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Animal-Assisted Therapy for Persons with Disabilities Based on Canine Tail Language Interpretation via Gaussian-Trapezoidal Fuzzy Emotional Behavior Model

W. Phanwanich, O. Kumdee, P. Ritthipravat, and Y. Wongsawat*

Abstract**—**In order to alleviate the mental and physical problems of persons with disabilities, animal-assisted therapy (AAT) is one of the possible modalities that employs the merit of the human-animal interaction. Nevertheless, to achieve the purpose of AAT for persons with severe disabilities (e.g. spinal cord injury, stroke, and amyotrophic lateral sclerosis), real-time animal language interpretation is desirable. Since canine behaviors can be visually notable from its tail, this paper proposes the automatic real-time interpretation of canine tail language for human-canine interaction in the case of persons with severe disabilities. Canine tail language is captured via two 3-axis accelerometers. Directions and frequencies are selected as our features of interests. The novel fuzzy rules based on Gaussian-Trapezoidal model and center of gravity (COG)-based defuzzification method are proposed in order to interpret the features into four canine emotional behaviors, i.e., agitate, happy, scare and neutral as well as its blended emotional behaviors. The emotional behavior model is performed in the simulated dog and has also been evaluated in the real dog with the perfect recognition rate.

Keywords**—**Animal-assisted therapy (AAT), Persons with disabilities, Canine tail language, Fuzzy emotional behavior model

I. Introduction

NOWADAYS, there are a lot of patients that lose the movement abilities and need a long term treatment in the hospital or health care facilities. These patients often have the physical, cognitive and emotional problems because of the depression, fear, or loneliness due to lacking of the communication with other people. Animal-assisted therapy (AAT) is a new alternative therapy that integrates the animal loveliness to the treatment process. There are many researches show that patient's positive emotions (for example, happiness, hopefulness, and optimism) are directly related with decreased disabilities, better health and increased survival [1-3]. Since the specialty of the well-trained animals is that they accept people as they are, unconcerned with age or physical ability [4], so they can create the positive emotion that could reduce the risk of dying from heart attack or stroke and also increase the survival rate of cancer patients. The activities with the animals, especially dogs, have an observable impact on the patients' emotion and increase their well being as some hospitals add the AAT program to be a part of the patient treatment process. For example, some AAT activities inspirit the patients to focus less on pain, reduce stress and anxiety [5], reduce blood pressure and increase the sensory stimulation.

For the severe disabled persons (e.g., spinal cord injury, stroke, and amyotrophic lateral sclerosis), they also need this alternative treatment because AAT can provide both physical and mental benefits. However, traditional AAT does not work because the severe disabled persons cannot efficiently move and observe their animal's emotional behaviors. This study aims to explore the new method to improve the efficiency of two-way communication between persons with disabilities and their animals. Normally the animal's emotion behaviors are shown via body language, i.e., ears, eyes, mouth and teeth, body, tail and vocalization. In this study, we focus only with some emotional behaviors that probably present when the animal (i.e. dog) stays in the environment of the severe disabled persons. Therefore, canine tail language is one of the possible and proper ways for enhancing the emotional behavior feedback in the AAT program for persons with severe disabilities because it is simple and can indicate several emotional behaviors.

According to our previous work in [6], triangular and trapezoidal fuzzy emotional behavior models are proposed. In order to further improve the classification accuracy, the new fuzzy emotional behavior models based on Gaussian and trapezoidal models are proposed. The achievement on modeling of the animal behaviors can lead to the real-time animal emotional interpretation. This system can proficiently improve the existing AAT system for the severe disabled persons.

II. Proposed Canine Tail Language Using A Fuzzy Behavior Model

In this paper, we propose the automatic real-time interpretation of canine tail language for human-canine interaction in the case of persons with severe disabilities. The scope of this paper will focus specifically on the human-

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W. Phanwanich is with the Department of Biomedical Engineering, Mahidol University, 25/25 Putttamonthon 4, Salaya, Nakornpathom 73170 Thailand (e-mail: pp_jung@hotmail.com).
O. Kumdee is with the Department of Biomedical Engineering, Mahidol University, 25/25 Putttamonthon 4, Salaya, Nakornpathom 73170 Thailand (e-mail: orrawan_k@yahoo.com).
P. Ritthipravat is with the Department of Biomedical Engineering, Mahidol University, 25/25 Putttamonthon 4, Salaya, Nakornpathom 73170 Thailand (e-mail: egprp@mahidol.ac.th).
*Y. Wongsawat is with the Department of Biomedical Engineering, Mahidol University, 25/25 Putttamonthon 4, Salaya, Nakornpathom 73170 Thailand (corresponding author, phone: 66-82-889-2138 Ext 6361; fax: 66-82-889-2138 Ext 6366; e-mail: egyws@mahidol.ac.th).

canine expression. Three emotional behaviors are employed, i.e. agitate, happy and scare because they are the basic emotional behaviors and possible to discriminate by tail language. Tail directions and frequencies are selected as our features of interest. Since the canine emotional behaviors cannot be clearly determined and we also need to process in real-time for AAT, we apply the fuzzy rule based system similar to [7] (which is applied to detect the emotion state in people from six angles on the face) to classify three emotional behaviors. Three fuzzy classification modules are thus developed as shown in Fig. 1. The voltage changing in x-axis and the wagging frequency in y-axis that represent tail direction (D) and frequency (F) are used as crisp inputs to each module. The output of each fuzzy inference system (intensity of emotional behavior) represents the level of its corresponding emotional behavior. Lastly, all emotional behaviors are calculated and defined as neutral, pure or blending (Fig. 1).

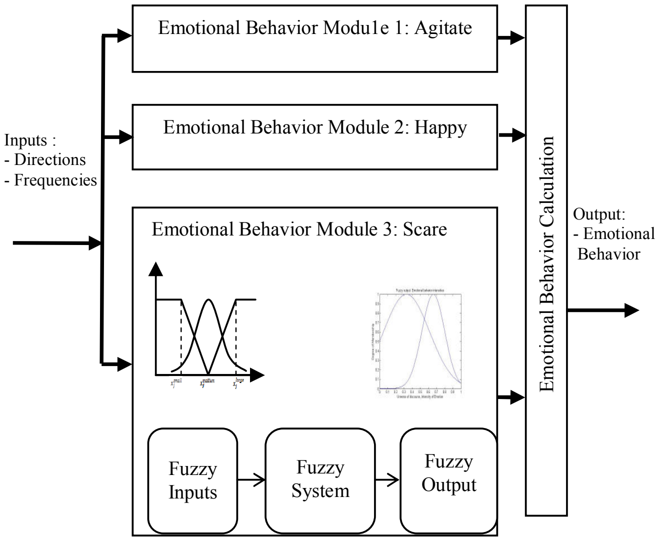


Fig. 1 Diagram of fuzzy classification modules.

Tail direction and frequency are used as crisp inputs to each fuzzy system as shown in Fig.1. Output of the fuzzy inference system is sent to the emotional behavior calculation in order to classify neutral, pure or blending emotional behavior.

A. Fuzzy Inputs

In this paper, we use a simulated dog to develop all membership functions under the veterinarian's opinion since dogs cannot be trained to express specific emotional behaviors. Once we get the emotional behavior model, we then test it with a real dog. The features of interest (input signals) are captured via two 3-axis accelerometers (MMA7260Q) that determine the changing rate of velocities in the x, y and z directions. The device is setup on the back and tail of the dog. The signal is converted from analog to digital via NI USB6009 DAQ and analyzed in LabVIEW™ (Fig. 2). In this study, we primarily focus on the signals from the tail accelerometer in the x-and y-axes, the z-axis is used as a backup to the x-axis since we figure out that the flip direction is not too much affected to our selected behaviors.

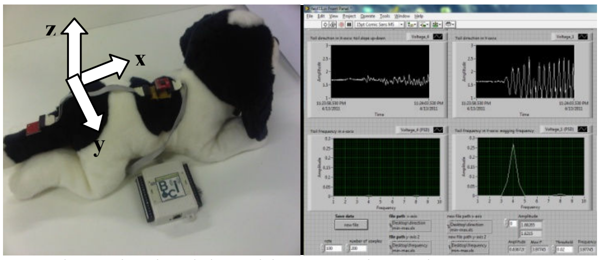


Fig. 2 Simulated dog with two 3-axis accelerometers on the back and tail

According to Fig. 3, each fuzzy input can be described by three linguistic terms, i.e., low (L), medium (M) and high (H). The membership functions for low and high input have trapezoid shapes while the medium input has a Gaussian shape.

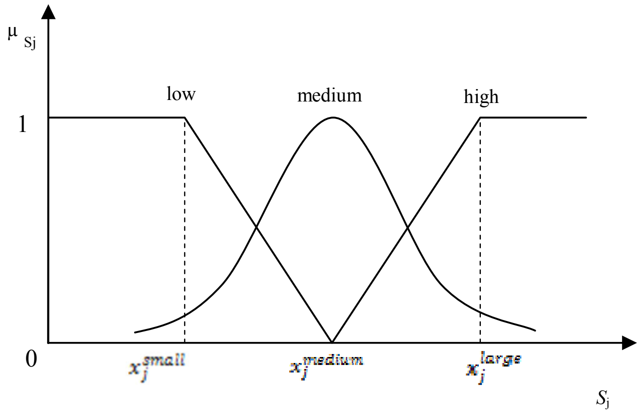
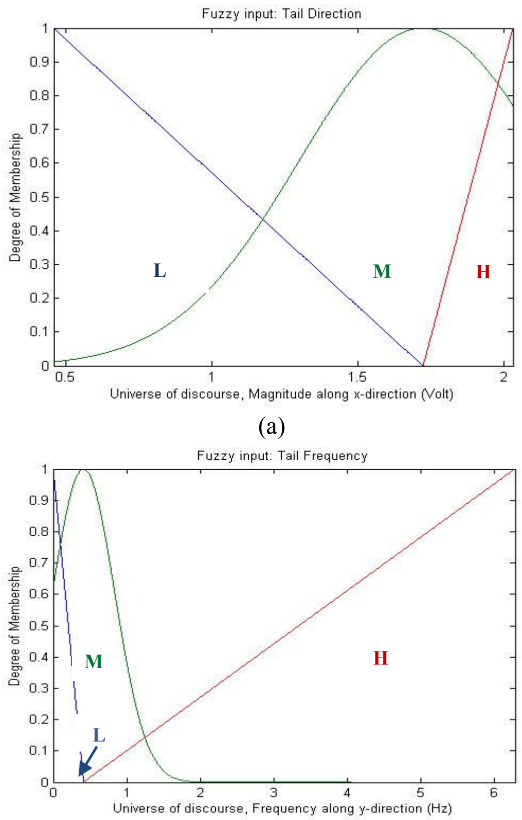


Fig. 3 Fuzzy inputs of a signal model. The membership functions for low and high have trapezoid shapes, medium has a Gaussian shape.

The exact trapezoidal and Gaussian (standard deviation equals to 0.3 and mean equals to x_j^{medium}) shapes are defined by 3 points of S_j related with the functions shown below:

$$x_j^{small} = \min\{S_j^i\}$$
$$x_j^{large} = \max\{S_j^i\}$$
$$x_j^{medium} = \frac{1}{N}\sum\{S_j^{neutral}\}$$

where S_j^i is the signal data, i = 1, 2, 3 (three emotional behaviors as agitate, happy and scare), j = D, F (two input signals as direction (D) and frequency (F)) and neutral is the neural expression. Each signal dataset is collected in 120 seconds with sampling rate of 100 Hz. The universe of discourse of tail direction is the magnitude along x-direction. The values are between 0.4 to 2.4 volts, the initial value of accelerometer is around 1.72 volts. The universe of discourse of tail frequency is the frequency along y-direction. The values are between 0 to 7 Hz. Hence, we get both inputs shown in Figs. 4 (a) and (b).



(b)

Fig. 4 Fuzzy inputs (a) Tail direction. (b) Tail frequency. Each input signal is defined to three linguistic terms as low (L), medium (M) and high (H). The blue plot can be constantly extended to the minimum value of sensor, while the red plot can be constantly extended to the maximum value of sensor to yield the trapezoidal shapes.

Since the lowest value of the tail frequency approaches to zero, the shape of the low membership function will look similar to the triangular shape.

B. Fuzzy Rules

A separate rule set is generated based on the veterinarian's opinion for each basic emotion. Each rule takes S_j, where j = D, F, as inputs and produces I_{ei} which is either strong or weak as output (TABLE I).

TABLE I
FUZZY RULES FOR EMOTIONAL BEHAVIOR CLASSIFICATION

Emotional Behavior	***Inputs***		***Output***
	Tail Direction(D)	**Tail Frequency(F)**	**Level of Emotional Behavior**
***Module1:* Agitate**	High	low	strong
	high	medium	weak
	high	high	weak
***Module2:* Happy**	Medium	high	strong
	medium	medium	weak
	medium	low	weak
***Module3:* Scare**	low	low	strong
	low	medium	weak
	low	high	weak

For example,

1) IF D is medium AND F is high THEN I_{happy} is strong. This means that if the tail direction is medium and the tail frequency is high. The emotional behavior is related with the rule in module 2 (happy) and the emotion level is strong.

2) IF D is low AND F is high THEN I_{scare} is weak. It indicates that if the tail direction is low and the tail frequency is high. The emotional behavior is related with the rule in module 3 (scare) and the emotion level is weak.

C. Fuzzy Outputs

The intensity I_e of an emotional behavior e_i is represented by two Gaussian membership functions with standard deviation of weak emotion equals to 0.2 and strong emotion equals to 0.1 (Fig. 5). The standard deviation of weak emotion is greater than strong emotion since it normally has higher chance to occur. Fuzzy inference is applied by the Mamdani Min technique.The output for each emotion is defuzzified by employing the center of gravity (COG) method. By projecting the COG to the x-axis, we can compute the corresponding emotional behavior intensity.

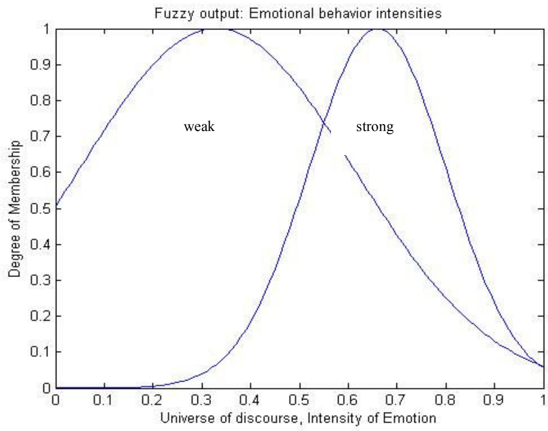


Fig. 5 Fuzzy output: emotional behavior intensities.

D. Emotional Behavior Calculation

To fairly compare the result with our previous work in [6], we also represent a fuzzy classification of emotional behavior model using fuzzy hypercube [6]. Let E be a finite set of 3 emotional behaviors, i.e., E = {e_1, e_2, e_3}, e_1 represents agitate, e_2 represents happy, and e_3 represents fear. BE is the member of μFE_j that can be mapped to the interval [0, 1] that is

$$\mu FE_j : BE \rightarrow [0, 1], j = 1, 2, \ldots$$

where μFE_j is a membership of FE_j, then

$$FE_j := \{(e_i, \mu FE_j(e_j)) \square e_j \square E\}, j = 1, 2, \ldots$$

defines a fuzzy set corresponding to an emotional behavior state. j represents an arbitrary point in fuzzy unit cube. The output of each fuzzy inference system represents intensity of emotional behavior. If all intensity values (agitate, happy, scare) are equal or under 0.55, such emotional behavior state is neutral. If the intensity value above 0.55, such emotional behavior state is an active emotional behavior. Sometimes dogs may express more than one emotional behavior, so called the blending emotional behavior. The blending of any two active emotional behavior state is called dyad. Three active blending is called triad.

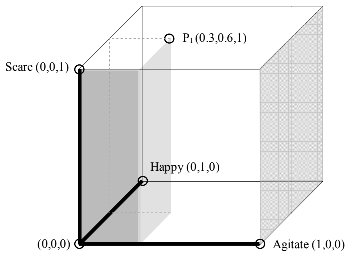


Fig. 6 Fuzzy unit cube for three emotion behaviors. Each axis represents an emotion behavior. P_1 = (0.3, 0.6, 1) corresponding to the fuzzy set FE_1 = {(agitate, 0.3), (happy, 0.6), (scare, 1.0)} represents a blend emotional behavior state between happy and scare

The emotion intensities are combined with an emotional behavior state in the fuzzy emotional behavior model as shown in Fig.6. Each axis represents an emotion behavior, i.e., x-axis represents the intensity of agitate emotional behavior, y-axis represents the intensity of happy emotional behavior, z-axis represents the intensity of scare emotional behavior. A point in the *n*-dimensional hypercube (P_j) is denoted by membership vector, (μFE_j (e_l), μFE_j (e_2),…, μFE_j (e_n)) = :(μFE_j (e_i)). For example, point P_1 = (0.3, 0.6, 1) corresponding to the fuzzy set FE_1 = {(agitate, 0.3), (happy, 0.6), (scare, 1.0)} which represents a blending emotional behavior state between happy and scare (dyad).

III. Experimental Results

In this experiment, we evaluate our fuzzy emotional behavior model with a real dog (Fig. 7). The accelerometer on the body illustrates the body slope and some activities that support the emotional behavior interpretations. At the same time, the accelerometer at the tail, which is the main objective of this study, shows the tail direction and wagging frequency. In x-axis of the accelerometer, the signal in time domain defines the dog's tail direction. The voltage will increase when the tail raise and decrease when the tail drop as can be seen in Fig. 8. In y-axis of accelerometer, the signal in time domain is converted to the signal in frequency domain via the fast Fourier transform (FFT). The amplitude in frequency domain defines the wagging frequency (Fig. 9). The comparisons of simulated and real dogs are display in the similar way, however the real dog signals look a little noisy (Figs. 8 and 9). Furthermore, in this experiment, we also try to draw attention and measure the signal when the dog expresses the obvious emotional behaviors. The data input is collected and 20 data are taken into consideration. After that we employ our Gaussian-trapezoidal fuzzy emotional behavior model. The average recognition rate is 100% since the recognition rates of agitate, happy, scare and neutral are all 100%. With the same dataset, this result is better than the 93.75% accuracy in [7]. From the experiments, blending emotional behavior cannot be observed (Table II). Investigation on a more realistic simulated data should further justify our recognition accuracy.

Fig. 7 Real dog with two 3-axis accelerometers at the back and tail

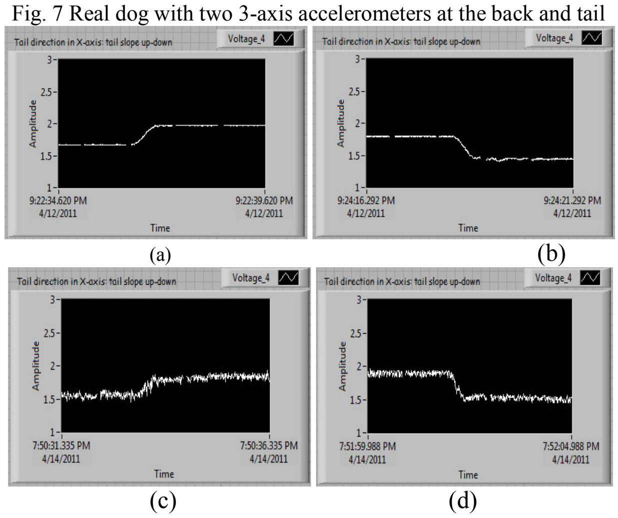


Fig. 8 Front panel of LabVIEW represents the tail signal of x-axis of accelerometer in time domain, 5 seconds time interval is recorded. The signal from simulated dog (a, b) is compared with the signal from the real dog (c, d). The voltage increases when the dog's tail is raised (a, c) and the voltage decrease when the dog's tail is dropped (b, d).

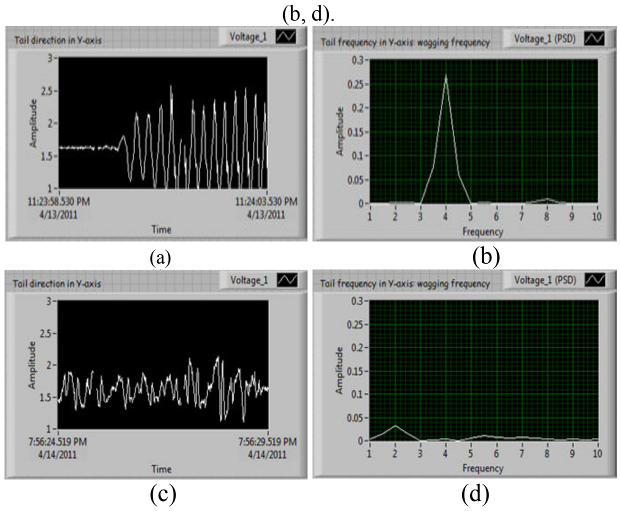


Fig. 9 Front panels of LabVIEW represents the tail signal of y-axis of accelerometer when the dog's tail is wagging, 5 seconds time interval is recorded. The signal from the simulated dog (a, b) is compared with the signal from the real dog (c, d). (a) and (c) are the voltages in time domain. (b) and (d) are the amplitudes in the frequency domain acts as the wagging frequency

IV. Conclusion

In this paper, we have proposed the new canine tail language interpretation method for the AAT system. In the proposed method, we have designed the fuzzy rules based on the Gaussian-Trapezoidal model and the center of gravity (COG)-based defuzzification method. The features of interest have been acquired via the accelerometers in order to obtain the directions and frequencies of the dog's tail. With the proposed rules the average recognition rate of 100% is achieved. For future works, clinical trials are needed in order to efficiently improve our fuzzy emotional behavior model.

TABLE II
CLASSIFICATION ACCURACY OF EMOTIONAL BEHAVIOR OUTPUT CALCULATED FROM THE REAL DOG.

Emotion	*Agitate*	*Happy*	*Scare*	*Neutral*	*Average*
Accuracy	100%	100%	100%	100%	100%

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