Persistent and Pervasive Real-World Sensing Using Games

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Abstract

Games With a Purpose can enable an intelligent agent to persistently and pervasively sense the real world by using game players as reconfigurable sensors. We propose a technique whereby an intelligent agent incentivizes players to collect data by translating data collection tasks into a series of quests played on a mobile device. In this paper, we define the concept of *Proactive Sensing* and provide a framework for *Game-Based Proactive Sensing* that can adapt games and narrative that optimizes for data collection and long-term player engagement.

Introduction

Using autonomous systems to persistently and ubiquitously observe the real world and make sense of the observations is a hard problem. Passive sensors can only observe the limited area around where the sensor is positioned. If passive sensors are carried with people (e.g., smart phones), they can only sense locales visited by people in the context of their daily activities. Furthermore, it may be intractable or impossible to make sense of the data collected at this time; e.g., machine vision is still an open problem. We introduce the concept of *Proactive Sensing*, the use of humans as reconfigurable sensors that seek out and report on specific aspects of the real world. Proactive Sensing benefits from the fact that humans are well suited for locomotion in the real world, make observations, and record those observations in forms that are easy for computers to digest.

A *Proactive Sensing Agent* is an autonomous system that works to continuously to build a knowledgebase about the real world. It is especially valuable for large-scale data collection problems that may last for very long times. For example, a Proactive Sensing Agent might seek to geospatially tag particular features of the real world necessary for accessibility and emergency services: handicap ramps, elevators, automatic external defibrillators, breastfeeding rooms, etc. However, Proactive Sensing by itself is not enough; the incentives necessary for humans to perform sensing and reporting tasks is a primary challenge. Proactive sensing may require humans to traverse a long distance in the real world, requiring the use of precious resources—time, physical exertion, money, etc.—in order to generate data about some specific aspect of the real world.

In this paper, we propose a technique whereby computer games are used to turn people into reconfigurable sensors. In *Game-Based Proactive Sensing*, a Proactive Sensing Agent distributes mobile games to humans such that success in the game requires player locomotion to a particular place in the real world and making and recording an observation. The theoretical advantage of Game-Based Proactive Sensing is that players voluntarily exchange work for entertainment. We specifically model our approach to Game-Based Proactive Sensing after Massively Multiplayer Online Role Playing Games (MMORPGs) with the following exceptions: (a) we use the real world instead of a virtual world, and (b) some quests proactively sense the real world.

Game-Based Proactive Sensing is a form of *Game with a Purpose*, a human computation system that uses game mechanics to incentive work (von Ahn and Dabbish 2008). Our approach to Proactive Sensing combines crowdsourcing games for geospatial tagging—e.g., *Gopher* (Casey, Kirman, and Rowland 2007) and the *MyHeartMap Challenge*—with Alternate Reality Games—e.g., Google's *Ingress* and *WeQuest* (MacVean et al. 2011).

Proactive Sensing with Games

Proactive Sensing is a means of turning people into mobile sensors. Given a purpose—the goal to collect knowledge of a particular nature—a Proactive Sensing Agent must solve four problems:

1. Select the next task to work on.

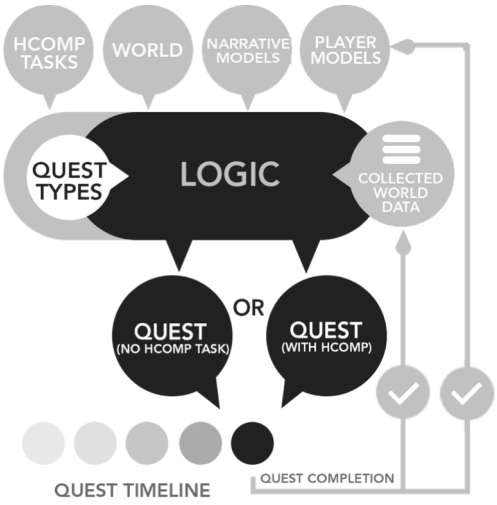

Figure 1. *Our game-based proactive sensing framework.*

2. Select the person to work on the task.
3. Select the method of delivery of a task.
4. Manage noise inherent due to human nature.

First, the task may be generated from a specification of the long-term objective or, more simply, selected from a pre-constructed list of facts or tags that it wishes to acquire. Second, the selection of the person to work on the task is important because of resource overhead associated with moving users or motivating users to perform a long or difficult task. Certain workers may be more or less likely to perform certain types of tasks. Third, method of delivery of task to worker may matter; different people may be motivated in different ways. Finally, Human Computation Systems are noisy systems and a Proactive Sensing Agent must be robust to noise due to uncompleted tasks and wrong answers. Robustness can be achieved in part by selecting multiple workers to perform the same task and by measuring the confidence of generated answers.

The limitations of Proactive Sensing are related to incentives for workers to perform proactive sensing tasks persistently over a long period of time. Games provide motivation by embedding a task in a game. However, an often-observed phenomenon in Games with a Purpose is player churn—an individual plays a small number of times because the replay value of repetitive games is quickly exhausted. One solution regularly adopted by the game industry is to use a narrative arc to motivate continuous play. This strategy has been enormously successful in game genres such as MMORPGs. We propose that the same strategy can be applied to Proactive Sensing by embedding tasks within quests.

Figure 1 provides the structure of our Game-Based Proactive Sensing Agent. The goal of the agent in our framework is to produce a number of quests, some of which, when played, generate data about particular aspects of the real world. There are five inputs to the system:

- *Human computation tasks.* This is a specification of the type of data or knowledge to be collected.
- *Narrative arc.* A fixed sequence of quests that make up the main storyline of the game and are played in the real world but do not collect data.
- *Quest types.* Templates for quests that can be parameterized to collect data in the real world.
- *The world.* The current known state of the world at the time that a quest is allocated to a player.
- *Player models.* Models may include past player performance, quest preferences, player willingness to travel, or other variables relevant to proactive sensing.

The Proactive Sensing Agent selects a task to work on, selects one or more players to proactively sense the world in support of the task, and distributes quests to the selected players through which the task can be completed. Quest generation is the parameterization of quest type templates with details from the task and the world. There are many ways of generating quests; see Li and Riedl (2010) for one a technique that adapts and merges quests in games.

We hypothesize that a balance between quests for the sake of entertainment and for the sake of data collection may keep and players immersed in the fictional context longer, thereby generating more data over the long-term. Thus a Game-Based Proactive Sensing Agent must optimize for both the accuracy of data collection and the long-term engagement of the pool of players. We note that it is also possible for a Proactive Sensing Agent to distribute quests to players for the sake of improving the player models by testing willingness of players to perform certain types of quests or certain types of tasks.

As an example, consider the problem of tagging the world for accessibility and emergency services. One type of quest may be to capture a creature that hides near such accessibility features. In this case, the Proactive Sensing Agent doesn't know where the creature should be until the player declares the quest complete. A second type of quest may be to verify the capture is legitimate.

References

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