Workshop Conference: Spot Making Social Body Language

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***Abstract* - One approach to facilitating human-robot interaction is to enable robots to communicate in a way that is already familiar to humans. Realistic canine-like behavior is one such pattern of body language that is recognizable. In this experiment, we survey humans to determine what behaviors make a dog seem "dog-like". Then we develop a library of these social behaviors, and program corresponding body movements into Boston Dynamics's robotic quadruped Spot. Finally, we conduct a survey determining responses to Spot with and without the added canine-like movements, to determine whether adding organic canine-like social body language improved the extent of its communication and interaction with humans.**

I. Introduction

As the field of robotics strives to increase the presence of robots in human society, it is vital for robots to communicate in a way that can be understood by humans. One way of doing that is by having the robots imitate behavior already known to people. In our case, having a dog-like robot implement real canine social behaviors can effectively create communication through a medium already familiar to humans. For this reason, we developed canine-like social behaviors for the Boston Dynamics' Spot to create a human-friendly robot. Spot is a robot consisting of a torso and four legs, with the agility and flexibility to mimic real-world canine behavior. First, we conducted a survey among voluntary participants to determine what body movements they associated with canine-like social body language. Based on the most popular responses, we programmed Spot to recreate tail wagging, looking at people, walking in circles, sitting, and playing bow. Phase 3 of our experiment involves taking Spot outside to interact with human participants. We will survey participants before they see Spot making these social body movements, and after they see Spot making social body movements in order to assess how much Spot's likeness to a canine has increased.

The goal is for people to believe that Spot behaves and acts like a real dog in order to communicate effectively with humans. Robotic movements can seem jarring and alien but canine-like body language will be more familiar.

II. Background

Spot by Boston Dynamics is a quadruped agile mobile robot that has the physical appearance of a dog. Spot's features include mobile manipulation, a 3D vision system with SLAM and obstacle avoidance, the ability to climb and descend stairs, and more. While Spot may seem like a dog physically, the behavioral functions of the robot do not match that of a dog [1]. Dogs are known to interact with each other and people through body postures, facial expressions, tail and ear positions, raising of hair or "hackles," vocalizations, and scents [2]. These are also known as canine social behaviors that humans associate with dogs.

Canine social behaviors are established based off of canine body movements. Canine movements are derived from the quality of the movement, like walking versus running, or based off of the different positions required for that movement like vertical versus lateral movements [3]. Likewise, behaviors can be examined separately, a "yawn" or a "paw raise," or pooled together to describe behavioral states that humans would identify as friendly or aggressive. Behavior can also be described by its frequency, duration, and intensity which then loops them into different behavioral pools [4] [5].

Canine movements are most often discerned through a dog's tail. Tails can be perceived in many ways, but the details of a tail's movements are presented through the base of the tail. From the base it can be seen if a tail is high, midline, or low; thus giving an indication of a dog's behavior. A high tail for example, can indicate excitement and can be seen in a variety of approach-oriented behaviors, ranging from greeting and playing, to fighting and threatening [6]. In addition, the movement of the tail is one of the most noticeable things about a dog. A tail wagging from side to side at the midline is most readily associated with greeting or excitement [4]. The canine social behavior of wagging a tail is an effective communication between dogs and humans as humans perceive a dog that wags its tail as "happy" [7]. Tails, are just one example of movement that constitute behaviors. Other examples can include movement of the ears, eyes, mouth, and body weight distribution that all have some effect on how dog behavior is shown and perceived.

Since canine social behaviors affect the temporal behavioral pattern, this changes how humans interact with a robot dog.

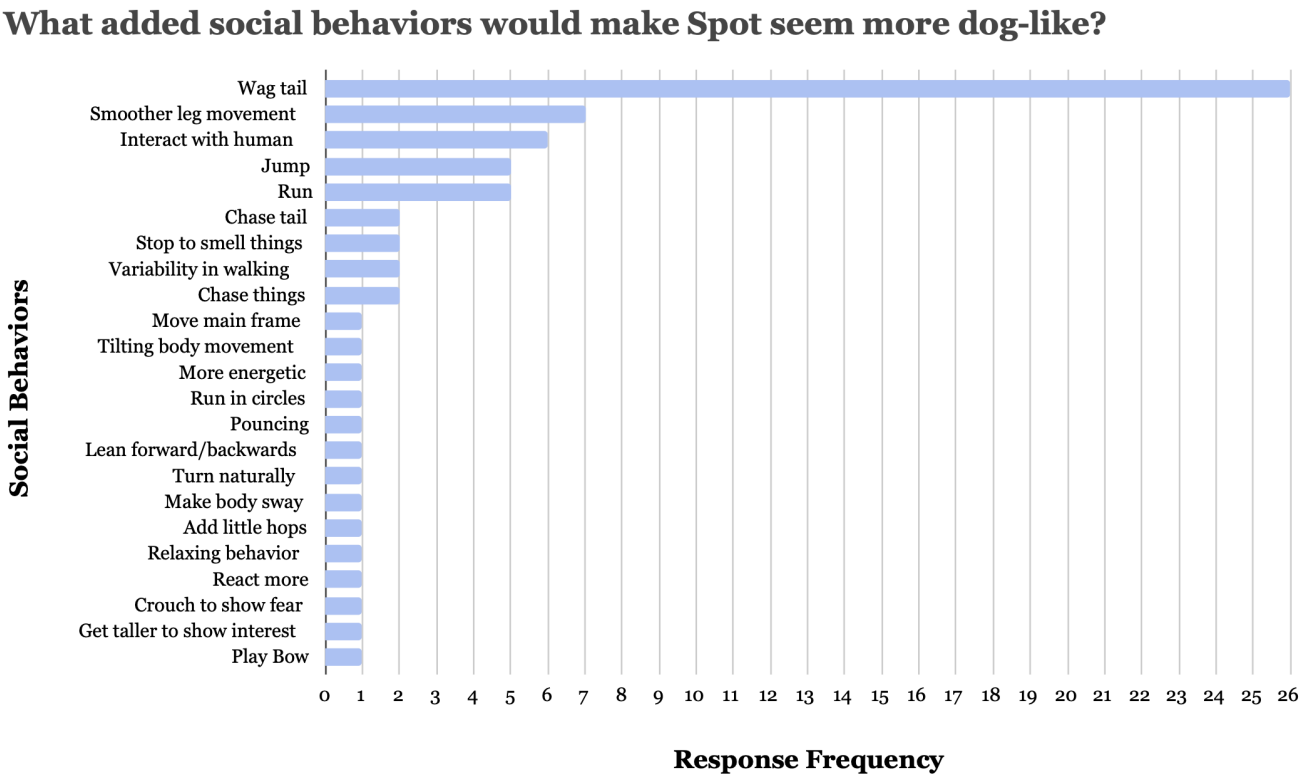


Fig. 1: Results of the human survey on perception of dog-like social behaviors, in order to determine how to make Spot seem more canine-like.

In order to achieve interactions like that of a human with a living dog, robot dogs need to implement behaviors such that the humans don't feel "bored" or "tired" of the interactions [8]. This one way of communication, that if implemented on a robot dog, can not only make the robot act more like a dog, but give it a recognizable emotion that humans fundamentally understand [9].

III. Methodology

A. Phase 1: Human Surveying for Social Perception

In order to determine what could be reliably constituted as "social body language" from a human perspective, we conducted a survey of 56 individuals. The individuals were voluntary participants and responded to a series of questions asking how they thought dogs behaved when feeling different emotions: friendly, happy, aggressive, anxious, sad, and relaxed. Finally, the participants were shown a brief clip demonstrating normal use of the Spot robot, and were asked how it could be made to seem more organically dog-like. The results of this survey were analyzed and graphed, and used to determine what movements we would add to Spot to enable it to behave socially and interact with humans organically (See Section 4A: What Constitutes Social Body Language?).

B. Phase 2: Developing Organic Social Body Language

Spot exists on a 3D plane, in which we control the roll, pitch, and yaw of the torso in order to make a body movement. Changing roll tilts the torso from side to side, changing yaw will tilt the torso towards one diagonal or another, and changing pitch will tilt the torso forward or backward. The frame that we're rotating is the center of the body mass. Additionally, $velocity_x$ and $velocity_y$ are used to plan the trajectory and change the position of Spot. For our purposes, we don't directly alter the $velocity_y$.

For each body movement, we created a trajectory, which includes points that the torso had to reach the position of in a certain amount of time for each movement. When we plan each trajectory, we need a time frame in in which each point in the trajectory occurred. The time frame we determined to look most organic (fast enough that it seems life-like, and slow enough that the motors don't seem jerky) is 500 milliseconds. This means that each trajectory point occurs in increments of 500 ms. Each trajectory point is packed into a method that plans out the trajectory and executes it.

The ranges for roll, pitch, yaw, $velocity_x$, the angle of rotation, and the number of trajectory points for each body movement are visible in Table 1.

One of the survey results involved smoother motions, and

Body Movement	Roll	Pitch	Yaw	$velocity_x$(m/s)	Rotation Angle (rad)	Number of Trajectory Points
Tail Wagging	-π/16 to π/16	0	-π/8 to π/8	0	0	3
Play Bow	0	0 to 3π/14	0	0	0	1
Sit	0	-π/7 to 0	0	0	0	1
Walk in Circle	0	0	0	2	-1.5 to 1.5	12
Spin	0	0	0	0	-1 to 1	8

TABLE I: Body Movement Values and Trajectory

part of our original goal was to make Spot's motions more organic-seeming. In order to make movements more fluid, we included midpoints between trajectory points of body movements to avoid jerky motions from the motors. Additionally, we combined some of the body movements in order to achieve more realistic and life-like motion, since it is unlikely that real canines will only exhibit one of each movements at a time, for example: play bowing and wagging tail, sitting and wagging tail, etc.

1) Tail Wagging: In the "tail wagging" motion, the yaw and roll are changing, since the hind should be moving from side to side at their diagonals. A mapping was created from one extreme of yaw and roll to the other extreme. Yaw and roll are of opposite negation.

Since smoothness of tail wagging was essential, we anchored the midpoint at the center, thus Spot tilts to the right, returns to the center, tilts to the left, returns to the center, and continues.

2) Play Bow: In the "play bow" motion, the pitch is changing, and the torso of Spot rotates all the way forward, while the yaw and roll remain unchanged.

3) Sit: The "sit" motion involves the opposite movement of play bow, and to a less extreme extent. The pitch is rotated backward in order to tilt the torso back so that Spot can look up at humans and interact with them.

4) Walk in Circle: In the "walking in circles" motion, since we want Spot to walk in a consistent circle, we made the velocity for each trajectory point the same. The rotation of 1.5 signifies that each time, Spot is changing relative to its current position, rotating 1.5 radians (counter-clockwise) or -1.5 (clockwise).

5) Spin: The "spin" motion was developed to mimic a dog chasing it's own tail, which was one of the popular survey responses. Although Spot doesn't possess a spine and cannot twist to mimic actual tail-chasing, spinning is the closest Spot can get. In this motion, the rotation changes without changing roll, pitch, yaw, or the velocity, since the torso angle isn't changing, and neither is the actual position. When Spot executes the "spin" movement, it has a rotation angle of 1 (counter-clockwise) or -1 (clockwise).

C. Phase 3: Human Surveying for Understanding Spot's Social Body Language

For the human experiment, we plan to conduct two different surveys on thirty people. Spot will perform both its original behaviors and the newly developed dog-like social behaviors for the human subjects, and we will gauge the human's reactions through the surveys. Our experiment will first have Spot demonstrate its original behavior (prior to the additional developed software of social behaviors) to the human participants. After the demonstration, the first survey will be conducted, asking the participants to rate Spot's dog-like behavior on a scale from 1-10 (1 being that Spot behaves nothing like an average dog and 10 being that Spot behaves exactly like a dog). Then, we will have Spot demonstrate its newly developed behaviors of tail wagging, looking at people, and sitting. The second survey will be conducted, asking the participants to rate Spot's dog-like behavior on a scale from 1-10 yet again with the same weights on the scale (1 being that Spot behaves nothing like an average dog and 10 being that Spot behaves exactly like a dog).

The statistical significance of the results will be calculated using the differences in the averages of original Spot versus Spot making social body languages with the new gestures. The questions on our two surveys will allow us to determine whether or not the human participants see the resemblance of a typical canine's social behaviors on Spot or not. In asking the humans if they recognized Spot's behavior as that of an average dog's both before and after showing the new social behavior software, the experiment will allow us to understand how successful the development of our software is in terms of canine behavioral recognition by an average person.

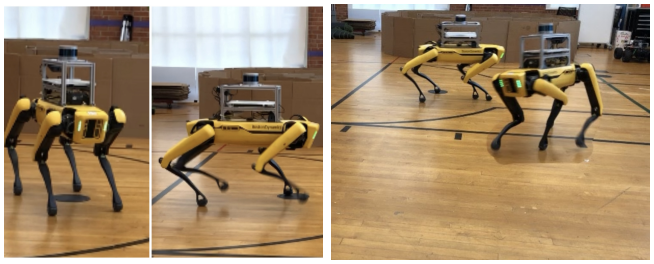
IV. Results

A. Phase 1: What Constitutes Social Body Language?

After we obtained results of the survey, we determined the commonalities and popularity of the responses in order to determine which social behaviors were most naturally associated with canines (see Figure 1). We discarded responses that involved altering body parts rather than body language, such as adding a face, ears, and eye movements.

From the resulting data, we took some of the most popular responses and combined them into cohesive canine-like gestures to add to Spot's movements. We added tail wagging, interacting with a human, play bow, walking in circles, and chasing its tail. Additionally, we added a variation of leg movements to make it seem more organic. These canine-like gestures is what comprised our library of Spot's social body language.

(a) Play bow (b) Sit



(c) Spin (d) Walk in circle

(e) Tail wagging to the left and right

Fig. 2: The library of Spot's social body movements

B. Phase 2: Spot's Social Body Language Library

Using the approach described, we developed the following body movements for Spot: tail wagging, interacting with a human, play bow, walking in circles, and chasing its tail, as shown in Figure 2.

We are planning to demonstrate these human body movements for human participants in Phase 3.

V. Conclusion

Our goal is for Spot to achieve fluid, organic social body gestures that emulate the behaviors of real canines, as a way of improving people's perception of Spot. People are still hesitant to either interact with or share a space with a robot, especially with what can appear to be an alien robot failing to imitate a dog. With Spot performing live canine behaviors, humans can view the behaviors as more natural and organic to their environment (through tail wagging, looking at people, walking in a circle, sitting, and play-bowing). We will conduct our experiment to demonstrate Spot's new social behaviors in order to see how Spot works in a human environment. Thus, by emulating dog behaviors, we will determine if Spot can fit in with minimal human discomfort or adjustment, setting up the way to direct human-robot interaction. We can continue to program more canine social features on Spot to continue to improve the perception of Spot in the public eye, making service robots seem more approachable and safe than the traditional machine.

VI. Related Works

The field of human-robot dog interaction has been explored mainly through the use of the AIBO robot dog from Sony. Humans are seen to interact with robot dogs differently than they interact with live dogs due to the limited ability of the robot to engage in temporally structured behavioural interactions with humans [10] [11]. During play time between humans and AIBO, their interactions were similar to those between the human and the living dog [10]. However, the differences in the behavior between the living dog and AIBO were still prominent as the living dog moved around and laid down more than AIBO did. Thus, the actual canine behaviors of AIBO were more limited than how humans interacted with it [12].

Furthermore, one study evaluated the consumer's perceived relationship with AIBO and found that most have a close bond with the robotic animal and continue to play with it in their daily lives. They also form a bond with the robot indicated by the assertion that "42% have feelings for AIBO" [13] [14]. And since AIBO can evolve from a "puppy" to a "dog" it made the robot seem more like a living animal which led to higher social engagement from the consumer. Users characterize their relation to AIBO to some degree in an analogous way as to a living dog, assign animal traits to it, treat it as a social "friend," and regard it as part of the family [15]. Hence, users do form some form of human-animal attatchment to AIBO even though it is a robot [11].

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