Towards an Augmented Assistance Dog

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Abstract. Despite the recent progresses in robotics, autonomous robots still have too many limitations to reliably help people with disabilities. On the other hand, animals, and especially dogs, have already demonstrated great skills in assisting people in many daily situations. However, dogs also have their own set of limitations. For example, they need to rest periodically, to be healthy (physically and psychologically), and it is difficult to control them remotely. This project aims to "augment" the service dog, by developing a system that compensates some of the dog weaknesses through a robotic device mounted on the dog harness. The present article shows that the dog's activity and some indexes of the animal emotional state can be successfully identified by the wearable device.

Keywords: Pervasive/wearable systems, remote monitoring, service dogs, assistive technologies, signal processing.

1 Introduction

1.1 Assistance Dogs

In the European Union, in 2002, 16.4% of the population in working-age (16-64 years old) reported that they had a long standing health problem or disability [1]. One of the existing ways to improve the mobility, autonomy, self-esteem and safety of this significant portion of the population is through the use of assistance dogs.

The term Assistance Dog corresponds to the international harmonized terminology to designate the various categories of assistance dogs for people with disabilities, including guide, earring and service dogs [2]. In 2008, solely in the European Union, over 13,000 people already benefited from this type of aid [3]. To be able to have the

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assistance dog status, the animal must be educated and trained in an establishment that meets quality and ethics standards, and that uses specially qualified trainers [2], thus seeking to maximize the safety of every person involved, and also to ensure the well-being of the animal.

1.2 Augmented Dog

Despite major advances in robotics, particularly in emulation and simulation of mechanical behaviour and intelligence of various types of animals, such robots still have too many limitations in order to be able to assist people with disabilities [4]. By contrast, animals, among which the dog, have already demonstrated capacities to assist reliably people in many everyday tasks. However, similarly to the robots, the dog also has its own limitations, being one of the most important ones the necessity of guaranteeing the dog's well-being - both physical and psychological.

In order to take advantage of the strengths and minimize the weaknesses of each (the dog and the robot) the concept of Augmented Dog arises [5]. The aim is to artificially enhance the monitoring and control over the dog, in order to facilitate human-dog interaction. This is done by placing, on the dog, a small robot whose task is to mediate the interaction between the dog and the human. This robot analyzes and interprets various behavioral and/or physiological signals from the dog, and transmits them to the human. In turn, the human can send a command to the robot that will trigger a reaction in the animal through a predetermined order, for which the dog has been trained to react appropriately. A very important feature of Augmented Dogs it's their ability of producing useful data that not only allows for a better understanding of the animal state and condition, but also provides information about the type and frequency of the patient's interaction with his/her quadruped companion.

1.3 Stress: Causes and Symptoms

Dogs can experience stress (both acute and chronic) due to a wide range of situations such as a noisy environment, being restraint, an inappropriate training, transportation, or housing, the presence of strangers, or when faced with completely new or/and unexpected situations. In response, the animal may have a physiological or behavioral reaction, both of them, or even one as a consequence of the other [6] [7]. Many behavioral indicators may be considered, such as tremors, circular locomotion, posture, sighs, vocalizations, urination, tail's agitation (frequency and direction), and panting [8]. Similarly, various physiological indicators can also be taken into account, such as changes in the body temperature and heart rate [9], the heart rate variability [10], the ratios between cortisol and creatinine, and also the amounts of catecholamine, epinephrine, and norepinephrine measured in the urine [8] [11].

1.4 Physiological and Behavioral Analysis

In order to study physiological symptoms, invasive techniques are typically used, such as blood sample collection, or electrodes to perform ECG [10], EMG [12] and acquisition of blood pressure data [6]. Other common ways are through urine sample collection, which usually require the presence of a person in order to acquire a mid-stream sample [11], or by measuring the body temperature – typically measured through rectal temperature – which requires a momentary restraint of the dog [9].

In order to study behavioral symptoms, one of the most common technique employed is through the usage of video recordings [13] [14] or photography [15], or by observing directly the subject of the study. The observation may [16] or may not [17] be made in real time, by strangers (in the dogs perspective) [9] or by the owners through the completion of questionnaires [18].

Overall, all these techniques involve quite specific and expensive equipment, and are not appropriated for real time monitoring of the animal, which is not evolving in the controlled conditions of the laboratory. In addition, the current visual analyses of the dog's emotional states [19] are not enough accurate and too dependent of a subjective interpretation of the behavioral indexes.

1.5 Objectives

Here, the proposed method to assess the dogs' well-being and health is to create a device that would be able to monitor the dogs' activity, behavior and some physiological indicators.

The idealized device should be non-invasive, light, small and wireless, so that it could be worn 24/7. It should also give information in "real-time", preferably on a mobile device, to help the dog's owner understand if and when the animal has problems dealing with certain situations.

The application that will serve as interface between the human and the dog should be as user friendly as possible, with clear information, comprehensible by all age groups.

2 Methodology

2.1 Material

In order to measure the required dogs' parameters non-intrusively it was decided to use a pair of tri-axial accelerometer and gyroscope; the selected sensor was the MPU6050. To acquire the data, and to serve as interface between the sensors and the monitoring device (Computer or Mobile device) an Arduino Uno Board was used. To preserve the dog total movement freedom the system also needed to be wireless, and for that a JY-MCU (V1.05) Bluetooth module was used as well. A small shield for the Arduino board was made to connect both sensors and the Bluetooth module.

A Python application was also developed to make possible the visualization of the acquired data, in real time, as well as the FFT of the signals (Fig. 1).

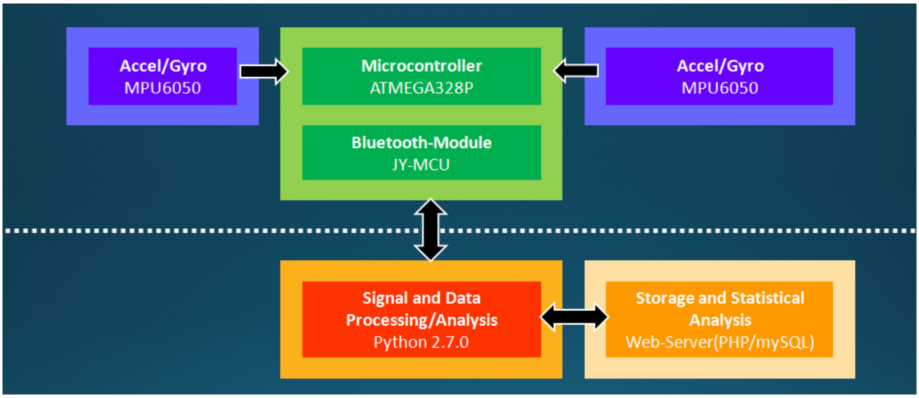

Fig. 1. The block diagram of the designed system

2.2 Sampling and Verification

Since the respiratory rate of dogs can oscillate between 0.5Hz and 6Hz, and because the sampling frequency (fs) needs to be at least twice the signal frequency, both sensors and the Arduino board were set to a sampling frequency of 25Hz. The sensors were set to the same rate to avoid any possible aliasing phenomenon.

Table 1. Input vs. sensor measured frequencies

INPUT FREQUENCY(HZ)	MEASURED FREQUENCY(HZ)
0.48	0.56
0.99	0.97
1.49	1.56
2.00	2.10
2.50	2.40
3.00	3.10
3.50	3.51
4.00	3.90
4.48	4.49
5.06	5.07

The sensors were then attached to a Permanent Magnet Shaker (PMS) (LDS – V406), controlled by using a signal generator (HP3311A) outputting a sinusoidal wave set at a determined frequency. The frequency was fine-tuned using a universal counter (HP5315A) to visualize the exact value outputted. Maintaining the amplitude of the generated signal, the frequency was progressively increased, from 0.5Hz to 5Hz, increasing 0.5Hz on each step. The signal read by the accelerometers, transmitted via Bluetooth and analyzed by the developed application, showed, at each step, a peak frequency close enough to the input (Table 1) thus validating the quality of the following measurements that will be made.

2.3 Experiment

The system was tested on two dogs: Shiva, a female Pit-bull, and Shrek, a male Boxer. One accelerometer was place on each side of a dog's coat, while the board and batteries were placed in the centre, on the animal's back, as seen in Fig. 2.

Fig. 2. Shiva with the device installed on her back

The placement and orientation of the sensors were chosen so that it would be possible to use a common-mode rejection method to clean the signal of undesired movements, and to be able to amplify the respiratory movement (since the chest will expand in opposite direction on each side).

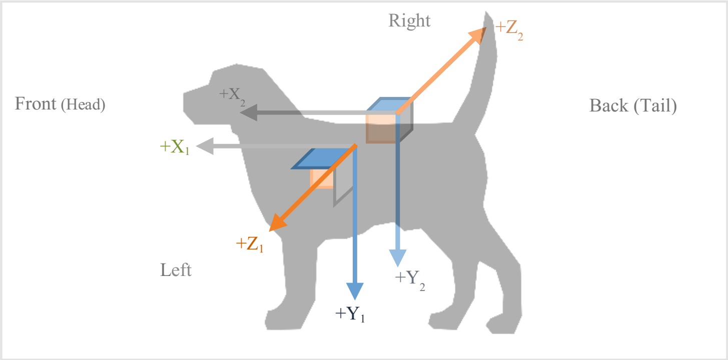

Fig. 3. Accelerometer axis orientation, as they were placed on the dogs

The sensors on the dog were placed in such a manner that the accelerometers +X axis pointed to the front of the dog, the +Y axis pointed towards the floor, and the +Z axis pointed to the outside of the dog (in opposite directions), as depicted above in Fig. 3.

The raw data from the sensors was recorded while one of the dogs performed some simple tasks: walk, run, seat and laydown. At the same time a video recording was made to correlate some of the data with real actions performed by the dog. The procedure was then repeated with the other dog.

3 Data Analysis and Results

Knowing the placement and orientation of the sensors, and in order to clean the signal, a Common-Mode Rejection method was used. In Matlab, the value of X1 and X2 were summed, as well as the values of Y1 and Y2, obtaining by that manner cleaner X and Y axis results. Similarly for the Z axis, Z1 was subtracted from Z2 (since they point in opposite directions on the same axis), obtaining also a cleaner Z axis measurement.

Observing the Y axis data, it was easily recognizable whether the dog was walking, running, or stationary. During the stationary state it was also possible to determine if the dog was standing/laying or seating. The activity can easily be read through the signal amplitude (Fig. 4), while the position can be read by Y+ vector amplitude value. If the dog is standing the vertical component (Y+) will be high because it is aligned with the gravity force vector, while in the seating posture the Y component will make an angle with the same gravity vector, reducing the value that is read by the accelerometer (Fig. 5).

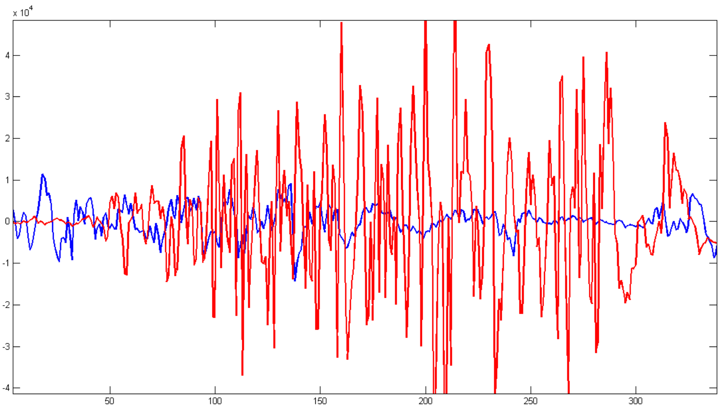

Fig. 4. Y axis read by the accelerometers. Blue: walking; Red: running. [Signal length: 14s at 25Hz] (Vertical axis: amplitude; Horizontal axis: samples).

On the other hand, the Z axis is better to provide the dog's respiratory rate, since the thorax of the dog moves outward and inward, simultaneously on the same Z axis but in opposite direction of each sensors, see Fig. 6.

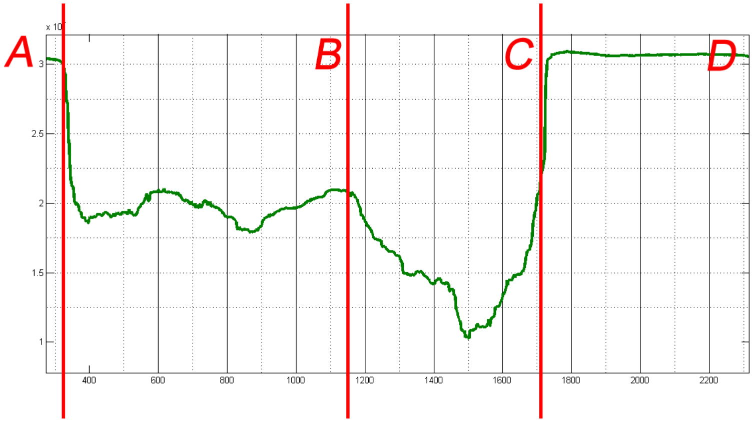

Fig. 5. Y axis read by the accelerometer (Median). A: standing, A-B: seating, B-C: seating more vertically, C-D: standing. [Signal length: 1m 20s at 25Hz] (Vertical axis: amplitude; Horizontal axis: sample).

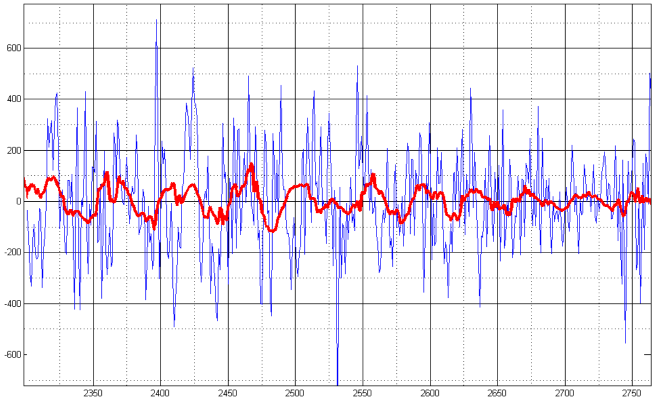

Fig. 6. Respiratory rate. Blue: Z2-Z1 axis. Red: median of the signal. [Signal length: 20s at 25Hz] (Vertical axis: amplitude; Horizontal axis: samples).

Analyzing the X axis data, a signal that could possibly correspond to a heartbeat was detected. Unfortunately both, respiratory and heart rate, signals are very low energy signals, and for that reason they are easily obscured by the movements of the dog, coat, or sensors. In order to confirm these results the experiment will be repeated, with some modifications. The next experiment will be carried out with a more fitted coat that enables the sensors to be maintained in a more stable position. Also, since it was now established that it was easy to detect the dog's activity, this future experiment will focus primarily on getting the respiratory rate, and on confirming that the heart rate is clearly readable.

4 Conclusions and Future Work

At present, the application is being optimized for a faster and more robust communication between the robot on the dog and the remote monitoring device.

Also, a board that encapsulates both the Arduino board components and the developed shield is being designed. This will allow us to produce a smaller, lighter and more robust system.

In any case, the promising results obtained in this midterm stage of the project open up the possibility of having a totally non-invasive low-cost device, with the ability of analyzing the dogs' activity and emotional state 24/7, in real time. Besides assistance dogs, this system will be also a useful tool for future ethological studies (not only in dogs), for veterinary usage, or for facilitating dog training.

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References

1. P. B. Eurostat Press Office, One in six of the EU working-age population report disability, Closing Ceremony of the European Year of People with Disabilities (2003), http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/3-05122003-AP/EN/3-05122003-AP-EN.HTML (accessed: October 22, 2013)
2. Cães de Assistência - Decreto-Lei no 74, 27 de Fevereiro. Diário da República, Portugal (2007)
3. IFAH-Europe, Facts and figures about the European animal health industry (2008)
4. Rybarczyk, Y., Ait Aider, O., Hoppenot, P., Colle, E.: Remote control of a biomimetics robot assistance system for disabled persons. AMSE Modelling, Measurement and Control 63(4), 47–56 (2002)
5. Rybarczyk, Y., Vernay, D., Rybarczyk, P., Lebret, M.C., Duhaut, D., Lemasson, G., Pesty, S., Lucidarme, P.: COCHISE project: an augmented service dog for disabled people. In: 12th AAATE Conference, pp. 109–114. IOS Press, Amsterdam (2013)
6. Beerda, B., Schilder, M.B.H., Van Hooff, J.A.R.A.M., De Vries, H.W.: Manifestations of chronic and acute stress in dogs. Appl. Anim. Behav. Sci. 52(3-4), 307–319 (1997)
7. Diederich, C., Giffroy, J.M.: Behavioural testing in dogs: a review of methodology in search for standardisation. Appl. Anim. Behav. Sci. 97(1), 51–72 (2006)
8. Beerdal, B., Schildert, M.B.H., van Hooff, J., Moll, J.A.: Behavioural and hormonal indicators of enduring environmental stress in dogs. Animal Welfare 9, 49–62 (2000)
9. Ogata, N., Kikusui, T., Takeuchi, Y., Mori, Y.: Objective measurement of fear-associated learning in dogs. J. Vet. Behav. Clin. Appl. Res. 1(2), 55–61 (2006)

10. Maros, K., Dóka, A., Miklósi, Á.: Behavioural correlation of heart rate changes in family dogs. Appl. Anim. Behav. Sci. 109(2-4), 329–341 (2008)
11. Rooney, N.J., Gaines, S.A., Bradshaw, J.W.S.: Behavioural and glucocorticoid responses of dogs (Canis familiaris) to kennelling: Investigating mitigation of stress by prior habituation. Physiol. Behav. 92(5), 847–854 (2007)
12. Ainsworth, D.M., Smith, C.A., Eicker, S.W., Ducharme, N.G., Henderson, K.S., Snedden, K., Dempsey, J.A.: Pulmonary-locomotory interactions in exercising dogs and horses. Respir. Physiol. 110(2-3), 287–294 (1997)
13. Custance, D., Mayer, J.: Empathic-like responding by domestic dogs (Canis familiaris) to distress in humans: an exploratory study. Anim. Cogn. 15(5), 851–859 (2012)
14. Rehn, T., Keeling, L.J.: The effect of time left alone at home on dog welfare. Appl. Anim. Behav. Sci. 129(2-4), 129–135 (2011)
15. Bloom, T., Friedman, H.: Classifying dogs' (Canis familiaris) facial expressions from photographs. Behav. Processes 96, 1–10 (2013)
16. Reefmann, N., Bütikofer Kaszàs, F., Wechsler, B., Gygax, L.: Ear and tail postures as indicators of emotional valence in sheep. Appl. Anim. Behav. Sci. 118(3-4), 199–207 (2009)
17. Kerswell, K.J., Bennett, P., Butler, K.L., Hemsworth, P.H.: The relationship of adult morphology and early social signalling of the domestic dog (Canis familiaris). Behav. Processes 81(3), 376–382 (2009)
18. Marinelli, L., Adamelli, S., Normando, S., Bono, G.: Quality of life of the pet dog: influence of owner and dog's characteristics. Appl. Anim. Behav. Sci. 108(1-2), 143–156 (2007)
19. Quaranta, A., Siniscalchi, M., Vallortigara, G.: Asymmetric tail-wagging response by dogs to different emotive stimuli. Current Biology 17(6), 199–201 (2007)