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

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*Abstract*— Animal-Assisted Therapy (AAT) is the science that employs the merit of human-animal interaction to alleviate mental and physical problems of persons with disabilities. However, to achieve the goal of AAT for persons with severe disabilities (e.g. spinal cord injury and amyotrophic lateral sclerosis), real-time animal language interpretation is needed. Since canine behaviors can be visually distinguished 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 frequency are selected as our features of interests. New fuzzy rules and center of gravity (COG)-based defuzzification method are proposed in order to interpret the features into three canine emotional behaviors, i.e., agitate, happy, and scare as well as its blended emotional behaviors. The emotional behavior model is performed in the simulated dog. The average recognition rate in real dog is 93.75% accuracy.

## I.    INTRODUCTION

Disability is the condition that human loses the capabilities of their voluntary movement. Many patients need a long term treatment in the hospital or health care facilities for medical, rehabilitation and long term care services. It is normal for patients to feel depress because of illnesses, separation from family, fear, loneliness, lacking of communication with other people. Moreover, some types of paralysis have no treatment. This often causes the patients experience physical, cognitive and emotional problems. There are many research projects show that patient's positive emotions (such as, happiness, optimism and hopefulness) are related with decreased disabilities, better health and increased survival [1], [2], [3]. Animal-Assisted Therapy (AAT) is a new alternative therapy that involves an animal with specific characteristics as an elementary part of a person's treatment. It provides a welcome change in routine as a part of the clinical health-care treatment process. The specialty of selected animals is that they accept people as they are, unconcerned with age or physical ability [4]. AAT is designed to improve the physical, social, emotional, memory, cognitive skills. Interacting with the animal has a noticeable

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impact on their emotion and increases their well being as some hospitals add AAT program to be a part of patient palliative. Many activities encourage patients to focus less on pain, reduce stress and anxiety [5], reduce blood pressure and increase sensory stimulation. The patients often move further in therapeutic activities than they have previously without the AAT. It has been observed that animals could reduce the risk of dying of a heart attack or stroke and also increase the survival rate of cancer patients.

Although AAT and activity visits provide many physical and mental benefits, for the severe disabled persons (e.g., spinal cord injury and amyotrophic lateral sclerosis), this treatment is limited. Since the severe disabled persons cannot efficiently move and observe their animals emotional behaviors, this study aims to explore the new method to enhance the two-way communication between persons with disabilities and their animals. Real-time animal emotional interpretation can provide more understanding about animal emotion. This idea can efficiently improve the existing AAT system for the severe disabled persons.

Likewise, human and dogs are communicated using "body language". Each dog normally expresses the emotional behaviors in a slightly different manner. There are various emotional behaviors in the dogs that show by the body languages, but, so far no efficient specific and fast rules for interpreting canine body language. Some signals, like tail-wagging, are simple and can indicate several emotional behaviors including the level of behaviors. For AAT, we concern just some emotional behaviors that probably show when the dog stays in patient environment. Therefore, canine tail language is one of the possible and appropriate ways for enhancing the emotional behavior feedback in AAT program for persons with severe disabilities.

## II.    PROPOSED CANINE TAIL LANGUAGE USING A FUZZY BEHAVIOR MODEL

This paper proposes the automatic real-time interpretation of canine tail language for human-canine interaction in the case of persons with severe disabilities. In this circumstance, the probably behaviors should be only human-canine expression. Three emotional behaviors are selected, i.e. agitate, happy and scare because they are the basic emotional behaviors and possible to distinguish 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 [6] (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. Finally, all emotional behaviors are calculated and defined as neutral, pure or blending (Fig. 1).
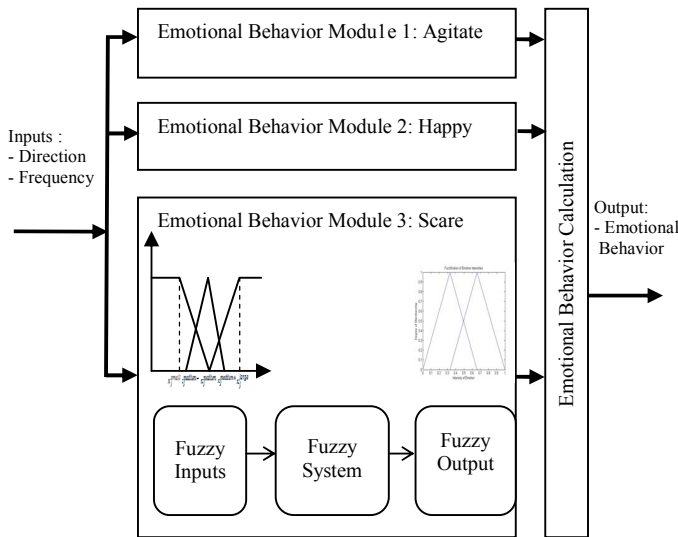
Fig. 1 Diagram of fuzzy classification modules.

In Fig. 1, tail direction and frequency are used as crisp inputs to each fuzzy system. 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

Since dogs cannot be trained to express specific emotional behaviors, in this paper, under veterinarian opinions, we use a simulated dog to develop all membership functions. Once we get the emotional behavior model, we finally test it with a real dog.

The input signals are captured via two 3-axis accelerometers, MMA 7260Q, that determine the changing rate of velocities in the x, y and z directions. The device is installed on the back and tail of the dog. The signal is converted from analog to digital by NI USB6009 DAQ and analyzed via LabVIEW program (Fig. 2). In this study, we mainly focus on the signal from the tail accelerometer in 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.
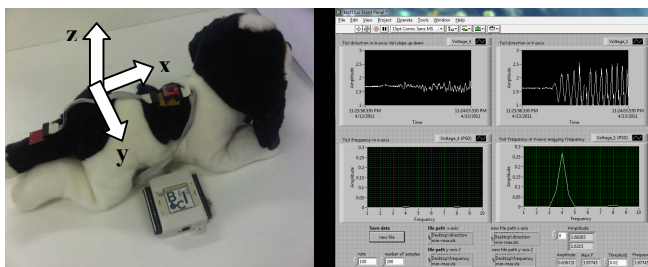


Fig. 2 Simulated dog with two 3-axis accelerometers at the back and tail.

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, medium input has a triangular shape (Fig. 3).
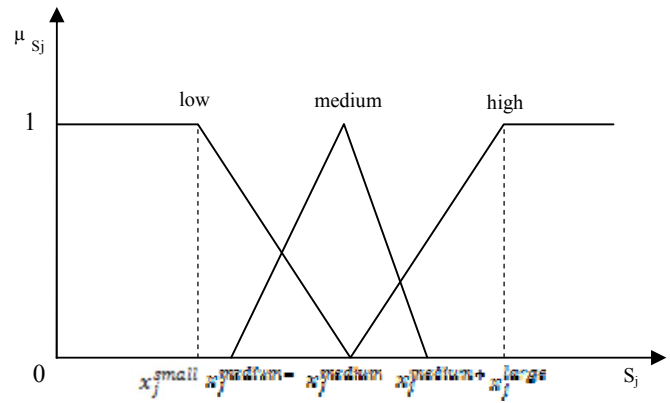


Fig. 3 Fuzzy inputs of a signal model. The membership functions for low and high have trapezoid shapes, medium has a triangular shape

The exact trapezoidal and triangular shapes are defined by 5 points related with the functions shown below:

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

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).
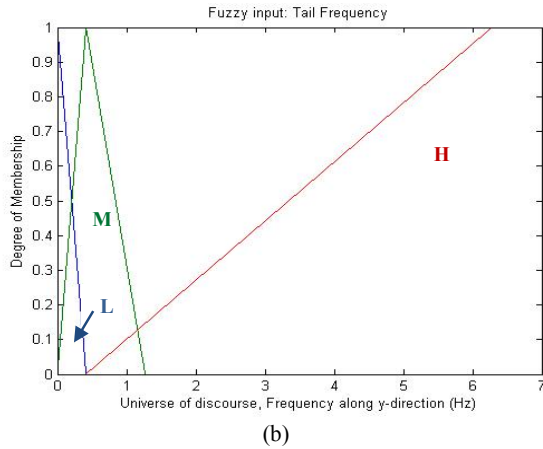


(a)

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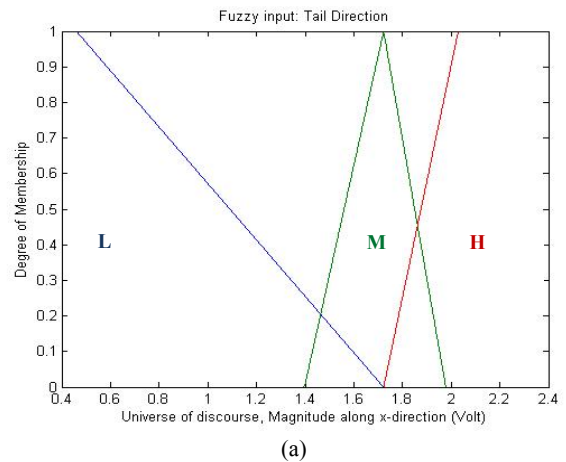
Fig. 4 Fuzzy inputs (a) Tail direction. (b) Tail frequency. Each input signal is defined to three linguistic terms as low (L), medium (M) and high (H).

Because the lowest value of the tail frequency approaches to zero so the shape of low membership function is similar to the triangular shape.

### B. Fuzzy Rules

For each basic emotion, a separate rule set is generated based on veterinarian opinion. 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,
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.

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

For an emotional behavior $e_i$, its intensity $I_e$, is represented by two triangular membership functions, i.e., weak and strong (Fig. 5). Fuzzy inference is applied by the Mamdani Min technique.

Output for each emotion is defuzzified using the center of gravity (COG) method. By projecting the COG to the x-axis, we calculate the corresponding emotional behavior intensity.
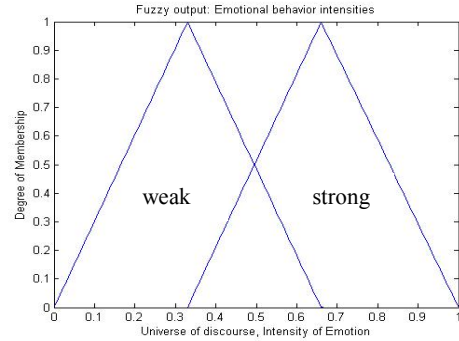


Fig. 5 Fuzzy output: emotional behavior intensities.

### D. Emotional Behavior Calculation

We 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 $\mu FE_j$ that can be mapped to the interval [0, 1] that is

$$\mu FE_j : BE \longrightarrow [0, 1], j = 1, 2, \dots$$

where $\mu FE_j$ is a membership of $FE_j$, then

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

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 under 0.5, such emotional behavior state is neutral. If the intensity value above 0.5, 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.
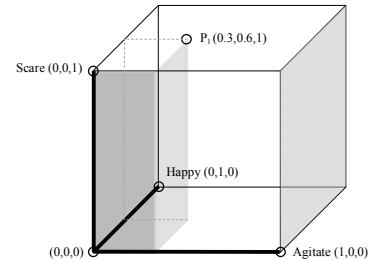


Fig. 6 Fuzzy unit cube for three emotion behaviors. Each axis represents an emotion behavior. $P_1$ = (0.3, 0.6, 1) corresponding to the fuzzy set $FE_1$ = {(agitate, 0.3), (happy, 0.6), (scare, 1.0)} represents a blend emotional behavior state between happy and scare.

According to Fig. 6, the emotion intensities are combined to an emotional behavior state in the fuzzy emotional behavior model. 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, ($\mu FE_j (e_l)$, $\mu FE_j (e_2)$,…, $\mu FE_j (e_n)$) = :($\mu FE_j (e_i)$). 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

We test our fuzzy emotional behavior model with a real dog (Fig. 7). The accelerometer on the body shows the body slope and some activities that support the emotional behavior interpretations. Meanwhile 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 (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 same way, but the real dog signals look a little noisy (Figs. 8 and 9).
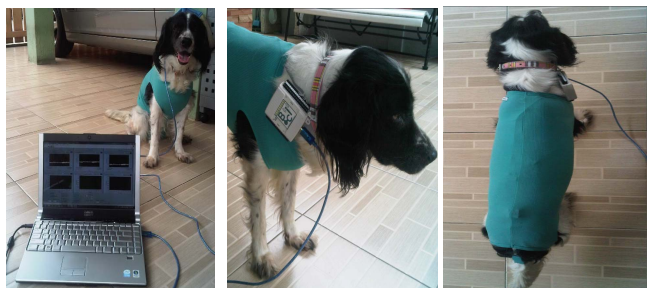


Fig. 7 Real dog with two 3-axis accelerometers at the back and tail.
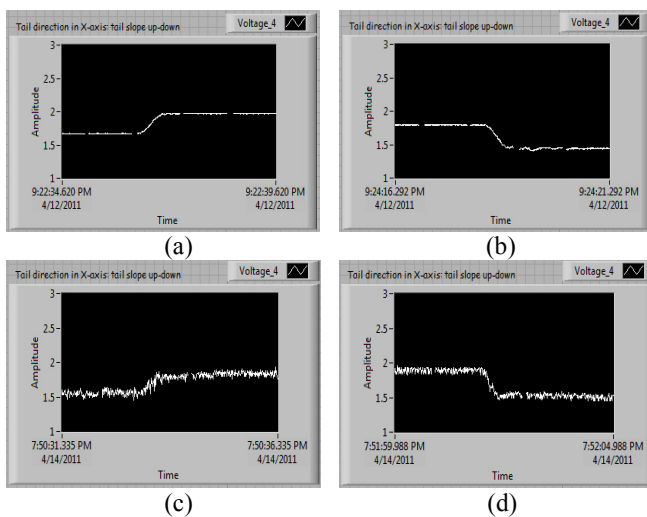


(a)

(b)



(c)

(d)

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).
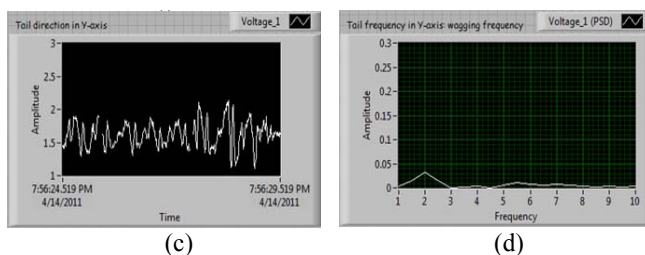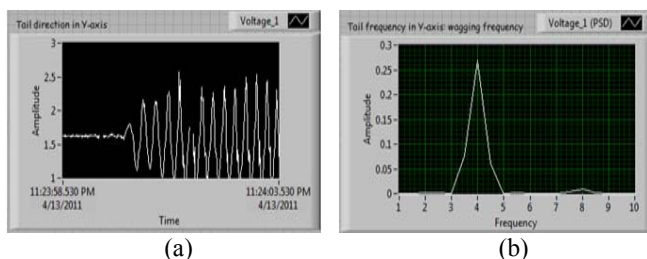


(a)

(b)



(c)

(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.

In this experiment, we 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 fuzzy emotional behavior model. The average recognition rate is 93.75%. The recognition rates of agitate, happy and scare are 100%. The recognition rate of neutral is 75%. The 25% inaccuracy of the neutral shows the output as scare. From the experiments, blending emotional behavior cannot be observed (TABLE II). The confusion of interpretation appears because the simulated data may not be the same as the real dog data. Investigation on a more realistic simulated data should increase our recognition accuracy.

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

| Emotion | Agitate | Happy | Scare | Neutral | Average |
|---|---|---|---|---|---|
| Accuracy | 100% | 100% | 100% | 75% | 93.75% |

## IV. CONCLUSIONS

In this paper, we have proposed the new AAT system. The main contribution of this system is that we have developed the new fuzzy emotional behavior model used specifically for recognizing canine emotional behaviors via tail language. We also propose to use the accelerometer and extract the direction and frequency as the features of interest. With the proposed rules and the proposed features the average recognition rate of 93.75% is achieved. For future works, more essential emotions for AAT will be included. Clinical trials are also needed to further improve the fuzzy emotional behavior model.

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