A Multi-touch Interface for Multi-Robot Path Planning and Control

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Abstract. In the last few years, research in human-robot interaction has moved beyond the issues concerning the design of the interaction between a person and a single robot. Today many researchers have shifted their focus toward the problem of how humans can control a multi-robot team. The rising of multi-touch devices provides a new range of opportunities in this sense. Our research seeks to discover new insights and guidelines for the design of multi-touch interfaces for the control of biologically inspired multi-robot teams. We have developed an iPad touch interface that lets users exert partial control over a set of autonomous robots. The interface also serves as an experimental platform to study how human operators design multi-robot motion in a pursuit-evasion setting.

Keywords: human-robot interaction; multi-agent path planning; biologically inspired motion; multi-touch interface

1 Introduction

The field of human-robot interaction has evolved beyond issues concerning the design and development of one person controlling one robot. Today, robots and humans routinely collaborate in multi-robot teams. Robotics has advanced such that teams of robots can be fully autonomous, completing multiple tasks in parallel. In addition to interaction with a group of agents that is fully autonomous, a group of agents could be fully controlled by the user, or some combination that exists in between.

In this paper, we present an experimental platform that helps to understand how motion and path planning for multi-robot swarms should be designed. We are especially interested in cases where a human exerts partial control over multiple robots. In [1] researchers explore biologically inspired motion by using an approach where the input is initiated by an operator, applies to the motion of a subset of robots, and in turn, affects the motion of other robots. In our work, we developed a multi-touch interface to study how decentralized control over a set of biologically inspired agents can be used to reach high-level pursuit-evasion strategies. In this paper, we describe the design and development of the interface.

2 Background

Research on path-planning has explored a number of algorithms for fully autonomous systems. Some of them, such as discrete search methods [5], [13], [12], work for path planning, but do not scale well to multiple robots. Other optimized methods [7], while working for multiple robots, do not function well in complex environments.

Multi-robot motion design research has often leveraged pursuit-evasion tasks. Different algorithms have been designed and tested in simulation to plan the path of pursuers and evaders, ranging from two pursuers are searching for one evader [16] to multiple pursuers searching for multiple evaders [3], [18].

Biological motion has also been a source of inspiration for those researching multi-robot path planning. The study of the collective behavior found in nature has led to attempts to create computational models to characterize and replicate that behavior. [4] offers a popular bio-inspired model that describes three circular zones around an agent: repulsion, orientation, and attraction. The motion of each robot is calculated based on the presence or absence of other individuals on each of these zones. This globally generates a collective behavior that resembles the behavior of a real swarms.

A number of interfaces and interaction studies can be found exploring how to control a single and multiple robots [2], [6], [8], [10], [11]. A special case is that of multi-touch interfaces. While surface and direct touch computing can offer challenges in the forms of less traditional input than the keyboard and mouse, it offers a direct means of controlling elements through multitouch freehand gestures [17]. A number of systems have explored multi-touch interfaces to control physical robot agents [14], [15]. In our work we try to understand how simple and direct multi-touch interaction could allow the user to create motion paths that affected subsets of robots, which would in turn affect others. We present a multi-touch interface that gives users the flexibility to use natural gestures, such as those defined [17], to control a swarm of biologically inspired robots. We leverage research on biological motion [4], multi-robot pursuit evasion, and decentralized control [9].

3 Implementation

We implemented a multi-touch interface on an iPad app that supports up to ten fingers. The app is meant to control a swarm of semi-autonomous biologically inspired robots with simple behavior and low connectivity. Each robot can sense other robots within a certain range, and no communication between robots is assumed.

In our design three main components contribute to the swarm motion:

1. Biological data
2. User input
3. Local interaction rules

When no input is given the swarm enters in a wandering status. While in this status the swarm follows a vector field derived from biological data stored in an xml file, i.e., the velocities of the individuals exactly match velocities measured from real swarms, flocks, etc.

When users touch the screen they start controlling the swarm. The fingers that touch the iPad create a virtual leader behavior at the position of the touch. Raising a finger from the surface corresponds to the removal of that leader from the swarm. As the user slides her fingers on the touch surface, the swarm reacts by following the leaders.

This behavior is coupled with additional interaction rules that make sure robots will avoid collisions and will try to stay with the group.

Following from [4], we define three different zones relative to each robot:

- Zone of repulsion (ZOR). Each individual attempts to maintain a minimum distance from others within a “zone of repulsion”.
- Zone of orientation (ZOO). An individual will attempt to align itself with neighbors within the “zone of orientation”.
- Zone of attraction (ZOA). An individual will attempt to move toward the position of leaders within the “zone of attraction”.

The app provides a drop-down panel to set parameters and save them for future simulations (Figure 1a). It is also possible to explore the effect of a parameter change in real-time, in effect, making the app usable for motion design.

We provide two different instances of the interface, one meant to test the evasion behavior and the other meant to test the pursuit behavior. In one instance, mobile pursuers try to hit the swarm and the goal is avoiding as much pursuers as possible. In the other instance, the iPad screen is filled with mobile targets, and participants are asked to control the swarm in order to catch as much targets as possible. Individuals in the swarm are represented as orange cirles, while blue circles represents computer-controlled pursuers/evaders (Figure 1). Below we give some examples of possible uses of this interface to design different kind of motions for the swarm.

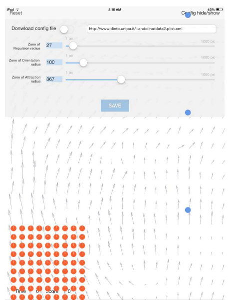
One finger One finger can be used to control the entire swarm (Figure 1b). This strategy can be used to hide the swarm outside the field of view of pursuers (evasion task)

Two fingers By using two fingers a line formation can be obtained (Figure 1c). This formation can be used for pursuing. Another strategy is to split the main pack of robot in two subgroups (Figure 1d). This strategy can be used both for evading and pursuing. When evading it is also possible to use a small number of individuals to draw the attention of the pursuers from the main group (Figure 1e).

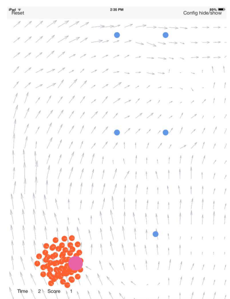
Three fingers A V-formation, typically used for pursuing, can be obtained with three fingers (Figure 1f). The same number of fingers can also be used to shape the swarm as a triangle (Figure 1g).

Four fingers More than three fingers are typically necessary when trying to obtain complex configurations. Figure 1h shows how a surround behavior is obtained using four fingers.

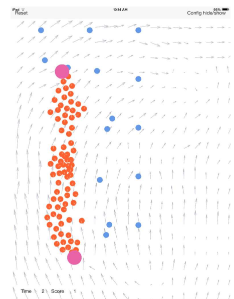
Playing with parameters A number of different kind of motion can also be obtained by playing with parameters. Figure 1h, for example shows the effects of an increment of the ZOR radius. This increases the repulsion component among robots of the swarm which causes a spreading behavior.



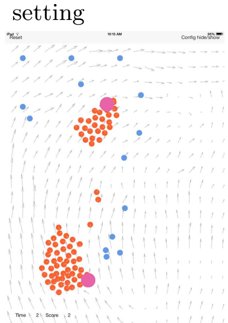
(a) Initial configuration and parameters setting



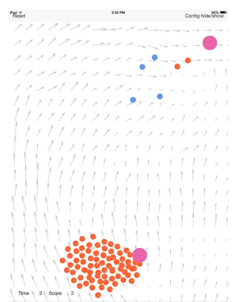
(b) One finger interaction: controlling the entire swarm



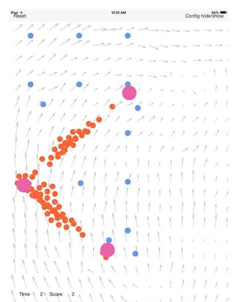
(c) Two fingers interaction: line formation



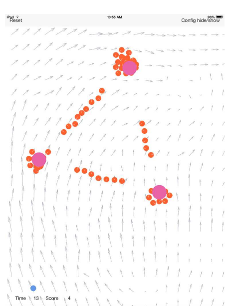
(d) Two fingers interaction: split in subgroups



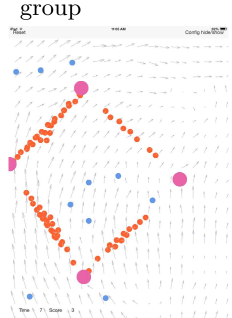
(e) Two fingers interaction: draw attention from the main group



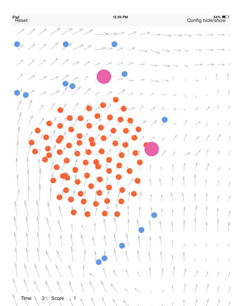
(f) Three fingers interaction: V formation



(g) Three fingers interaction: triangle formation



(h) Four fingers interaction: surround



(i) Playing with parameters: increasing repulsion

Fig. 1: iPad interface.

4 Demo Set Up

The setup comprises an iPad mini and a charger. In order to fully take advantage of the system, the user should be allowed to interact with the iPad in a comfortable way. A desk and a chair may be necessary to allow users to comfortably input commands even with two hands. Alternatively a flexible iPad stand to hold the device can be used.

5 Running experiments

The platform described can be used to run different kind of experiments. In [1] it was used to understand how users would take advantage of the multi-finger control in the context of pursuit-evasion.

During the experiment,participants were given three to five minutes for each of the two tasks. Within that time, they performed multiple trials to iteratively refine the evading/pursuing strategy. Experiments containing iterative trials are useful to understand how people interact with swarms of autonomous robots. For example in [1], a similar setup was used to gain insights about frequently-used strategies for pursuit-evasion and the way they are achieved. Our work seeks to define new pursuit-evasion strategies and to suggest natural high level gestures that can be used to provide users with even more control over the interface while minimizing attentional demands.

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