2325 & 0.2515 & 0.2625 & 0.2436 & 0.2119 & 1.1498 & 2.997 & -6.9872 \end{pmatrix}$$

The heat map for the error in the estimation of infinitesimal generator shown in the Table 6, help us to evaluate the performance of the estimator.

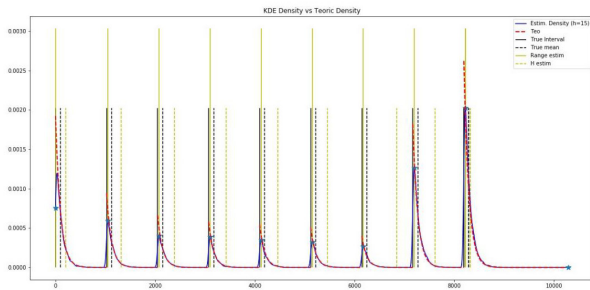


Figure 5. Theoretical and estimated density, using Kernel Estimation techniques.

Table 6. Heatmap for error estimation in the infinitesimal generator



The confusion matrix M that we show below, allow us again to evaluate the performance in the estimation of the states

$$M = \begin{pmatrix} 3534 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 426 & 1324 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 290 & 953 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 289 & 803 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 256 & 733 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 260 & 700 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 204 & 574 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 953 & 2795 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1479 & 4418 \end{pmatrix}$$

Figure 6 shows the comparison of the estimated EB for a trace with the theoretical value.

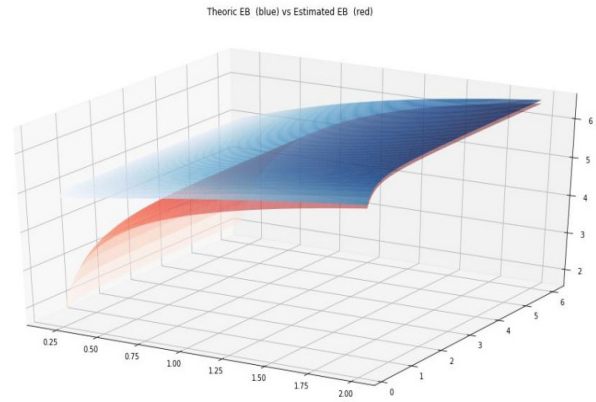


Figure 6. Theoretical bandwidth (blue) vs. Estimated bandwidth (red).

We can see that estimated EB is always under real one. This behavior is opposite than the Gaussian case, but this is also not a problem because convergence is fast enough, in order that overflow probability and other QoS estimation, are near enough to its real values.

5. Conclusions

In this paper we have proposed a non-parametric methodology to estimate effective bandwidths from traffic traces of a GMFM source with expected properties. These results allow us to estimate the effective bandwidth from traffic traces with very little prior knowledge of the GMFM. Of course, we pay for the versatility of this method with a slightly larger estimation gap.

The estimation involves the calculation of the maxima and minima of the estimated density function. This process is easy for the human eye but it is perhaps the most complicated part to implement computationally because noise can generate spurious maxima or minima.

Numerical examples of simulated traces were presented showing the results obtained. The estimation process worked much better in the Gaussian distribution case than in the Exponential one, which can be seen in both the heat map and the confusion matrix presented for each case.

It is expected to extend the statistical calculation to the more realistic case where the number of dispatch classes is not known, distributions are not of the same family, and also where the supports of each probability law have bigger intersection, in order to develop the estimation to real data scenarios.

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