Human-robot state estimation on quadruped robots

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MOTIVATION

The flexibility, robustness and locomotion capabilities of quadruped robots can make them ideal partners with humans in various scenarios, such as navigation for a visually-impaired person, or search and rescue in a disaster scene. While substantial researches have explored the use of four legged robots in autonomous settings such as plant inspection, few have studied the human-robot teaming aspect of quadruped robots. The main proposal of this project is to develop new state estimation algorithms for human-robot teaming applications using quadruped robots.

OBJECTIVES

The main objective of the research is to devise a state-estimation framework that could leverage external sensing capabilities on a quadruped robot to estimate the state of a human-robot team. Two important modalities are cable suspension and computer vision. Separate objectives are formulated for estimation with either modality and their combination:

1. State estimation for human-robot with cable suspension model;
2. State estimation for human-robot with computer vision;
3. Sensor fusion of cable and vision models;
4. Human intent modeling with cable and vision sequences.

METHODOLOGY

To start with, we are going to assume that the human and the robot are connected via a cable, and that the human's intent is strictly following the robot. We could leverage work of cable suspended loads on aerial/ground robots to model their dynamics.

We intend to work under the state estimation framework Simona et al developed for quadruped robots and use EKF as the main estimation framework. In addition to the existing states of quadruped robots, we plan to add states of the cable, the human pose and velocity as well as other necessary states into the estimated states.

To derive optimal actions for the robot, human's intention must be accounted for, e.g. if the human is leading or following. We could leverage the work by Anca Dragon on estimating human's intent during human-robot interaction, to learn human's intent online.

Furthermore, we plan to leverage work on stereo vision tracking and derive state estimation algorithms for the robot and human team using visual information. A hybrid state estimation algorithm can then be developed to combine cable suspension and vision models, as taut cable could provide valuable info on the state of the human for the vision model.

TENTATIVE WORK PLAN

Here's a tentative work plan of the project proposal, broken down into milestones into three years:

Year 1:

1. Familiarize with kinematics and existing state estimation algorithms of quadruped robots;
2. Model human-robot teaming via cable-suspension system, and derive motion and measurement models for the system;
3. Derive state estimation algorithm, e.g. EKF for the human-robot team with cable suspension model;

Year 2:

4. Build upon and improve on existing CV algorithms for estimating moving human's relative position and velocity on stereo cameras;
5. Devise methods for estimating human teammate's intention using cable tension and video images;

Year 3:

6. Derive fusion algorithm for combining cable suspension model and vision model;
7. Integrate with the aforementioned EKF framework for estimating human-robot states.

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