Toward Using Games and Artificial Intelligence to Proactively Sense the Real World

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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 in a larger narrative arc in a real world MMORPG. 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. We lay out our initial steps toward a Proactive Sensing Agent that seeks to tag the geo-spatial locations of accessibility and emergency features in the real world using a set of quests in a mobile game called *SnaPets*.

1 INTRODUCTION

Using autonomous systems to persistently and ubiquitously observe the real world and make sense of what it observes is a hard problem. Passive sensors can only observe a limited area in the locale where the sensor is positioned. If sensors are carried with people (e.g., smart phones), they can only sense where people actually go. Further, it may be intractable or impossible to make sense of the data collected at this time. For example, although we make ample use of cameras, 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 has the benefit that humans are well suited to locomote in the real world, make observations, and record those observations in forms that are easy for computers to digest.

Proactive Sensing is a form of human computation system [5]. A *Proactive Sensing Agent* is an autonomous system that works continuously using Proactive Sensing 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, one may use Proactive Sensing to construct a commonsense knowledge base similar to *Cyc* or *Open Mind* [Singh]. Proactive Sensing might also be used to geospatially tag particular features of the real world necessary for accessibility and emergency services: handicap ramps, elevators, automatic external defibrillators, nursing stations, restrooms with infant changing tables, unsafe sidewalks, etc. However, Proactive Sensing by itself is not enough. How can a Proactive Sensing Agent incentivize humans to perform tasks that may require them to possibly traverse a long distance in the real world, requiring the use of precious resources—time, energy, possibly gas—in order to generate data about some specific aspect of the real world? What would make people want to perform such a task multiple times over a long period of time?

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 that the player locomotes to the requisite place in the real world and makes and records an observation. The theoretical advantage of Game-Based Proactive Sensing is that players voluntarily exchange work for entertainment. What kinds of games should players be given that will suit the needs of large-scale, longitudinal data collection? We additionally argue that structuring proactive sensing tasks as quests in the context of a larger real world, persistent, pervasive role-playing game will keep players sufficiently motivated to continuously engage in proactive sensing activities over a long period of time. We specifically model our approach to 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.

Artificial intelligence is an integral part of Game-Based Proactive Sensing. In addition to the optimization of the data collection behaviors of humans, it also plays an important role in motivating human players to act on behalf of the Proactive Sensing Agent. We posit that the complex and variable nature of the real world requires artificial intelligence to generate quests for each person, based on their preferences, in each context, according to the types of Proactive Sensing tasks available, according to task urgency and according to resource availability. In games like MMORPGs, some management of narrative, player skill, and player preference is believed to improve engagement. The player is a resource that must be managed so as to optimize the sensing capabilities and retain the player in a Proactive Sensing task, increasing the exigency for an engaging and adaptable gameplay experience.

In this desideratum, we make the following contributions:

- The introduction of the concept of Proactive Sensing as a new application domain for computer games and Game AI.
- A proposal for a framework for using narrative-based games to achieve Proactive Sensing.
- The report of initial stages toward implementing a solution to Game-Based Proactive Sensing that uses narrative to longitudinally engage players in proactive sensing tasks.

The remainder of the paper is as follows. In Section 2 we provide additional background and related work on real world games involving narrative and proactive sensing. In Section 3, we present details of Proactive Sensing and our framework for a Game-Based Proactive Sensing agent that uses narrative to engage players In Section 4 we detail our initial steps toward realizing Game-Based Proactive Sensing.

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2 BACKGROUND AND RELATED WORK

A Proactive Sensing Agent is a type of *Human Computation System*, intelligent systems that organize humans to manually carry out computational processes that are too hard to solve, to collect commonsense knowledge typically not available to computational systems, or label data [5]. Crowdsourcing has come to refer to the outsourcing of tasks by computational systems to a large number of anonymous workers via Web services for the purposes of computing a process [7]. *Games with a Purpose* (GWAPs) are Human Computation Systems that use game mechanics to incentive crowd workers [11]. *The ESP Game* [12] is the most well known GWAP. In it pairs of players generate labels for images such that label agreement indicates label quality. Our work differs in that it (a) does not require partners, and (b) focuses specifically on tagging geospatial coordinates in the real world.

Others have investigated the use of games to tag the real world environment. *Gopher* [2] used gameplay to encourage players to photograph and tag their environment. *MyHeartMap* [3] has gamified the search for certain objects like automated external defibrillators. We also note that *PhotoCity* [10] and *EyeSpy* [1] have successfully employed mobile games for structure-from-motion tasks. Our proposed approach differs from the above by layering a fictional context over the real world and using a variety of dynamically adapted quests instead of multiple separate games that require redundant, costly authoring overhead and may quickly lose player engagement due to task repetition.

Alternate Reality Games (ARGs) are interactive narrative experiences that engage the player by layering a fictional world over the real world; as players act in the real world their actions influence the state of the fictional world. Geo-location-based ARGs [6] make use of geo-location aware mobile devices such as phones, tablets, and Google Glass to reference the physical world as the environment for which the game plays out. There are numerous examples of commercial ARGs that utilize mobile technology but are constrained to a specific time and place.

We observe that ARGs can be similar in nature to Massively Multiplayer Online Role Playing Games; ARGs can be broken up into simple, finite length quests embedded within a larger narrative context that may persist for a large number of game play hours. To our knowledge, no such ARG has been built or deployed with the possible exception of Google's *Ingress* game. One of the reasons for the dearth of large-scale ARGs is due to the fact that real world games require artificial intelligence to sense the state of the real world; they must do this to adapt the game accordingly and monitor the real world for unpredictable state changes that interfere with or augment gameplay. Simply put, most people are not in the right place at the right time to participate in an ARG. Without artificial intelligence to adapt the game context, real world games such as large-scale ARGs are intractable to author in a way that can be played by virtually anybody in any location at any time [13].

Alternate Reality Game systems that adapt their narrative contexts according to players' real world contexts are rare. *WeQuest* [6] uses data mining to map hard-coded quests into novel locations. *Backseat Playground* [4] triggers story elements based on features of the local environment as one rides in the back seat of a car. Other ARGs that use artificial intelligence, such as *SpyFeet* [8], uses generic narrative structures that do not reference specific geo-locations (e.g., go to the nearest body of water).

3 PROACTIVE SENSING AND GAMES

Proactive sensing turns people into mobile sensors. Given a purpose—the goal to collect knowledge about a particular topic—a Proactive Sensing Agent must solve four problems in order to optimize the speed and quality of data generated:

1. Select the next task to work on.
2. Select the person to work on the task.
3. Select the method of delivery of a task.
4. Manage the noise inherent in human computation systems.

We look at each of these challenges briefly as follows. 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. For Game-Based Proactive Sensing, there may be different types of games that can be played that will complete the desired task—here we are describing framing a task in terms of certain gameplay objectives. Finally, Human Computation Systems are noisy systems; a Proactive Sensing Agent must be robust to noise in the form of uncompleted tasks and wrong answers. Robustness can be achieved by selecting multiple workers to perform the same task and by measuring the confidence of the distribution over generated answers.

The limitations of Proactive Sensing, as noted earlier, 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, a well observed phenomenon in Games with a Purpose is player churn: an individual either plays a single time, or a small number of times until the game becomes repetitive and replay value is exhausted. The solution in the game industry is to use a narrative arc to motivate continuous play. This strategy has been enormously successful in genres such as MMORPGs. We propose the same strategy can be applied to Proactive Sensing.

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 reliable 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. For simplicity, we shall assume it is a list of specific tasks, although this list may be generated in a just-in-time fashion from an abstract specification.
- *Narrative arc.* Adaptable or fixed sequences of quest types with additional narrative information that can be selected to create multi-stage objectives.
- *The world.* The current known state of the world at the time that players receive tasks. This involves contextual data like time, number of players, any outstanding quests, as well as any external APIs for gathering location-data.
- *Player models.* Data about people who have agreed to partake in the fictional world. Models may include past player performance, preferences, and other data that the system can use to choose the appropriateness of player for tasks with which to adapt quests.

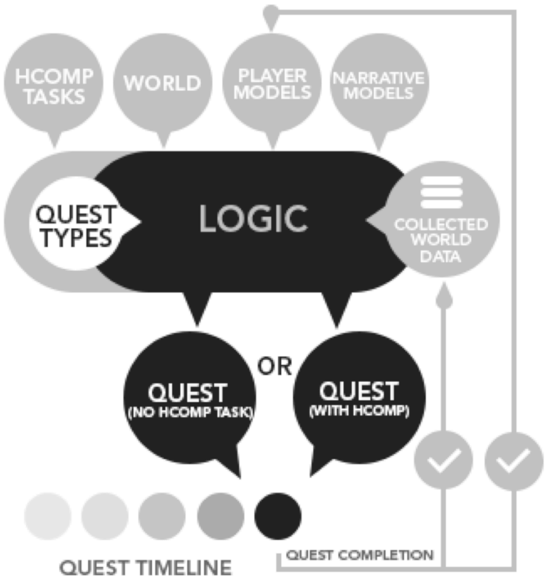

Figure 1. Our Game-Based Proactive Sensing framework.

- *Quest types.* A library of quest types that can be adapted to meet the needs of human computation tasks.

Examples of quests that we have implemented include: observation quests that involve taking a picture; tagging quests that involve providing some metadata about a given object; movement quests that involve travel from some point to a point or collection of points. The logic of the Proactive Sensing Agent follows that enumerated earlier—it 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.

As a game-based approach to proactive sensing that uses a strong narrative component, the framework is intended to achieve its objectives by embedding quests into a larger narrative arc so that players have a sense of long-term progression. The translation of tasks into quests and the embedding of quests into a larger narrative arc requires artificial intelligence—the set of tasks to be worked on and the state of the world that players are in when they choose to play are unpredictable at the time that quests are created. We enumerate four ways in which artificial intelligence can be used to adapt quests to make proactive sensing feasible:

1. *Adapt quest to task.* A quest type must be selected and parameterized such that the completion of the quest also generates the required data for the human computation task. For example, GPS traces or movement may translate to a traveling quest objective, or taking a picture may map to an observation quest objective.
2. *Adapt quest to real world context.* Shifting context demands awareness of where, when and what an agent can demand of a generic user. Theoretically, the greater the quest can incorporate details about the real world, the more the lines between the real world and fictional context can be blurred, and the more engaged the player may feel.
3. *Adapt quest to individual players' preferences.* To the extent that the quest can accommodate how the player moves, plays, acts, etc., the game will be more effective.
4. *Adapt quest to narrative.* Appropriate connections must be created between tasks, progress through the arc tracked, generic text converted to narrative-specific text, and game objects skinned to reflect the narrative theme and components.

Only the first type of adaptation is necessary. The others are posited to increase motivation and keep players playing longer. Not all quests must be for the purpose of completing a human computation task.

We hypothesize that a balance between quests and gameplay for the sake of entertainment and purpose-specific tasks may keep and players immersed in the fictional context longer, thereby generating more data over the long-term. The framework is designed to optimize both the accuracy of data collection and the long-term engagement of the pool of players. Maximization of player engagement has the anticipated benefit of generating more task-specific data and also improving accuracy of observations by tasking different players with redundant observation tasks, although at the expense of duration that the system must operate. Finally, we note that it is theoretically 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 indicated by the loop from quest to player model in Figure 1.

4 SNAPETS

SnaPets is the beginning of the larger quest-filled world which the agent will eventually fill with a variety of differing quests. We have built a preliminary system where users can log in on mobile devices and choose to complete any combination of three types of quests continuously. These quests involve the creation and capture of fantastical creatures in the real world, a style of game based on *Pokemon*. The game has a number of types of creatures, each of which is associated with an accessibility or emergency feature of the real world. For example, Automatic External Defibrillators (AEDs) are associated with the "Guardian" type of creature. A mapping exists between all creature types and environmental features. At present we have five types of creatures and thus five types of tags.

The first type of quest involves taking a picture of the real world location with a smart phone and tagging the image with a creature type. That is, creatures are placed in the world for others to collect. A secondary quest type exists to verify a player assigned tag by providing a secondary tag—this increases tag confidence. The third type of quest is to verify the type of creature found at a particular location by seeking out the location as seen in an image. A player is prompted to "go as close to where this image was taken as possible" and allowed to guess when they think they are close enough. If they get within a certain radius (currently set at 200m to account for possible GPS inaccuracy) and submit a guess, they will complete the task. From an entertainment perspective, this third task "collects" a creature. Figure 2 shows screens from each of the three quest types. Players are rewarded for their efforts with points and the collection of cute creature sprites.

The Proactive Sensing Agent logic is currently simple at this stage. It distributes quests of the second and third types randomly. A given task is distributed to multiple players to account for the noise due to incomplete quests and careless

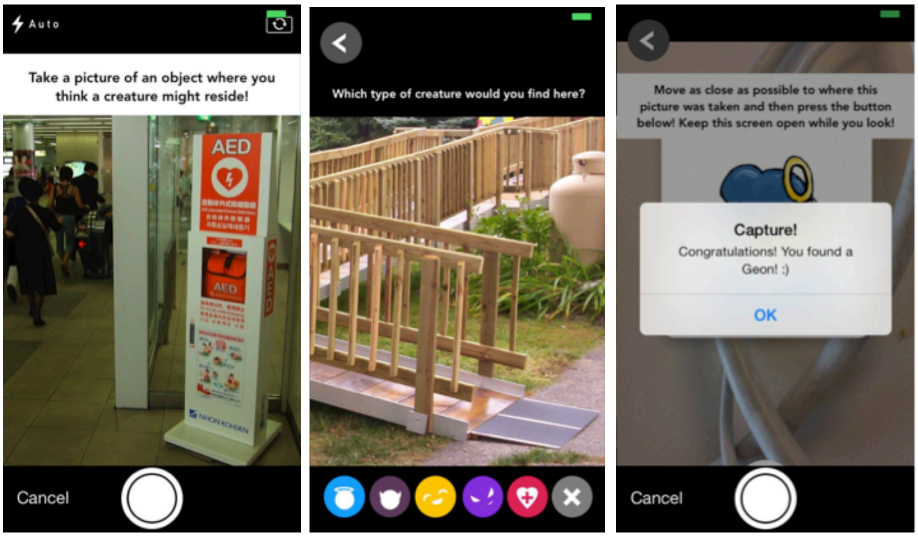

Figure 2. Screenshots from the three *SnaPets* quest types.

tagging. As a result of these three tasks, a robust environmental dataset is created through human computation in the form of gameplay. While basic at this stage, future work will involve the crafting of a persistent narrative, more complex quests, and additional quest-to-task mappings.

6 CONCLUSIONS

Computer games can be used to overcome the limitations of large-scale passive sensing of the real world. Proactive Sensing is an approach to tagging the real world and collecting commonsense knowledge that uses humans as a reconfigurable sensor that can go places passive sensors cannot and provide reliable data in computer-friendly form. Game-Based Proactive Sensing uses game playing to incentivize people to proactively sense the real world and to participate on a regular, and long-term basis. To make Game-Based Proactive Sensing work, we posit that proactive sensing tasks can be embedded into an unfolding narrative arc such that players engage with the system to seek entertainment such that the occasional quest also serves the purpose of collecting data. In our framework, proactive sensing tasks are mapped to quests, which are then adapted to incorporate world context, incorporate personal preferences, and to fit into the larger narrative arc.

In the long run, Game-Based Proactive Sensing converts the real world into a form of Massively Multiplayer Online Role Playing Game. We are exploring Proactive Sensing through the application of tagging the real world with information that might be later used by mobile accessibility and emergency services. We believe that Game-Based Proactive Sensing can result in new intelligent services that can collect a variety of knowledge, tag the real world, and generally provide services for the greater good without running into common human computation limitations such as engagement and churn.

REFERENCES

[1] M. Bell, S. Reeves, B. Brown, S. Sherwood, D. MacMillan, J. Ferguson, and M. Chalmers. Eyespy: supporting navigation through play. *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, 2009.

[2] S. Casey, B. Kirman, and D. Rowland. The Gopher game: a social, mobile, locative game with user generated content and peer review. *Proceedings of the 4th International Conference on Advances in Computer Entertainment Technology*, 2007.

[3] L. Grey. My heartmap seattle challenge enlists the public to locate city's life-saving devices. *@ONLINE*, October 2009.

[4] A. Gustafsson, J. Bichard, L. Brunnberg, O. Juhlin, and M. Combetto. Believable environments: Generating interactive storytelling in vast location-based pervasive games. *Proceedings of the 2006 ACM International Conference on Advances in Computer Entertainment*, 2006.

[5] E. Law and L. von Ahn. *Human Computation*. Morgan and Claypool, 2011.

[6] A. MacVean, S. Hajarnis, B. Headrick, A. Ferguson, C. Barve, D. Karnik, and M. Riedl. WeQuest: Scalable Alternate Reality Games Through End-User Content Authoring. *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*, 2011.

[7] A. Quinn and B. Bederson. Human computation: a survey and taxonomy of a growing field. *Proceedings of the 2011 ACM SIGCHI Conference on Human Factors in Computing Systems*, 2011.

[8] A. Reed, B. Samuel, A. Sullivan, R. Grant, A. Grow, J. Lazaro, J. Mahal, S. Kurniawan, M. Walker, and N. Wardrip-Fruin. A step towards the future of role-playing games: The SpyFeet mobile RPG project. *Proceedings of the 7th Annual Conference on Artificial Intelligence and Interactive Digital Entertainment*, 2011.

[9] P. Singh, T. Lin, E. T. Mueller, G. Lim, T. Perkins, and W. L. Zhu. Open Mind Common Sense: Knowledge acquisition from the general public. *Proceedings of the First International Conference on Ontologies, Databases, and Applications of Semantics for Large Scale Information Systems*, 2002.

[10] K. Tuite, N. Snavely, D. Hsiao, N. Tabing, and Z. Popovic. Photocity: training experts at large-scale image acquisition through a competitive game. *Proceedings of the 2011 ACM SIGCHI Conference on Human Factors in Computing Systems*, 2011.

[11] L. von Ahn. *Human Computation*. Ph.D. Thesis, Carnegie Mellon University, 2005.

[12] L. von Ahn and L. Dabbish. Labeling images with a computer game. *Proceedings of the 2004 ACM SIGCHI Conference on Human Factors in Computing System*, 2004.

[13] A. Zook and M. Riedl. AI for game production. *Proceedings of the IEEE Conference on Computational Intelligence in Games*, 2013.