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Original Article

Multi-Layer Perceptron Neural Network and Internet of Things for Improving the Walking Stick with Daily Travel Surveillance of Suburban Elderly

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Abstract - *Many countries are entering the era of the elderly, causing the population of the elderly to increase steadily. However, these elderly people still want to be self-reliant, especially walking anywhere without needing a caretaker. Thereby, the walking sticks have become a daily tool to support and walk for the elderly. This paper proposed improving the walking stick as an intelligent cane that is a walking aid and monitoring tool for the daily travel surveillance of suburban elderly in Thailand. The intelligent cane's daily travel surveillance forecasting model was built by applying the Multi-Layer Perceptron Neural Network. Further, the performance of the model accuracy was enhanced by synthesizing imbalanced data based on Synthetic Minority Over-sampling Technique. The effectiveness of the model showed that the prediction accuracy was 96.89%, the precision was 97.62%, the recall was 98.80%, and F-measure was 98.21%. Moreover, the developed intelligent cane architectures allow their family to monitor, track and communicate with the elderly using the Internet of Things technology and real-time camera by remote control via the mobile application. As a result, this work showed that the suburban elderly could perceive, learn, and appreciate the recent technology necessary for their life.*

Keywords — *Elderly, Internet of Things, Multi-Layer Perceptron Neural Network, SMOTE, Walking stick.*

I. INTRODUCTION

Elderly people are defined in Thailand as individuals aged sixty and over [1]. Today, Thailand can be considered as another country from many countries entering the era of elderly aging. As of the end of 2020, the elderly population has increased from 1994 to 17.57% and is likely to continue. The latest statistical data shows that Thailand has 11,627,130 elderly people, divided into females and males, totaling 6,496,767 and 5,130,363, respectively [2]. According to the aging society, Phromphak [3] stated that an aging society comprises people aged sixty and over, representing over 10% of all people in the country, or the country with a population over sixty-five years which represents over 7% of the people whole country. It could be said that Thailand has already stepped into an aging society. Thus, an aging society is a matter that many countries have to manage and prepare for the completeness of the era of the elderly. In particular, the development of innovations or facilities to enable the elderly to live on a daily basis with minimal dependence on other people. Generally, most elderly people do not want others to see themselves as old, especially walking anywhere without needing a caretaker. This will give them a sense of self-esteem and not become the responsibility of their family or communities.

Walking canes or sticks, commonly used by older people, help stabilize or reduce the strain on both legs or one side, exclusively for patients with muscle weakness [4] or pain in the leg. Also, the walking canes help reduce the pain in the hip and knee area [5]. Furthermore, it can create confidence and sentiment of safety for the elderly. Each walking cane has different shapes and abilities, but the primary feature is no different; it helps the elderly move around. Referring to commercial walking canes or sticks [6–12], the authors gathered and summarized the properties of walking canes available in the markets, as described in Table I.

TABLE I
OVERALL PROPERTIES OF WALKING STICKS AVAILABLE IN THE MARKETS

Feature	Description
Good material	Principal components are aluminum, casting alloys, carbon (or fiber)
Lightweight	Around 500-800 grams
Cane extensibility	Full-length between 55 to 110 centimeters
Wrist strap	It was produced by rope or elastic to increase the fit and prevent slipping out of the hand
Tip of cane	Monopod or tripod or quad

Flashlight	Light-emitting diodes (LEDs) or bulb
Battery capacity	Around 1,000-2,700 milli-amps
Data storage unit	microSD memory supported
SIM card support	The frequency between 800 and 900 MHz
Emergency call	Press a button to make a quick call
Dial and receive a call	Press a button to dial or receive a call
Sound alarmed	Dynamic ranges from 70 to 100 decibels
Light alarmed	little light and a small LED
Text or short message	Fixed messaged for an emergency occurs
Location-based tracking	Display the current position on the application
Built-in camera	Snapshot photo or record video
Music and radio	Receive AM/FM radio, play the MP3 file
Umbrella	Sunproof and rainproof

There are eighteen properties or favorite features to support the elderly while using the walking sticks in Table 1. In general, the primary structural material for walking canes is plastic or lightweight metal material but durable such as aluminum, casting alloy (aluminum alloy). Also, carbon or fiber is used as the cane rod to make it even lighter. However, it is more expensive than aluminum alloy. The tip of the cane has a different number of legs that vary with usage and balance such as a monopod (single-legged), tripod (three-legged), quad cane (four-legged), and wheels [13]. There are two styles for the top of the shaft for holding the cane: a straight shaft and a bent shaft (or a 90-degree angle). For the straight shaft, it is a walking cane that looks like a straight line without any bends or angles. Suburban seniors prefer to use natural wood, which is straight as a cane, to support them. These canes are most commonly used as a spike or a guide rather than a walking aid. There are two ways to hold the cane in this manner. First, use the hand around directly on the shaft of the cane. Second, using the hand grab at the top of the cane, which their thumb may press down, helps increase the grip. For the bent shaft or 90-degree angle on top of the walking cane, this cane improves grip and helps transfer weight down the wrist to the cane. These canes are the typical walking canes that are available in the commercial.

Currently, electronic devices have been developed to contain technologies that help and facilitate daily life. Significantly, the electronic devices that can connect to a network or the internet that was called the Internet of Things (IoT). With this technology, many innovations have been developed for life. For example, the robot works automatically to collect plastic garbage on the water surface [14]. Alternatively, the developed smart walking cane is based on the IoT to help visually-impairment walking [12] and blind navigation using location-based tracking [15–16]. Also, the iCane [17] can balance and allow the elderly to walk more freely. Furthermore, 3DCane [18] applied the accelerometer and magnetometer sensor for real-time monitoring of the elderly motion [19], fall detection [20–21], and fall risk estimation [22] while using the walking stick. Moreover, some smart stick helps elderly farmer detect dangerous electricity flow [23]. Thereby, smart walking canes are essential devices and necessities for supporting elderly persons in daily life.

Although some commercial walking canes are relevant to the properties or characteristics of the elderly are available in the market. However, these are still unable to meet the daily life needs of the elderly regarding the characteristics that the cane should have in this era. Therefore, this research focuses on improving the walking stick by applying the Internet of Things and machine learning for helping to track the elderly by reporting to their families in suburban areas, Thailand. Furthermore, this work has also developed a daily travel surveillance forecasting model for elderly people who are more likely to go off their regular routes or spend time at a particular point longer than usual and alert their families. However, the data used for modeling is very specific to each individual, causing an imbalance in the data. Thus, the Synthetic Minority Oversampling Technique, also called SMOTE, is used to solve imbalanced data problems by synthesizing data that is minority class. It is relatively easy to operate and is entirely accurate in resolving unbalanced datasets [24]. A dataset with a minority class was increased by duplicating examples. The imbalanced data were synthesized by randomized value and finding the difference between the value and the others, then selecting the closest value [25].

Moreover, the elderly need and can learn endlessly, known as lifelong learning [26]. This learning will help the elderly be mentally strong, encouraged, and motivated to do activities without becoming worthless older people. Nordstrom [27] stated that some research in the 1990s supports that a stimulated mind positively affects human brain health and mental. If stimulated and challenged, it will result in brain development. Hence this paper develops the intelligent cane in walking to various locations while monitoring the daily travel surveillance for the elderly in suburbans. It is a tool for navigation rather than the regular walking cane made from wood. It is also another good effect that stimulates the mind and learning in the use of technology. This intelligent cane allows seniors to be self-sufficient in their travels and to be able to monitor through mobile applications remotely.

II. METHODOLOGY

The research process consists of five stages: 1) proposed the intelligent cane design, 2) Internet of Things for intelligent cane development, 3) modeling of daily travel surveillance forecasting, 4) the development of the mobile application, and 5) the effectiveness evaluations, as follows.

A. Proposed the intelligent cane design

The authors gathered data on walking canes from suburban elderly people for intelligent cane design. The intelligent cane rod was designed to carry it easily and adjust the length to the suitable height of individual users. According to the data collected, it was found that the walking canes have three styles of adjustable length, including elastic cord, twist lock, and clamping lever lock, as demonstrated in Fig. 1.

Fig 1: Three styles of adjustable walking cane rod

The twist lock is more suitable for building intelligent cane in this research because the lock style is compact and easy to use. Also, it allows for the shortest cane length compared to elastic cord or clamping lever lock. Based on the wrist and arm characteristics to hold the cane, there were three styles for holding the walking canes while being used, including horizontal, top-horizontal, and vertical styles, as demonstrated in Fig. 2. Thereby, the intelligent cane was designed to support the elderly for all three holding styles, including the flashlight, as illustrated in Fig. 3.

Fig 2: The three holding styles of the walking cane

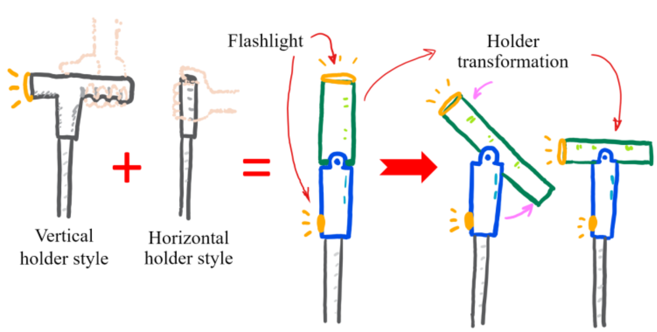


Fig 3: The sketch handle layout design for the intelligent cane with flashlights

B. Internet of Things for intelligent cane development

The whole intelligent cane was made mainly of aluminum. It has some plastic components on the handle and the control unit system based on IoT. The IoT devices used in the intelligent cane contain ESP32 chips, sensors, and modules as follows.

a) ESP32 microcontroller

It is the primary central processing unit for controlling a whole system in intelligent cane. In general, the ESP32 chip has been produced in various versions. ESP32-D0WD was applied in this work because it was smaller compared to another version of ESP32. Also, it consumes low power while working, making it can be used for a long time. Thereby, ESP32-D0WD is suitable for applying to the development of this cane, requiring a small size of devices inside.

b) GSM with a location-based tracking module

It is required for the intelligent cane features of the internet and communication. Thus, the Quectel UC20E with a subscriber identification module (SIM) was applied to this cane. It supported the Global System for Mobile communications (GSM) with a radio frequency range of 850 to 2,100 megahertz. This module has internet communication with a maximum download of 14.4 megabits per second (Mbps) and a maximum upload of 5.76 Mbps. Further, a Global Positioning System (GPS) receiver was built in this Quectel UC20E module for location-based tracking.

c) OV2640 module

OV2640 module includes the camera for monitoring by the elderly family on application. The maximum picture quality is two megapixels and up to 1600x1200 pixels at fifteen frames per second.

d) GY-BMI160 module

It has a built-in 3-axis of gyroscope and a 3-axis gravity accelerator sensor. It is required to the process of fall overdetection and logging the intelligent cane movement data.

e) Voice module and speaker

The voice module and speaker with an 8-ohms impedance rated at 0.25 watts are audio input and output to communicate via GSM network for dialing or receiving calls.

f) TZT buzzer module

It is an audio signaling device with hi-decibel conducted to alarm in case of emergencies such as fall over, or the elderly need someone to help them.

g) Light-emitting diodes (LEDs)

LEDs were used as alarm lights or notification signals for people in the surrounding area to see the elderly. Besides, it also acts like flashlights in which there is insufficient light.

h) Music player module

It is the most common music player for MP3 (Moving Picture Experts Group-3) files, which are digital audio-coded formatted. This module can play music and voice messages that are recorded on a micro secure digital (SD) card.

i) TEA5767 radio module

It is a frequency modulation (FM) receiver module for the elderly to listen to the radio.

j) Lithium-ion (Li-on) charger module and 18650-batteries

These devices are used to supply the power source that is rechargeable for the intelligent cane.

The assembled intelligent cane was controlled by Arduino code written in C ++ language on the Arduino IDE version 1.8.12, a development tool on the Windows platform. The compiled file was uploaded into ESP32 directly. These developed operations support both devices and web application controls based on the station mode of ESP32 and the internet connection to the central server. This central server includes the application program interface (API) and MySQL database for logging data of the elderly traveling while holding the intelligent cane. These logging data are sent directly from the cane, which has benefits for tracking the elderly and modeling the daily travel surveillance forecasting. IoT devices used to develop the intelligent cane are illustrated in Fig. 4.

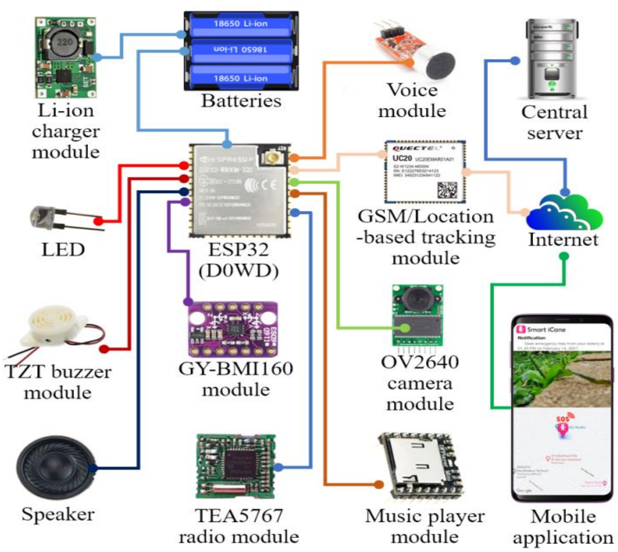


Fig 4: The IoT devices used to develop the intelligent cane

C. Modeling of the daily travel surveillance forecasting

The daily travel surveillance forecasting model monitors and tracks the daily elderly walking, whether abnormal or not. There are three processes for building the model as follows.

First, there are 3,331 records of data in this study. These data were collected from the daily journeys of twenty elderly people in Ratchaburi province for thirty days. After the data were cleaned, the remaining data was 1,916 records and formatted into comma-separated values (CSV) files for the second process with Python version 3.8.3 programming.

Second, the data in the CSV file was carefully checked. It was found that there were some groups of data with limited inputs or imbalanced. Therefore, to improve machine learning opportunities and validity, the data were adjusted to balance using the SMOTE method by increasing the dataset of the minority class with the smallest number of inputs. This work applied (1) to increase the number of minority observations [6, 28–29].

$$X_{new} = x_i + (\acute{x}_i - x_i)\delta \tag{1}$$

where:
X_{new} indicates new dataset;
$\acute{x}_i$ indicates the latest randomized variable;
x_i indicates other random variables;
δ indicates the generated random number from 0 to 1.

In this study, the parameter of the percentage of SMOTE was increased between 100% and 400%. Thus, five datasets were produced to build the model, including original data (imbalanced data), 100%, 200%, 300%, and 400% of SMOTE, which has data between 1,916 and 5,106 records, as in Fig. 5.

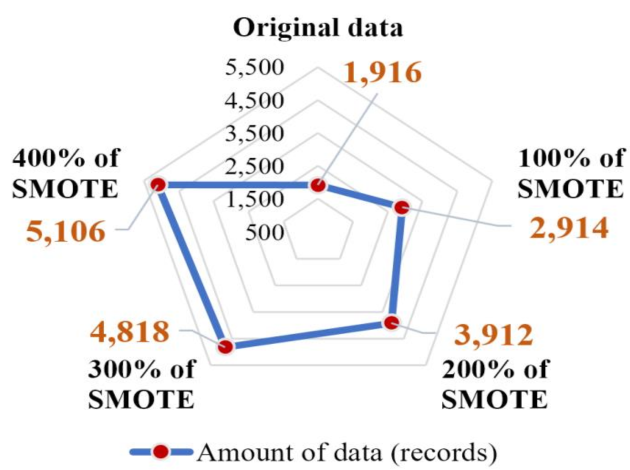


Fig 5: The new balanced datasets using the SMOTE method

Last, all five datasets were delivered to the learning process with the Multi-Layer Perceptron Neural Network (MLPNN) [30]. MLPNN is one of the deep learning techniques that is used for complex work very well. Basically, MLPNN consists of three layers: input layers, hidden layers, and output layers [30], each with a different number of nodes or neurons based on the complexity of the input and learning needs. Each layer generates the output (x) from the summation of inputs and weights, then applied the favorite activation function such as sigmoid function (σ) [31] to classify the class output, as in (2) [32] and (3) [33].

$$x = \sum_{i=1}^{n} W_i a_i + b \quad (2)$$

$$\sigma(x) = \frac{1}{1+e^{-x}} \quad (3)$$

where:
$x$refers to the output of each layer;
$n$refers to the number of inputs of the previous layer;
$a_i$refers to the input vector;
$W_i$refers to the weight;
$b$refers to the bias to adjust the output.

In this work, the authors specified the parameters of the MLPNN for building the model as follows: hidden layer sizes=4, activation=relu, learning rate=0.3, momentum=0.2, max iteration=500, batch size=auto, and early stopping=true. These parameters provided the highest effective results and were measured by 10-fold cross-validation.

D. The Development of Mobile Application

The mobile application was designed and developed for use together with the developed intelligent cane. This application was called Smart iCane, which works on both iOS and Android. The application user interfaces were designed and shown in Fig. 6 and Fig. 7.

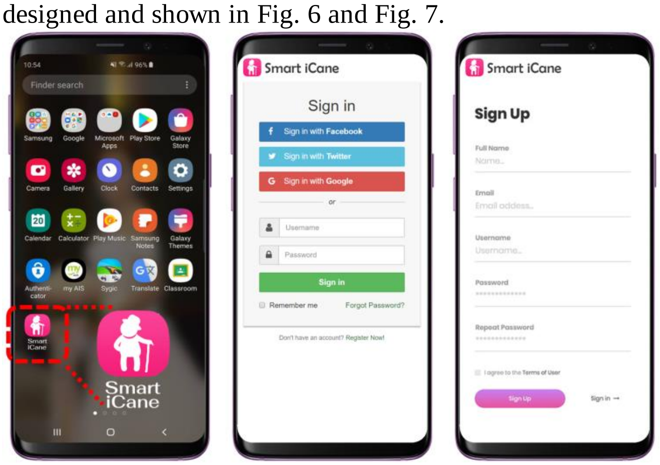


Fig 6: The Smart iCane app icon and user interface

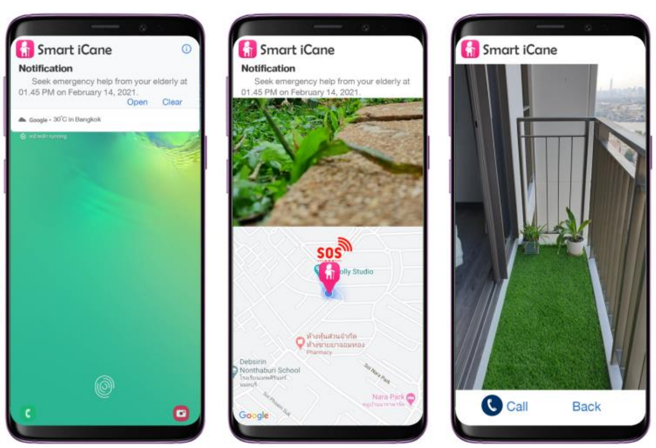


Fig 7: The sample notification and live streaming remotely by the elderly family

The primary function was developed based on the Ionic framework and JavaScript technology, while the mobile application layout and user interfaces (UI) were designed based on the Hypertext Markup Language revision 5 (HTML5) combined with the Cascading Style Sheets (CSS). Also, the Google Map API was applied to display the elderly position based on GPS tracking operation. The users of this application are family members of the elderly person. They can be tracking, monitoring, and communicating with their elderly while being used the intelligent cane.

Furthermore, the user can remote control the camera on the cane to snapshot photos or live video streaming with user authentication to access their intelligent cane. Moreover, the mobile application communicates with API on the central server to forecast the daily travel surveillance of the elderly. Thus, in case of abnormal daily travel, the application will alert message to the user. This API was developed based on the Flask framework written in Python version 3.8.3.

E. The effectiveness evaluations

The effectiveness evaluations were explained as follows.

a) The effectiveness of the daily travel surveillance forecasting model.

It was evaluated by the four effectiveness evaluation methods, including accuracy, precision, recall, and F-measure, as in (4), (5), (6), and (7) [34–35], respectively in the confusion matrix.

$$Accuracy = \frac{TN+TP}{TP+FP+FN+TN} \quad (4)$$

$$Precision = \frac{TP}{FP+TP} \quad (5)$$

$$Recall = \frac{TP}{TP+FN} \quad (6)$$

$$F - measure = \frac{2 \times Precision \times Recall}{Precision + Recall} \quad (7)$$

where:

TPrepresents the number of results predicting that the elderly daily travel is not abnormal (positive) while the actual class is positive;

TNrepresents the number of results predicting that the elderly daily travel is abnormal (negative) while the actual class is negative;

FPrepresents the number of results predicting that the elderly daily travel is not abnormal while the actual class is negative;

FNrepresents the number of results predicting that the elderly daily travel is abnormal while the actual class is positive.

b) The effectiveness of the intelligent cane

It was evaluated in terms of the satisfaction of all features that can work appropriately by twenty users, including fifteen elderly persons and five experts. According to Table 1, it was found that the commercial canes have a total of eighteen features or abilities. This work removed an umbrella feature and added four features into the intelligent cane, including 1) automatic call and snapshot photo to alert the application in case of fall over, 2) automatic light and sound alarm in case of fall over, 3) family user remote control the camera to snapshot photo and live video, and 4) alert abnormal daily walking with daily travel surveillance forecasting. The twenty samples, including five experts and fifteen elderly, were informed on conducting the trials and received introductory intelligent cane usage training by signing a voluntary memorandum of understanding on research methodology and ethics. The mean ($\bar{x}$), standard deviation (SD) [36], interquartile range (IQR), and quartile deviation (QD) were conducted to evaluate the effectiveness. The scores of effectiveness are between 1 and 5 points regarding the Likert scale [37].

c) The effectiveness of the learning outcomes

It was evaluated by twenty elderly persons who were trained in intelligent cane usage and answered both pre-training and post-training tests [38]. Both pre-test and post-test consisted of ten pairs of questions and answers that use the same set of questions only with an alternating sequence of questions and answers. All the answers were used in an analysis to compare the training achievement of twenty-persons samples (N). The statistical t-Test of the hypotheses was conducted using the comparison of achievements obtained from taking pre-training test and post-training test. The statistically significant level (α) was set at 0.05 in this research.

III. RESULTS

In this research, the effectiveness evaluation results and learning outcomes were shown as the following.

A. The effectiveness evaluation result of the model

The original dataset was synthesized the imbalanced data by increasing minority class using 400% of SMOTE up to 5,106 records. This new dataset produced higher effectiveness than other datasets to generate and validate daily travel surveillance forecasting models by applying the MLPNN technique. The effectiveness of the model was evaluated and shown as the confusion matrix in Fig. 8.

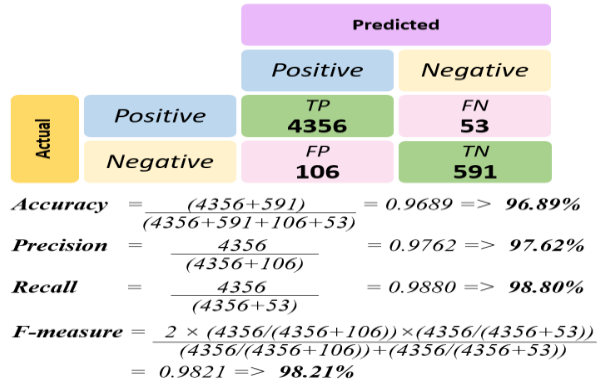
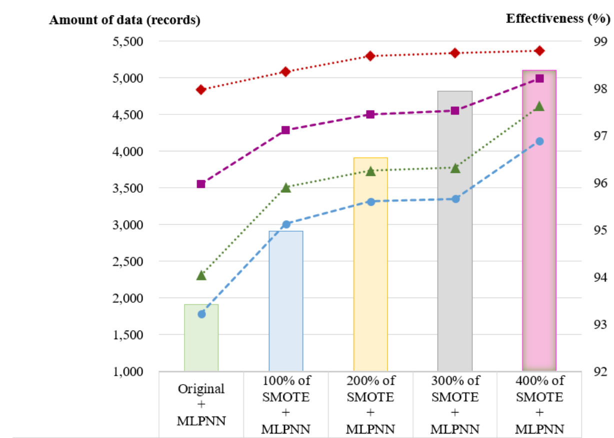


Fig 8: The effectiveness of the model of 400% of SMOTE in the confusion matrix

The confusion matrix has shown that TP, FP, FN, and TN values are 4,356, 106, 53, and 591, respectively. The results illustrate that the accuracy was 96.89%, the precision was 97.62%, the recall was 98.80%, and F-measure was 98.21%. The comparison results of the five forecasting models are shown in Fig. 9.



	Original + MLPNN	100% of SMOTE + MLPNN	200% of SMOTE + MLPNN	300% of SMOTE + MLPNN	400% of SMOTE + MLPNN
Amount of data (records)	1,916	2,914	3,912	4,818	5,106
Accuracy (%)	93.22	95.13	95.60	95.66	96.89
Precision (%)	94.04	95.90	96.25	96.32	97.62
Recall (%)	97.97	98.35	98.68	98.75	98.80
F-measure (%)	95.97	97.11	97.45	97.52	98.21

Fig 9: The comparison results of the effectiveness evaluation of the models

B. The effectiveness evaluation results of the intelligent cane

Experts and the elderly evaluated the effectiveness of intelligent cane features in terms of user satisfaction. The evaluation result is demonstrated in Table II.

TABLE II
THE EFFECTIVENESS EVALUATION RESULT OF THE INTELLIGENT CANE

Feature	User satisfaction					
	$\overline{x}$	SD	IQR	QD	Percentage	Level
Good material	4.75	0.43	0.25	0.13	95.00	The highest
Lightweight	4.60	0.49	1.00	0.50	92.00	The highest
Cane extensibility	4.80	0.40	0.00	0.00	96.00	The highest
Wrist strap	4.75	0.43	0.25	0.13	95.00	The highest
Tip of cane	4.65	0.48	1.00	0.50	93.00	The highest
Flashlight	4.85	0.36	0.00	0.00	97.00	The highest
Battery capacity	4.80	0.40	0.00	0.00	96.00	The highest
Data storage unit	4.55	0.50	1.00	0.50	91.00	The highest
SIM card support	4.95	0.22	0.00	0.00	99.00	The highest
Emergency call	4.90	0.30	0.00	0.00	98.00	The highest
Dial and receive a call	4.95	0.22	0.00	0.00	99.00	The highest
Sound alarmed	4.65	0.48	1.00	0.50	93.00	The highest
Light alarmed	4.50	0.50	1.00	0.50	90.00	The highest
Text or short message	4.85	0.36	0.00	0.00	97.00	The highest
Location-based tracking	4.95	0.22	0.00	0.00	99.00	The highest
Built-in camera	4.95	0.22	0.00	0.00	99.00	The highest
Music and radio	4.60	0.49	1.00	0.50	92.00	The highest
Automatic call and snapshot to the application when falling over	5.00	0.00	0.00	0.00	100.00	The highest
Automatic light and sound alarm when falling over	4.90	0.30	0.00	0.00	98.00	The highest
Remote control the camera to snapshot and live	5.00	0.00	0.00	0.00	100.00	The highest
Alert abnormal daily walking by a forecasting model	4.75	0.43	0.25	0.13	95.00	The highest
Average	**4.80**	**0.40**	**0.32**	**0.16**	**95.90**	**The highest**

According to Table 2, the result showed that two new features of 'Automatic call and snapshot to the application when falling over' and 'Remote control the camera to snapshot and live' are the highest mean at 5.00. On the other hand, the mean values of 'Automatic light and sound alarm when falling over' and 'Alert abnormal daily walking by a forecasting model' were 4.90 and 4.75, respectively. In total, the average mean value was 4.80, with an SD of 0.40, and the percentage was 95.90%. There are no features scored with a mean value lower than 4.50, as shown in Fig. 10.

Additionally, the developed system was also analyzed in terms of conformity by the users in quartiles. The results suggested that the IQR values were not higher than one. Moreover, the QD values had no more than 0.5. These results indicated that all samples shared the same viewpoint and rated the application similarly.

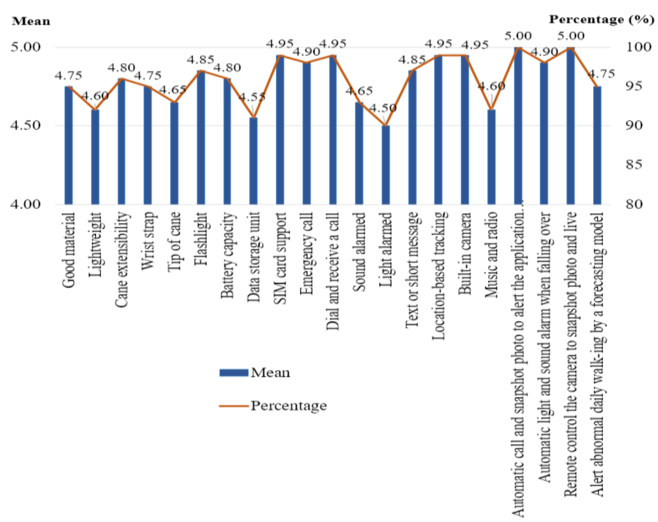


Fig 10: The comparison of features of the intelligent cane effectiveness evaluation

C. The learning outcomes results of the intelligent cane and application

The learning outcomes can be measured by learning achievements using the intelligent cane obtained from twenty samples using statistical hypothesis testing methods defined as follows.

H0: There was no difference in the scores obtained from the pre-test and post-test on the training of using the intelligent cane and the application.

H1: There were differences in the scores obtained from the pre-test and post-test on the training of using the intelligent cane and the application.

According to the results of doing the pre-test and post-test, it was found that the pre-test had a mean score was 11.30, and the standard deviation was 0.50, while the post-test score averaged a mean of 18.20 and had a standard deviation of 0.35, as exhibited in Table 3. By applying the statistical t-Test, the significant level was set to 0.05. The result has shown that the t-Test score was -13.56, and the p-value was 0.000, which is lower than the significant level of 0.05. Thus, it is possible to reject the H0 hypothesis and accept the H1 hypothesis. Therefore, it can be said that there were statistically significant differences in the scores obtained from the pre-test and post-test on the training of using the intelligent cane and the mobile application.

TABLE III
THE EFFECTIVENESS EVALUATION RESULT OF THE LEARNING OUTCOMES

Comparison issue		Learning result
Pre-test	Mean	11.30
	SD	0.50
Post-test	Mean	18.20
	SD	0.35
	t	-13.56
	p-value	0.000

IV. CONCLUSION AND FUTURE WORK

This paper presents intelligent cane development for suburban elderly using MLPNN and the IoT. There are twenty-one features in a total of the intelligent cane. Incredibly, four new features were developed and added, which were not found in the commercial or market. Incredibly, these features focused on creating a daily travel surveillance forecasting model for elderly people who are more likely to deviate from their regular routes or spend more time at a new location expected. This cause might be an abnormal event and needs to raise awareness among their families based on the deep learning technique. The SMOTE method was used to synthesize the imbalanced data to increase the accuracy of the model. According to the study result, after synthesizing, the most appropriate data size was 400% of SMOTE, which increased up to 5,106 records. These datasets were used to construct the models by using the MLPNN method. It was discovered that the model that was generated by 400% of SMOTE and classified by MLPNN had the highest accuracy in data classification, with an accuracy of 96.89%.

The developed intelligent cane is based on the IoT, which is coded on Arduino. Simultaneously, the developed mobile application is based on an Ionic framework that supports cross-platform applications. Experts and suburban elderly people who are samples evaluated the effectiveness of the intelligent cane and the mobile application using the user satisfaction approach. The result of user satisfaction showed that the users provided a mean of 4.80 and an SD of 0.40 while using the intelligent cane. According to the IQR, all values were not over one, and the QD had no more than 0.5. It was indicated that all participants' evaluations were in the same direction and similarly rated the application and the intelligent cane.

Moreover, the pre-training and post-training assessment tests were conducted to measure the elderly's learning outcomes effectiveness. The learning outcome has shown that the mean of the post-testing score was higher than the pre-testing score, which was a statistically significant difference. According to the learning outcomes result, it was found that the elderly could perceive, learn and appreciate the new technology necessary for walking. It could be said that lifelong learning helps stimulate the bodies and minds of the elderly to be ready to use innovations and technologies beneficial to their daily living. It was agreed with the concept of lifelong learning in the elderly of Conley and Rauth [26] and Nordstrom [27].

For future work, the authors planned to study the learning of the elderly through collecting information on the health of the elderly through the use of an intelligent cane, study techniques to predict the risk of disease of the elderly, and to closely and timely link to the local health database in suburban areas for elderly health care.

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