Estimating Position of Bio Electric Potential Dataset as A Natural Sensor using Time Series Approach

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Abstract

The application of plants as natural sensors to detect human behavior is very interesting to investigate. One benefit is to know the position of elderly people living alone in a house in order to avoid accidents resulting in death because of not immediately helped. The previous authors already use some method to estimate the position such as classification and multilayer perceptron methods. However, to find the best estimation is so difficult. Therefore, this study tried to use time series approach to solve bioelectric potential dataset problem because the data type is numeric and data stored are based on time. The time series model which is used is Autoregressive (AR) model. The purpose of this study is to estimate the position based on the distance of training dataset to AR model. The result performed that the AR model selected is AR of order 3. In addition, the estimation accuracy is pretty good of 75% compared with the other methods, such as multi layer perceptron or decision tree.

1 Introduction

In 2014, a publication of the aging society published by the Japanese cabinet office, announced in October 2010 and October 2013 which there are 23% and 25.1% of the elderly population respectively [Nomura *et al.*, 2016]. Then, from the resulting this percentage, the number of elderly people in Japan the average age is more than 65 years. This condition is the highest proportion in the world [Nomura *et al.*, 2016][Chen *et al.*, 2016].

Based on the research of Nomura et al [Nomura *et al.*, 2016], the condition of the elderly is mapped into two groups: the elderly who live with their families and the elderly who live alone. Based on data from samples taken in one of the major provinces in Japan Kyoto mention that the number of the first group in 1990 is 284.013 (86.7%). After 20 years in 2010, it increased nearly two-fold as many as 495.343 (81.8%). Next, the second group in 1990 is by 43.416 (13.3%) then in 2010 increased to 110.366 (18.2

There is an interesting phenomenon of the second group, that the proportion of elderly people living alone in 2010 is high at 18.2%. These conditions lead to various problems one of which is the death that is not known by others, whether caused by accidents in the home or other factors such as murder. Based on research by the same number of deaths caused by accidents in the home because it was not helped as much as 12.5%. This condition be attention for all parties, including the researcher. One of the measures being initiated is to examine the installation of cameras in their house so that accidents that occur immediately known by a neighbor or an authorized officer so it can be helped. However, this solution is less widely accepted because of privacy concerns, therefore, the study conducted to make plants as a camera to monitor the location of the elderly activity at home. It is known as Bio electric potential.

Basic use leafy plants are because it can be treated with the installation of electrodes on the leaf that can produce low-voltage electrical signal but it also can be used as a room freshener that impact both on the health of its inhabitants like to reduce stress. Plant bio-electric potential generates an electrical signal low because the activity of the plant such as photosynthesis and transpiration, but it is also due to environmental factors such as temperature, humidity living things and human behavior around [Shimbo and Oyabu, 2004].

The use of bio electric potential as a natural sensor is an innovation in an effort to detect the human behavior like accident in order to prevent the eldery death who live alone in a home because of accidents are not helped immediately. A previous attempt to use the camera a lot of rejection because the monitor in place of privacy as the bathroom and the bedroom [Shimbo and Oyabu, 2004], [Nomura *et al.*, 2014], [Nambo and Kimura, 2017], [Nambo, 2015], [Nambo and Kimura, 2016]. Besides, the use of infrared sensors tested to solve this problem, although the results were pretty good but costly due to capture human behavior requires many sensor cells, so that are not economically [Jin, 2014]. Then the other solutions tested using the sense of odor but the results are not so good because there is often noisy when the data records [Jin, 2014]. Hence, the use of bio-electric potential could be the solution to these problems because it is friendly to monitor the behavior of people in privacy place and may also be a producer media of oxygen to reduce stress (for healing) [Shimbo and Oyabu, 2004], [Nomura *et al.*, 2014], [Nambo and Kimura, 2017], [Nambo, 2015], [Nambo and Kimura, 2016].

Furthermore, based on the results obtained from previous

studies that bioelectric potential has the ability to capture human behavior well. Research conducted by Hirobayashi et al [Hirobayashi *et al.*, 2007], states that human activities like stepping around the plants produce a strong correlation with changes the signal by using plant bio-electrical potential. Another study conducted Nomura et al [Nomura *et al.*, 2014], Shimbo et al [Shimbo and Oyabu, 2004] with using machine learning method that shows the results of human behavior such as talking, moving, walking, opening the door can be detected using bioelectrical plant potential. Subsequent research conducted by Jin et al [Jin, 2014] using artificial neural network algorithm successfully detects a distance of person within the plant of bioelectric potential. Then another study conducted by Nambo et al utilize bioelectric potential for determining the position in a room. This study uses several algorithms including decision tree (J48) for the classification point and multi layer perceptron locations to determine the position and then make a regression model to matching process. The results obtained show that a person's position can be estimated with an accuracy rate of 60% [Nambo and Kimura, 2017], [Nambo, 2015], [Nambo and Kimura, 2016].

Utilization of plants as a natural sensor is a breakthrough to help some problems in daily life of human activities. Recorded data using plant media, can be used as input learning by using various methods such as machine learning, statistics and data mining. Furthermore, this research is expected as an effort to face a new era in data computing, known as AI cognitive system. That is a technologically advanced system that has learning features and can continue to adapt just like a human brain.

The previous researches about artificial intelligence cognitive system are able to outline as follow. J. Suchan and M. Bhatt study about Semantic Q and A with Video and eye-tracking data. This study is the foundation of AI for human visual perception which is studied based on Cognitive Film Studies. By using a demonstration of major technological capabilities aimed at investigating the effects of attention and recipients on motion pictures; These results have a high degree of analysis of the subject's visual fixation patterns and correlations with the semantic analysis of the dynamic visual data [Suchan and Bhatt, 2011]. Research on cognitive programming is conducted by L. Michael et al. They explain that by following a vision where humans and machines share the same level of common sense. They have proposed cognitive programming as a means to build cognitive systems. Cognitive programming adopts a machine view as a personal assistant. The point is that humans demand completion of tasks, perhaps without specifying fully and clearly determining what is needed, but relying on the experience of the assistant, and finally, the machine is able to perform the task. Cognitive programming aims to bring traditional programming flexibility to existing technology users, enabling them to view their personal devices as novice assistants, who can receive training and personalization through natural interactions [Michael *et al.*].

A. Lieto and D.P Radicioni study about the Cognitive AI system. They reviewed the major historical and technological elements that characterize the recent rise, fall and resurgence of the cognitive approach to Artificial Intelligence. They say that the scientific vision of Artificial Intelligence (AI) can be successfully synthesized by the words of Pat Langley: "AI aims to understand and reproduce computing systems of various intelligent behaviors observed by humans" (Langley, 2012) [Lieto and Radicioni, 2016]. Other studies discussed Artificial Cognitive systems, by A. Lieto and M. Cruciani. This paper presents the AI collaborative studies of many disciplines such as computer scientists, psychologists, engineers, philosophers, linguists and biologists. This collaboration led to its influence on the study of natural and artificial systems. The author describes the use of many AI cognitive system frameworks such as SOAR and A-SOM as well as the development of research on Artificial Cognitive systems [Lieto and Cruciani, 2017]. Paper "Cognitive System: Argumentation and Cognition" was performed by A. Kakas and Michael. This paper discusses the relationship between argument and cognition from a psychological and computational point of view. In addition, this paper also investigates how the synthesis of work on reasoning and understanding of narrative texts from the Cognitive Psychology of work which is based on computational arguments from AI that can offer a scientific and pragmatic basis for building human cognitive systems in performing everyday tasks [Kakas]. An evolutionary study of architectural cognitive frameworks, ICARUS was presented by D. Choi and P. Langley. The paper mentions that two early versions of ICARUS explain in more detail the third incarnation that has stabilized over the past 12 years. These include modules for conceptual inference based on perception, goal-based reactive execution, problem solving with shield analysis, skill acquisition of new solutions, and achievement of top-level objectives [Choi and Langley, 2017].

The paper "The level of knowledge in cognitive architecture: current limitations and developments" is written by A. Lieto et al. The authors say that the level of cognitive architecture (CA) is not only a technological issue but also epistemological one, because they limit the comparison of knowledge representation and CA processing mechanism to that of humans in their daily activities. In addition, they say that it should be tackled to build artificial agents that are capable of demonstrating intelligent behavior in a common scenario [Lieto *et al.*, 2017]. J. Rosales et al., presented the integration of cognitive computing model of planning and decision making by considering affective information. The contribution of this research is that the resulting model considers affective information and motivation as a fundamental and essential trigger in the planning and decision making process; In addition, the model is capable of mimicking the internal human brain as well as human external behavior [8]. F. Martinez et al., studied computational analysis of general intelligence tests to evaluate cognitive development. They mentioned that to understand the role of basic cognitive operational construction (such as identity, difference, order, calculation, logic, etc.) required intelligence testing and serves as a proof of evaluation concept on other developmental issues [Martnez *et al.*, 2017].

The paper "Enabling the social intelligence of robots by the engineering of human social-cognitive mechanisms" is written by T.J. Wiltshire et al. This study explains the basic techniques of human social cognition to illustrate how the embod-

ied social robot can be designed to function autonomously as an efficient co-worker. Adopting the engineering human social cognition (EHSC) as an approach to modeling the socio-cognitive mechanisms in robots, not only provides a robust, flexible, sophisticated, cognitive, perceptual, motor and cognitive architecture, but also enables a more direct understanding of, and natural interaction with the environment and human colleagues. It also provides a mechanism for better understanding human behavior and mental states as well as enabling the prediction and interpretation of new and complex social situations [Wiltshire *et al.*, 2017]. D.L. Dowe and M.V. Herna discussed a universal psychometric that measures cognitive abilities in the machine kingdom. This paper presents the measurement of cognitive ability, and the creation of a new foundation for redefining and mathematically formalizes the concept of cognitive tasks, evaluable subjects, interfaces, task choices, difficulties, agency response curves, and so on. The authors explain that the AI Evaluation may receive important impacts from the cognitive system view characterized by its diversity and cognitive ability level, analysis of the relationship between the spectrum of capabilities, the difference between characteristics and measuring tools, or borrowing of item response theory, as well as other theories and concepts developed in psychometrics [Dowe and Herna, 2014].

The paper "Advanced user assistance based on AI planning" is conducted by S. Biundo et al. This study presents a hybrid planning approach in detail and demonstrates its potential by describing the realization of various aid functions based on complex cognitive processes such as generation, improvement, and explanation of the Author's plan that the user's instructions are given based on an action plan synthesized by the hybrid planning system. If a particular action execution fails due to some unexpected environment change, for example, the system can help the user out of the situation by starting the plan improvement process. The resulting plan overcomes a failing and stable situation by simply pointing out the deviation from an indispensable starting plan. Finally, an explanation of the plan can be given based on the analysis of the structure of the rich knowledge plan generated by the planner and also the planning process itself [Biundo *et al.*, 2011].

This research attempts to estimate the position of human in a room. The method to solve this problem is using time series method. The time series approach to bioelectric potential dataset is interesting to perform because it is stored based on time and indicate the specific pattern. The use of time series for prediction has been done by Abdurahman (2014) about time series algorithms which combined with Particle Swarm optimization [Nambo and Kimura, 2016]. In addition, the research about the discovery knowledge in time series databases. This study aims to predict an important attributes and extract rules in association analysis [Schluter, 2012]. Furthermore, in 2015 conducted research on time series analysis through AR modeling. In this study shows various types of AR models such as univariate and multivariate AR models, a radial base function autoregressive model and so on [Ohtsu *et al.*, 2015].

The research is described in the following sections: section 2 is talking about a research method includes the measurement of bio electric potential, positioning coordinates, experiment design and datasets. section 3 presents results and discussion. Then conclusions and future work are described in section 4.

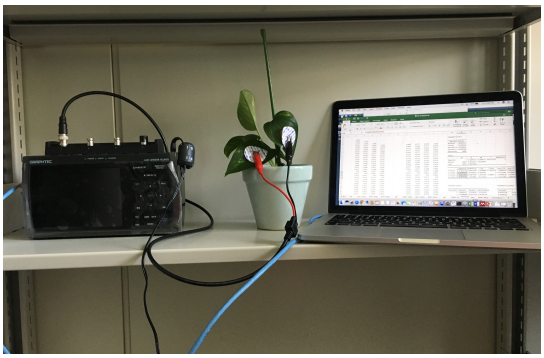

Figure 1: Bio electric potential

2 Proposed Method

2.1 Measurement of Bio electric Potential

To perform measurements using a data logger. Specifications data logger used is GRAPHTEC GL400-4. It measures the low voltage at an average altitude of sampling (approximately 1 kHz). This tool has four channels so that it can simultaneously measure voltage. For the measurement of electrical potential of plants by attaching electrodes on two different leaves then measured the voltage generated between both the leaves. The measurements are stored on a PC in real time via the local network (figure 1).

2.2 Positioning coordinates

P1 is plant of bio electric potential and M1-M3 are the locations of the experiment. For the position coordinates of the plants and experiment point is seen in Table 1.

Table 1: Coordinate position of observation point and plant bio electric potential

Observation point	X-Coordinate	Y-Coordinate
M1	260	475
M2	200	490
M3	140	430
P	160	340

2.3 Experiment Design

The design of this research can be seen in Figure 2. Referring this figure, the observed bioelectric potential data is divided into two types, namely training and testing dataset. In the process of training data analysis are used Autoregressive time series method. Through this method selected AR model that is based on the level of feasibility and size of the standard error.

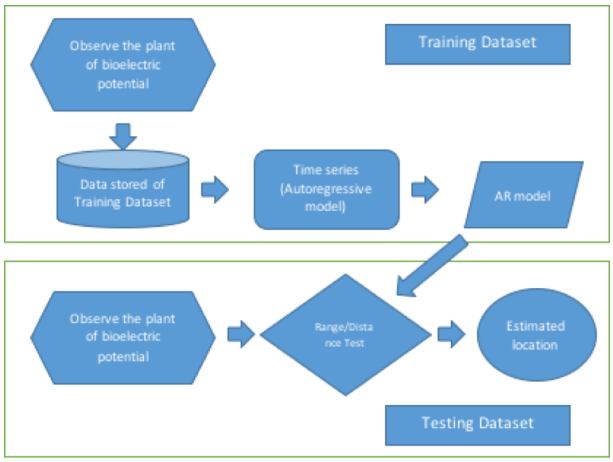

Figure 2: The research design

Furthermore, to determine the position by using data testing which find the difference of the actual to the estimated value of AR model.

2.4 Dataset

Data were obtained by using plant of bioelectric potential in a room of size 3 m x 4 m. The position of observation there are three points and the plant used there are two trees. The process of recording data is done by someone by walking around each position point for 30 seconds. Once the people move on each observation point, the recording process starts from both bioelectric potential plants. Data obtained is spectrum data format and can be converted into numerical data using data logger. Therefore, from the experiment obtained three dataset point position of two potential bioelectric plants so that there are six total datasets. The first data collection is used as training data. Next the second experiment in the same way is used for data testing.

3 Results and Discussion

3.1 Experimental Setup

The data used is Bioelectric potential dataset from three positions using one plant. Data analysis was performed using a MacBook Pro with specification: 2.7 GHz Intel Core i5, 8 GB 1867 MHz, and DDR3.

Best Model Determination

This research experiment was conducted in three positions. To determine the best AR model performed in each position of the experimental object, by comparing the p-value and error standard of each AR model (table 2). Based on the analysis results obtained p-value and standard error as follows:

Based on the table 2, it is found that all p-values on each model of AR are zero because all of the p-value is smaller than alpha value (0.05) so that all models are selected as candidate models. Next is a comparison of standard error values in each selected position and the result of the 3rd order of AR model because the standard error value is smallest compared to the other AR order. The selected error values from position 1 to 3 are almost the same (0.033). Therefore, the selected AR model is used to create a model at each position.

Table 2: Standar error of AR model

Parameter	Position 1			Position 2			Position 3		
	AR(1)	AR(2)	AR(3)	AR(1)	AR(2)	AR(3)	AR(1)	AR(2)	AR(3)
p-value	0	0	0	0	0	0	0	0	0
standar eror	0.045	0.038	0.033	0.044	0.038	0.033	0.045	0.038	0.033

Table 3: The component of each model

Component	Position 1	Position 2	Position 3
Intercept (a_0)	-9.31485E-05	-8.39632E-05	-9.24376E-05
X Variable 1 (a_1)	0.665990568	0.66779352	0.668736298
X Variable 2 (a_2)	-0.061332529	-0.062073254	-0.062234636
X Variable 3 (a_3)	-0.497219399	-0.497083196	-0.496436779

Constructing AR Model

According to the selected AR order, the models are constructed as follows:

The table 3 explains the modeling component which is obtained at each position. The first component is constant value then the next three values are coefficients for the three variable values of the previous time series in sequence. Models that are formed in general are as follows:

$Y_t = a_0 + a_1 Y_{t-1} + a_2 Y_{t-2} + a_3 Y_{t-3}$

Where :

Y_t = signal value of bioelectric potential at t
Y_{t-1} = signal value of bioelectric potential at t-1
Y_{t-2} = signal value of bioelectric potential at t-2
Y_{t-3} = signal value of bioelectric potential at t-3
a_0, a_1, a_3 = coefficient value for signal value of bioelectric potential at t, t-1, t-2, and t-3

Determination of data testing positions

In this testing process there are five datasets are used. From each dataset we select the sequential data at time t to the order of data to 1500, 4000, 7500, 11500, and 13000 respectively. The determination of this sequence is the basis of consideration to seek and to cover the overall pattern in each dataset (15000 observations). After that, the sequence is tested to the selected AR (3) model. Next, the calculation of the difference of the estimation result and the actual test value. The smallest difference is selected as the estimated dataset position result. Here is the design and test results:

Based on the table 4, the estimation of the five datasets tested, there are three appropriate datasets and the rest are

Table 4: The Position estimation

Experiment position	Position 1	Position 2	Position 3	Estimation result
Position 1	0.039034078	0.039049273	0.039019109	Position 3
Position 2	0.025319258	0.025360625	0.025391858	Position 1
Position 3	0.038997821	0.03898176	0.038939225	Position 3
Position 1	0.021176831	0.021190519	-0.021182437	Position 1
Position 2	0.020541127	0.020538297	0.020574728	Position 2

missed. The first and the second experiment are fail because the estimation result is not true and the third to five experiment are accurate. Therefore, the value of accuracy obtained by 75%.

3.2 Discussion

The research related to plant of Bio electric potential to estimate position is conducted in the simulation experiment. That experiment is performed in a small room size 3 m x 4 m. Then the number of plants used as much as two trees and the point of observation positions are three points. This means that if this research is successful it is possible to use in a house with several room as the observation positions and the number of bio electric potential plants that are used more than two trees.

Based on the results which was conducted by using time series approach, AR model has been able to estimate a person's position with accuracy level of 75%. This level of accuracy is very important to be improved further with different methods approach. However, this accuracy level is quite competitive when compared with previous research like using multilayer perceptron and decision tree methods.

The important point of this research that must be considered is the contribution points. That this research contributes to determine someone's position. Especially it is used to determine the position and movement of an elderly which living at home alone. We wish can help the elderly people for something unexpected happens. Utilization of plants as a media for human activity aid oriented are more deeply studied. Included in the study of AI cognition system. Hopefully, the topic of bio electric potential can be developed further on the topic of AI cognition design like a smart robot. The plant is being smart by utilizing the data recording as a learning material to be used as a knowledge. Furthermore, with the knowledge possessed utilized for various human interests such as measurement of room temperature, distinguishing objects of life, counting the number of people in a space, measure the burning of calories and so forth.

4 Conclusion

This study analyzes the time series method using AR model on Bioelectric potential dataset. Based on the analysis result obtained the best model that was AR (3). Furthermore, the selected model is used to estimate the position of data testing. Finally, this research obtained the estimation result accuracy of 75%. This research is exciting to be developed further by using optimization methods such as Steepest Ascent, Newton Raphson, or Particle swarm optimization, in order to increase an accuracy value. In addition, it is better to try using the others model of time series methods such as MA, ARMA and ARIMA.

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