Human-Robot Rendezvous by Co-operative Trajectory Signals

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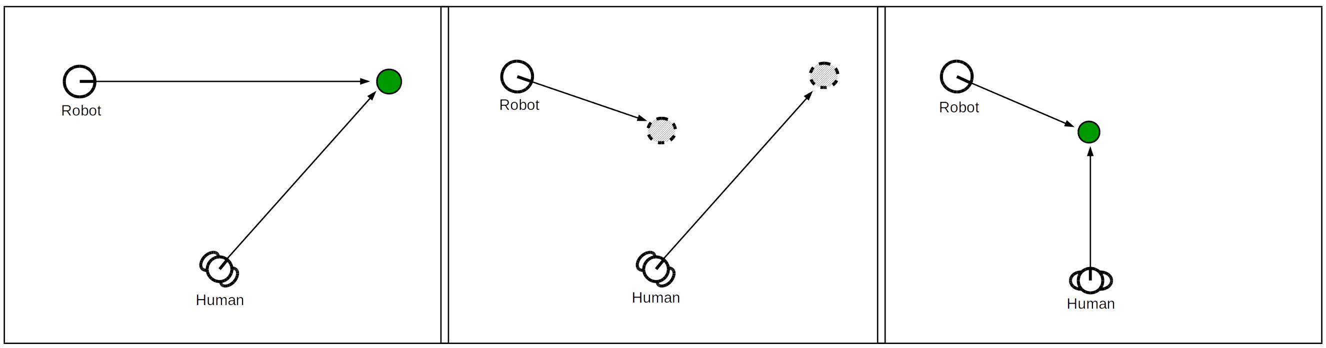


(a) Robot and human on an intercept course

(b) Robot varies its trajectory to remove the intercept

(c) Interested human corrects its own trajectory to maintain an intercept

Figure 1: Behavior sequence for human-robot rendezvous by co-operative trajectory signals.

ABSTRACT

We present an interaction pattern for co-operative human-robot rendezvous in which the robot determines whether an unknown human is interested in interaction. Our system exploits agent trajectories for signalling intent to interact: when the robot detects a future intercept with a human, it probes the intent of the human by varying its trajectory to remove the intercept point. An interested human will correct its trajectory to maintain an intercept, which we interpret as a strong signal of intent to interact. We demonstrate this system in an outdoor environment with a human and robot equipped with wireless communications and mobile phone GPS for localization.

Categories and Subject Descriptors

I.2.9 [**Artificial Intelligence**]: Robotics, Human-Robot Rendezvous, Spatial Reasoning, Natural Human-Robot Interfaces

1. TRAJECTORY SIGNALS

Many human-robot interaction (HRI) systems provide feedback to the human user in the form of auditory or visual cues [3]. Users must often be instructed in how to interpret the cues or behavior of the robot before useful interaction can be performed, and we have found that these cues tend to be most effective at close ranges. We are interested in developing HRI interfaces and behaviors that are natural and intuitive, require minimal special equipment and training, and work at long ranges.

An established approach to achieving robust and natural HRI involves a dialogue between human and robot, where the two agents dynamically converge to agreement about the task at run-time [2]. In this work, we propose a behavior pattern for co-operative human-robot rendezvous that uses motion trajectories, a feature common to all mobile agents, as an interaction signal to determine whether a distant human is interested in interacting with the robot.

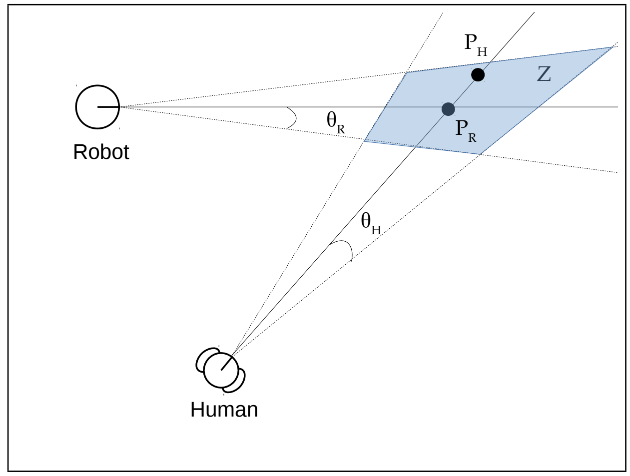
1.1 Behavior

Our co-operative rendezvous behavior requires only that the approximate geometry, relative position and velocity of the human and robot are known, and does not assume any specific sensor modality. The behavior sequence (Fig. 1) begins during a default behavior (random wandering in our case) by continuously computing whether the trajectory of the human will intercept the robot before some maximum time. If the human is on an intercept course with the robot, the robot then tests this coincidence by varying its trajectory until it has removed the intercept. If the human corrects its own trajectory to recreate an intercept, we consider this a strong signal that the human intends to interact, and the robot continues along the current trajectory until intercepting. At this point, close-range interaction techniques such as gesture or speech recognition can be used ([4], [5]) with confidence that the user intends to interact with the robot.

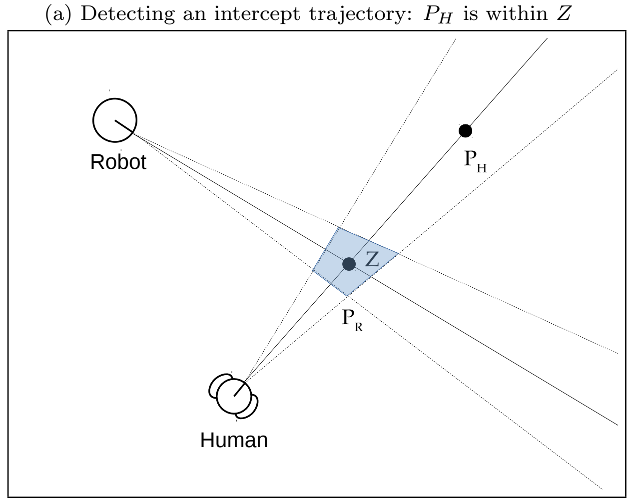
1.2 Intercept Detection

In order to detect future intercepts, we use simple spatio-temporal geometric reasoning on a 2D plane, as shown in Fig. 2. Since we know the heading of the robot and human to within uncertainty of θ_R and θ_H respectively, we can create trajectory cones representing sets of potential future locations given the current orientation. Trajectory cones have the desirable property of widening with distance, which represents intercept uncertainty growing as range increases.

We define the spatial region of intersection between the two cones as a potential intercept zone Z, and compute the time t for the robot to reach the center of mass of this region at its current velocity. As in [1], we model the geometry of the robot and human by planar discs, and report an intercept only if at time t the human is expected to be located inside Z or closer to P_R than the combined radius of the two agents, in the case that Z is small.



(a) Detecting an intercept trajectory: P_H is within Z



(b) Detecting a non-intercept trajectory: P_H is outside of Z

Figure 2: Detecting intercepts from position and velocity. Z is the shaded intercept zone between trajectory cones. P_R and P_H are the expected locations of the robot and human at time t.

2. DEMONSTRATION

We demonstrate that trajectory signalling provides a basis for successful discrimination and rendezvous with interested humans in an outdoor environment, using filtered GPS signals from consumer mobile phones to determine the position and velocity of both the robot and human. We first demonstrate that the robot will ignore humans who are not attempting an intercept trajectory, and then show that interested humans attempt an intercept trajectory, successfully signal to the robot and complete the rendezvous. Informally, the system performs as described and feels natural to use. A video has been provided at `www.youtube.com/watch?v=_gV8cmUsIhA` showing the system in operation.

3. REFERENCES

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