

Animal-Inspired Human-Robot Interaction: A Robotic Tail for Communicating State

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ABSTRACT

We present a robotic tail interface for enabling a robot to communicate its state to people. Our interface design follows an animal-inspired methodology where we map the robot's state to its tail output, leveraging people's existing knowledge of and experiences with animals for human-robot interaction. In this paper we detail our robotic-tail design approach and our prototype implementations, and outline our future steps.

Categories and Subject Descriptors

H.1.2 [Models and principles]: user/machine systems—*human factors*

General Terms

Design, Experimentation, Human Factors

Keywords

Human-robot interaction, animal-inspired interfaces.

1. INTRODUCTION

In this rapidly emerging field of HRI, many robots are designed and built as utility robots to help people in their homes and workplaces. Some argue that it will be important in these environments for robots to maintain a peripheral presence similar to that of Victorian servants [4,5]: that is, the robot should interrupt people as little as possible, but people should have peripheral awareness of the robot. This is important, for example, to identify when the robot requires assistance. One challenge with this goal is to enable the robot to communicate a range of states without being intrusive. In this paper we present a robotic tail interface as a passive means for a robot to broadcast its state.

The premise of our interface is that many people have intimate experience with tailed animals such as cats and dogs and understand much of their tail vocabulary [1], understanding which we can leverage for HRI. Although we concede that not everyone will understand a tail vocabulary, we note that most people at least have passing familiarity from the social stock of knowledge [6], for example, that dogs are happy when they wag their tail.

Several robots exist that use robotic tails, for example, the Sony AIBO, and Necoro the robotic cat [8,9]. In these cases the robotic tail was used to mimic the behavior and appearance of the actual animal, with less attention paid to the communication capabilities of the tail and how they can be used to communicate a utility robot's state [2]. In our work we extend this idea to focus on developing communication mappings and more capable tails to enable communication for even non-zoomorphic robots: for example, if an iRobot Roomba gets stuck, it could lower its tail to suggest a fearful state (Figure 1c), or could wag its tail to indicate that it found a particularly dirty spot that it was happy to clean.

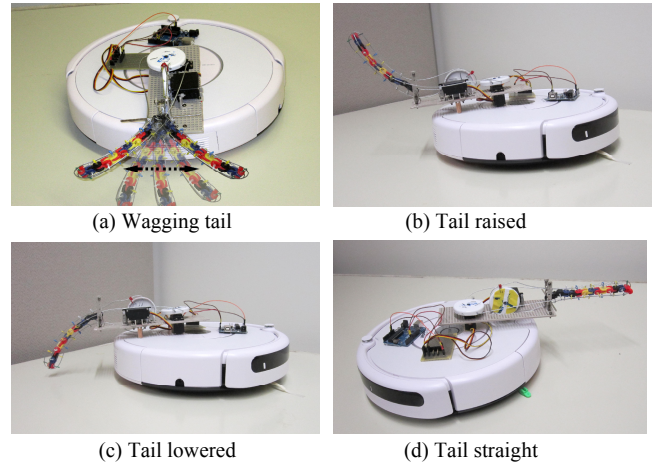


Figure 1 – iRobot Roomba with a actuated-cable robotic tail.

Specifically, we modeled our initial prototype after a dog's tail: different animals such as dogs and cats have different tail vocabularies, and perhaps the dog is most commonly understood. Below we outline our approach to mapping robot state to tail state, and various prototype implementations and designs.

2. MAPPING ROBOT STATE TO TAIL

In order to leverage people's understanding of dog-tail vocabulary for HRI, we must first investigate how dogs themselves use tails to communicate, and, how people interpret this communication. For our initial prototype, and to provide a starting point for our engineering challenge, we informally explored dog tail language and behavior using pet-training resources. However, to develop meaningful robot state to tail mappings it will be important to investigate animal-behavior literature more deeply.

One challenge of adapting dog-tail language to a robot like the Roomba is that, with a real dog, the tail forms only one part of an overall expression. For example in Figure 1b, the robot could be angry or could be highly interested; for both a dog places its tail in this position to indicate high arousal, and uses other body language cues to specify the meaning more clearly. Thus we will investigate how relevant emotional models can be used to decompose an expression and explain which role the tail can play.

One such model which we will explore is the Pleasure-Arousal-Dominance Temperament Model [7], which decomposes an emotional state into the three dimensions. As with our dog example above, for example, both *anger* and *joy* would have high arousal but would be on opposite ends of the *pleasure* scale. In addition to providing a structure for tail vocabulary, this model also provides us with a mechanism for integrating the tail with other robot expression, for example, movement patterns or sounds.

3. PROTOTYPE DEVELOPMENT

We are currently exploring methods for implementing our robotic tail. Throughout this process we aim to procure smooth and fast movement over the tail range, enable continuous tail deformation to form a curve rather than piece-wise links, minimize noise from tail actuation, and minimize tail mechanism size for easy robot integration. Below we detail our current designs, a servo tail and actuated cable tail, and briefly discuss future prototype directions.

We implemented the servo-tail as a three-piece link of micro servo motors mounted on perpendicular axes to enable a wide range of tail movement. This prototype was unsuccessful as the servos were very noisy, moved too slowly for convincing behavior, and the piece-wise result did not resemble a tail.

Our current prototype is an actuated cable tail which we developed by loosely following animatronics hobbyist techniques for tails [10]: we modified Klxxx toys and used servo-driven guide wires to enable rapid and smooth tail deformation (Figure 1, 2). With this setup the tail can move left-right and up-down, or both simultaneously to hit the corners, the tail curves when deformed into a smooth arc, and the servos leverage a wheel to achieve fast tail movements and direction changes.

Although this prototype gives convincing results, it unfortunately has noise problems, requires a large mounting mechanism, and the deformation shape breaks down at large deformations. Looking forward, we are investigating methods using, e.g., springs and guide wires, magnets and an outer skin, or nitinol wire (shape-memory alloy [3]), as means to improve movement range, deformation quality and smoothness, and reduce noise

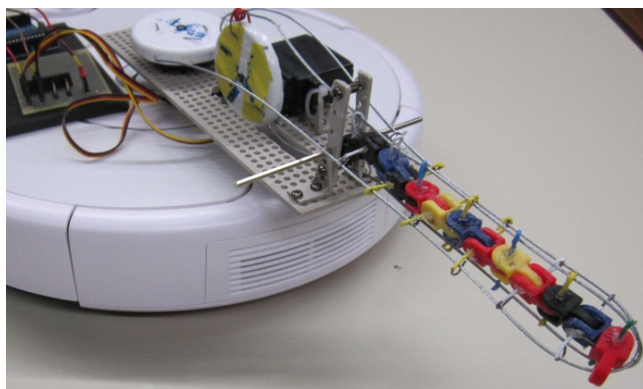


Figure 2 – actuated cable tail prototype

4. RESEARCH DIRECTIONS

We intend to conduct user evaluations to investigate questions regarding how the tail is received and how useful it can be as a communication mechanism. Questions for exploration include: if people will draw from previous experiences with animals to interpret a robot's tail movements, if we can develop effective robot state to tail mappings for domestic use-case scenarios, and the overall effect that the existence of the tail has on a person's perception of the robot. We will also investigate the differences based on user background, e.g., by classifying people as cat or dog people (or both or neither) based on their experiences, and

investigating differences of expectations and reception. For people without prior animal experience, we may investigate what sort of "tail-vocabulary" training may be useful.

In addition, as we continue research into animal behavior and build targeted research questions about tail vocabularies, we intend to conduct studies to investigate, e.g., the effects of tail movement speed, pose locations and movement patterns. Finally, we intend to investigate the importance of particular physical tail properties such as length, thickness, color and appearance (e.g., robotic versus furry), or even different tail formats such as a lizard or elephant-style tail instead of a dog-style tail.

Overall, we believe that our animal-inspired HRI approach of having a robot use a tail for communicating state can provide an effective, easy-to-understand peripheral awareness channel for robots entering into people's everyday spaces.

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