Wireless Estimation of Canine Pose for Search and Rescue

[1]Cristina Ribeiro, [2]Alexander Ferworn, [1]Mieso Denko, [2]James Tran, [3]Chris Mawson

[1]Department of Computing and Information Science, University of Guelph, 50 Stone Road, Guelph, Ontario, N1G 2W1,Canada {cribeiro,mdenko}@uoguelph.ca

[2]Department of Computer Science, Ryerson University, 350 Victoria Street, Toronto, Ontario, M5B 2K3, Canada {aferworn,q2tran}@scs.ryerson.ca

[3]School of Engineering and Information Technology, Deakin University, Pigdons Road Geelong,Victoria, Australia crmawson@deakin.edu.au

Abstract - *In this paper we discuss the use of accelerometers and Bluetooth to monitor canine pose in the context of common poses observed in Urban Search and Rescue dogs. We discuss the use of the Canine Pose System in a disaster environment, and propose techniques for determining canine pose. In addition we discuss the challenges with this approach in such environments. The paper presents the experimental results obtained from the Heavy Urban Search and Rescue disaster simulation, where experiments were conducted using multiple canines, which show that angles can be derived from acceleration readings. Our experiments show that similar angles were measured for each of the poses, even when measured on multiple USAR canines of varying size. We also found measurable and consistent differences between each of the poses, making them clearly distinguishable from one another, again even when comparing with different USAR canines.*

Keywords: Canine Augmentation Technology, Urban Search and Rescue, Accelerometers, Bluetooth, and WiFi.

1 Introduction

Urban Search and Rescue (USAR) is a difficult, time consuming and strenuous undertaking for humans [1]. Often canines are employed in the search because of their agility, speed and strong sense of smell. While their agility is an asset to USAR it is also a potential impediment for canine handlers as the handler is not as fast or as agile as the dog [1,2]. As a result, the handlers and other emergency responders are sometimes unaware of the canine's actions and orientation [3,4]. The Network-Centric Applied Research Team (N-CART) is developing Canine Augmentation Technology (CAT), adding technology components to canines in order to improve the interaction between the dog and rescuers. The system is equipped with wireless pan and tilt cameras mounted on each shoulder of the canine. This enables rescuers to view the disaster site from the canine's perspective without entering the unsafe zone.

We have achieved some success culminating in our participation in a large structural collapse exercise held by Canada Task Force 3 (Toronto) in June 2007. CAT took valuable footage of the surrounding disaster area within a space that human were not allowed to enter, including a picture of a casualty. One area, which is lacking is the ability to know what the dog is actually doing when the video is taken. This information is important because it is often difficult to have sufficient situational awareness of what is going on with the dog when one does not have a grasp of what the dog is going through and in what way it has aligned its body to achieve a particular shot.

The Canine Pose System determines pose through the use of technology and provides interested individuals with the dog's current body position. This has implications for a variety of search situations when the canine is working in extremely confined spaces and it cannot be directly observed. From pose information it may be possible to determine clues about the situation of any discovered human casualties. The canines are trained to indicate different events employing both sound (barking) and body position (pose).

For example, the canine may be in the sitting position—an indication that the dog has found a cadaver. When the canine is standing or lying down, this indicates when the dog actively searching (in the standing pose) or not (lying down pose). This paper looks at reproducible patterns in data collected for each of the poses. The closest work that was done in our research area was conducted in [8]. However, this research was conducted for one feline and using only one accelerometer. They studied patterns arising from the acceleration readings using a fast Fourier transform algorithm. In our work we use acceleration to determine angles, and use the angles to devise an algorithm to determine canine pose. Our experiments include two dual axis accelerometers mounted on multiple canines.

The rest of this paper is organized as follows: Section 2 presents an overview of USAR, its implementation, some challenges and the use of accelerometers to determine

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canine pose. Section 3 presents, a description of the methods and materials used and communication challenges. Section 4 presents discussion of the experimental results. Finally, section 5 presents the conclusion and discusses future research directions.

2 Background and Related Work

Service dogs exist all around us, many already carrying a variety of technology on them. One example is the PetsCell, a cell phone for dogs with GPS, which enables the owner to track their dog [10]. Another example is FIDO, adopted by various UK police forces, a camera system for police canines involved in arrests, specifically for weapons seizures [5]. When it comes to search and rescue, it would be helpful to know more about what the dog is experiencing in terms of orientation and position to achieve better situational awareness (SA). We call this "pose" determination. Situational awareness has been shown to be a problem in a number of fields including Human Robot Interaction (HRI) with USAR response robots. The problem is that the robot operators often do not have a direct view of the robot and rely solely on the robot's cameras for SA. For the most part, the operators look outward and do not have access to self-views. In [6, 7] it was shown that operators spent on average 30% of their time on SA activity. It was found that they had less SA of the space behind the robot in comparison to the space in front or on the sides of the robot. They have encountered difficulty in maintaining SA when in autonomous mode. These issues are also apparent in CAT.

Often rescuers cannot determine where the "up position" is, making it extremely difficult to discern the camera's orientation. This is an especially difficult problem with regard to the use of canines, as their agility allows them to twist into very small cavities in rather odd orientations. On occasion it may be important to know what the dog is doing in order to give it further instructions when it can still hear its handler but cannot see him. For example, a USAR dog may become interested by a certain scent that does not relate to finding a casualty. It would be useful for the handler to know that the dog is stopped and has his head down. This information about the dog is difficult to obtain since no one can see the dog and placing a camera on the dog in order to see the dog is not feasible as there is no obvious way of doing this.

3 Materials and Methods

3.1 Use of Accelerometers to Determine Canine Pose

The Canine Pose System is designed with accelerometers. By taking appropriate readings, motion vectors can be established and position can be determined. We analyzed the data collected (angle) correlating it with the canine pose in the video taken concurrently with the data collected.

The Canine Pose System collects data from two points on the canine, near its head and tail. The system determines the pose, which is relayed wirelessly back to the handler or another responder for monitoring. Utilizing this system one can monitor the canines orientation based on the data collected from these two points on the canine. The monitoring system must be able to correctly determine the canine's orientation in any environment, including from the top of a rubble pile, and in areas with different materials interfering with communication, such as reinforced concrete.

3.2 Use of Bluetooth and WiFi for Data Transmission

Our first prototype, transmitted data obtained from the accelerometers via Bluetooth. The accelerometer data was captured from the canine and transmitted to the canine handler's laptop, which was based on a single hop communication scheme. Bluetooth technology has the advantage that it has very low power consumption. The operating range of the Class 1 device we are using is 300 feet. This device class is used in industrial applications, which makes for easy use and implementation for our application. While this offers only a limited range and bandwidth, it is sufficient for us to collect the data we need for testing within simulated USAR environments, for preliminary testing, in order to prove the concept of deriving angles from acceleration was possible. For actual use in Search and Rescue environments it would be necessary to extend the communication range using networks with multi-hop communication capability. For this purpose wireless mesh networking technologies can be employed.

Once we were able to attain angles from the acceleration readings, the next prototype developed, transmitted the data through WiFi. This enabled us to extend network coverage in the Urban Search and Rescue environment. We also implemented a wireless mesh network, whereby the Canine Pose System successfully transmitted the data through the network across distances over 500m. The wireless mesh network was connected to the internet and the data could be received by anyone in the world with access to the Canine Pose System. This proves very useful in search and rescue as the data can be monitored at a command center miles away. If any pertinent information becomes available instructions on how to proceed to handle the situation could be disseminated, thereby decreasing search times and enabling responders to send medical attention sooner to casualties in dire of assistance.

3.3 Method for Determining Canine Pose

One axis on the accelerometers is aligned with the spine of the dog. With the data collected from this axis we can calculate the angle of each accelerometer. This information will help us understand the pose of the dog. When the canine is standing, the angle should be close to, if not parallel to, the ground. When the dog is sitting, we might expect the angle to be under 90 degrees and greater than 10 degrees. The laptop will run an application that analyzes the data collected from the accelerometers and will perform the calculations necessary to find the angle and other important information about the dogs pose.

Our final application could analyze the data collected to determine the canine's orientation then display a graphical representation of the canine and its current orientation in real time. This would enable responders to have situational awareness of the canine, even when they are not collocated.

3.1.1 Testing Procedures

Our tests include the multiple measurement of the same dog to determine if the results are repeatable and accurate. Another set of tests have been performed with different dogs to see if the correct pose can be determined for each dog using similar heuristics. There are five canine poses that we believe we can predict from the data. These include: standing, lying down, sitting, climbing up, and climbing down. Each test involves testing the algorithm for each of the different orientations. USAR canine handlers have confirmed that these canine orientations would provide them useful information if they could be determined without actually looking at the dog.

The canine's pose is determined by having the handler command their dog assume different poses. When the dog is in the desired pose and stationary with minimal movement we start collecting data from the accelerometers and simultaneously film the canine in that pose. We have discovered that minimal movement is a relative concept when it comes to dogs. Simultaneous collection and video recording allows us to correlate each frame of the video with the data read at the time it was recorded with the accelerometer data.

3.1.2 Error Reduction

By charting the data we can see if we can determine co-relations between what we see the dog doing in the video and the change in data. The video is very important to determine when the canine is making slight movements, which has the affect of adding spurious noise to the data collected. Examples of this include head motion and tail wagging.

It quickly became clear that accurate placement of the accelerometers on the canine is essential. This involves mounting the accelerometers in the same position each time, so that the distance between the accelerometers and the distance between them and the ground are the same for each test. This ensures that the data obtained for these distances remain constant, consistent and controlled. Of course, this is problematic in practice as different dogs are different sizes and the accelerometers will have to be mounted slightly differently for each dog being tested.

3.4 Data Transmission Challenges

3.4.1 Communication Range

As the working environment is essentially an urban disaster consisting of network-challenging features such as a collapsed wall, we experienced many challenges using Bluetooth. At times it randomly stopped working and we lost connection, requiring us to restart the Bluetooth connection and the test. With WiFi and a wireless mesh network many of these problems were eliminated. Network coverage was extended and became more reliable. Some related experiments have been conducted in order to test the reliability and network coverage. The preliminary results show promising but further analysis is required in order to report the usability of a wireless mesh network with the Canine Pose System in an actual Urban Search and Rescue Situation.

3.4.2 System Noise

The accuracy of the system will differ greatly depending upon the test environment. Weather conditions such as rain and wind, may affect the system. In addition, variation in materials and landscape of the disaster area, also have an effect on the system. For example, we cannot guarantee that stairs or floors are perfectly even. We also cannot control the dog's gait. Their walk, by nature, has a wobble, which adds some noise to the system. The results tend to be more accurate when run in an indoor environment on flat surfaces. Ultimately, however, the system must be tested in an USAR environment in order to be able to determine if canine pose can be estimated.

3.4.3 Signal Interference

In many cases the debris and materials such as thick concrete and rebar, and even other signals from equipment in the surrounding area caused significant interference with the Bluetooth signal [9]. In some cases the device required a re-start. There were many tests that were abandoned due to interruptions in the data, due to signal interference. In some cases more tests were discarded than were kept.

4 Experimental Results

After preliminary analysis of the data acquired in the National Heavy Urban Search and Rescue (HUSAR) disaster simulation exercise, we found several observable distinctions in the data between different orientations.

The methodology used to analyze the data was directed towards finding any similarities in the results of different canines performing the same pose. In addition we want to see if there is a clear difference between different poses. We ran the experiments on different canines, so that we could determine if the results would vary vastly from canine to canine or if they would be similar when comparing the same pose. It should be noted that due to the limited access to USAR canines, as many tests were run, with as many available canines as possible during the disaster exercise. It should be noted that for one of the sitting tests with the dog the data was corrupt and therefore we do not have pose data for this one test. This is denoted in the chart and tables, accordingly.

We look at the average of the angles measured from accelerometers A and B (denoted as Acc A and Acc B hereafter) on each dog, for each of the poses. Our analysis looks at three poses, Sitting, Standing and Walking. We also look at the standard deviation of each of the angles measured, across all the tests and different poses. We assess how similar the data is among the same poses across different canines. We also assess the variation and standard deviation between the different poses.

4.1 Experimental Setup

Accelerometer data was collected while the canine was directed by its handler to perform different poses. The poses we tested include: standing, sitting, lying down, walking, and climbing up and down. Simultaneously we filmed the dog while the accelerometer data was collected. This was done so that the video would be compared to find patterns. The tests were run repeatedly for each pose, in addition to being run with multiple search canines.

4.2 Collection of Data

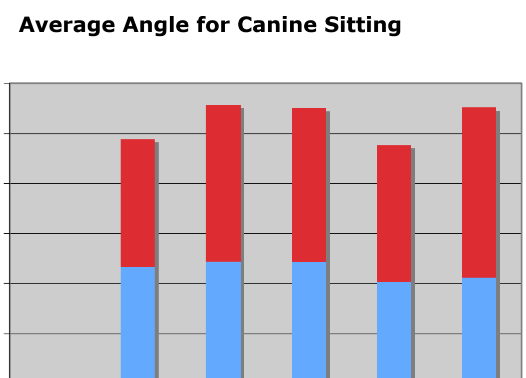
Through the use of two dual-axis accelerometers, mounted on a canine body harness, we may be able to find some distinct correlations in the data obtained from the accelerometers that would indicate the canine's pose. Each accelerometer is mounted on opposite ends of the dog, with one axis lined up with the spine of the dog.

One accelerometer is mounted near the tail of the canine and the second is mounted near the canine's head, on the dog's withers, as can be seen in Figure 1. Two accelerometers are used to extract vectors of motion that could give an indication of different rises and falls or lateral movement of the dog, which, in turn, indicate a change of position.

Figure 1. Canine Pose System mounted on Dare a USAR Canine.

4.3 Sitting Canine Pose Analysis

Looking at the Sitting pose in Figure 2, we can see that the average angles measured from accelerometer A and accelerometer B are similar for all dogs we tested. The standard deviation of Accelerometer A for all the canines ranges from 2.05 degrees to 3.63 degrees, as can be seen in Table I. This shows that for all tests, across each canine is less than a 2 degrees difference from each other for accelerometer A.



	Darby1	Darby2	Dare1	Dare2	Moose1	Moose2
Acc B		51.323	62.451	61.5847	54.5883	67.8747
Acc A		46.2911	48.8398	48.5535	40.6967	42.3861

Figure 2. Average angle measured of canines sitting

Looking at the standard deviation across all canines and tests run, we found the standard deviation for accelerometer B ranges from 1.80 and 8.16 degrees as can be seen in Table I. This again shows that a difference of less than 8 degrees for accelerometer B.

Canine & Test#	Standard Deviation Acc A	Standard Deviation Acc B
Darby1	N/A	N/A
Darby2	3.0302	2.8749
Dare1	3.6386	2.0011
Dare2	3.0784	1.8012
Moose3	3.1508	8.1684
Moose5	2.0509	5.0648

Table I. Standard deviation of angles measured for canines sitting

4.4 Standing Canine Pose Analysis

Looking at the Standing pose in Figure 3, the average angles measured from accelerometer A and accelerometer B are similar for most of the dogs we tested. The standard deviation of accelerometer A for all the canines ranges from 1.86 degrees to 10.02 degrees, as can be seen in Table II. The standard deviation across each canine is no more than 8.16 degrees difference from each other, showing the similarity of the measured angles for this pose, even when tested on different USAR canines.

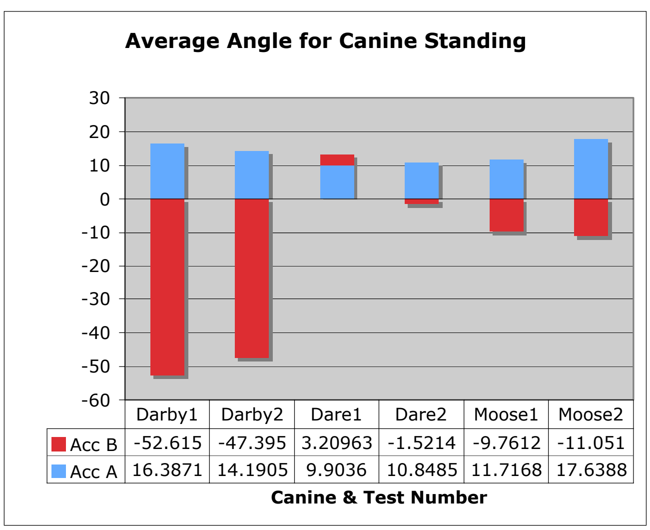


Figure 3. Average angle measured of canines standing

Looking at the standard deviation we see the range for the different canines and tests run is a range of 1.12 to 18.91 for accelerometer B, as can be seen in Table II. This again shows that difference to be no more than a difference of 10 degrees for accelerometer B. This difference is much higher than that found in the sitting pose. This is a clear, measurable indication, of a difference in angles when comparing sitting and standing poses.

Canine & Test#	Standard Deviation Acc A	Standard Deviation Acc B
Darby1	3.5565	15.2558
Darby2	3.7939	18.9155
Dare1	1.8696	1.1218
Dare2	1.8690	1.6529
Moose2	10.0244	1.3979
Moose5	3.9738	3.7208

Table II. Standard deviation of angles measured for canines standing

4.5 Walking Canine Pose Analysis

The walking pose in Figure 4, shows the average angles measured from accelerometer A and accelerometer B for all the tests run. The standard deviation of accelerometer A for all the tests ranges from 9.36 degrees to 13.16 degrees, as can be seen in Table III. The standard deviations across each canine differ in about less than 4 degrees.

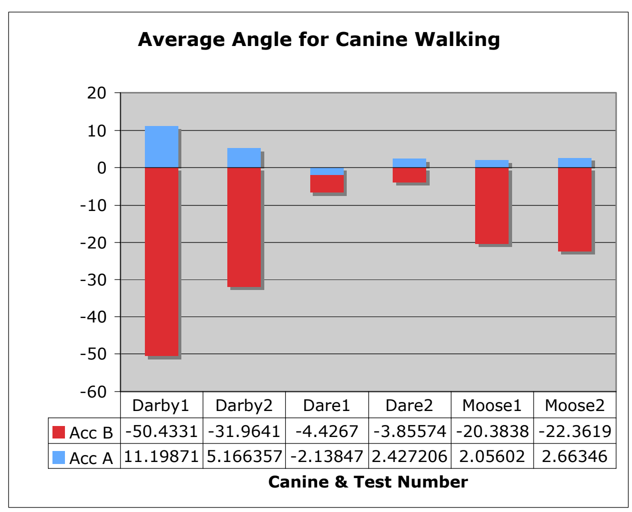


Figure 4. Average angle measured of canines walking

Looking at the standard deviation of accelerometer B, we see ranges from 13.38 to 26.93 degrees. This shows the difference to be no more than 4 degrees and a difference of 13.55 degrees for accelerometer A and B, respectively. The angles measured are similar across all tests run even when performed on multiple canines. Again we see that the standard deviation of angles for the walking pose is higher than that of the standing pose and even considerably higher than that of the sitting pose.

Canine & Test #	Standard Deviation Acc A	Standard Deviation Acc B
Darby1	10.6408	16.1929
Darby2	11.2075	26.9334
Dare1	10.4577	13.3891
Dare2	10.7851	14.3769
Moose4	9.3646	17.4886
Moose5	13.1651	21.8548

Table III. Standard deviation of angles for canines walking

5 Conclusion

Upon preliminary analysis of the data collected at the HUSAR disaster simulation, we observed significant differences between different poses and consistent readings for stationary poses. Consistent results were achieved for all the experiments run for the sitting pose, even when compared to the measured angles obtained from experiments run on different USAR canines. It is possible to derive an algorithm based on this data that would determine the sitting pose on different USAR canines.

When looking at the standard deviation of each of the poses, we found that the sitting pose standard deviation is less than that pose the standing pose. If we compare the standard deviation of the standing and walking poses, we can see that the standard deviation is considerably higher for the walking pose and even more so when compared to sitting. This shows that there are clear distinctions between the angles measured for each of these poses even when testing on multiple USAR canines.

This forms a basis for future investigation and it may allow us to determine canine orientation through the use of accelerometers for more poses. We will be conducting further signal analysis on the data acquired at the HUSAR exercise, to determine any repeating patterns that can be translated into simple states.

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