



AI, Virtual Worlds, and Massively Multiplayer Online Games

Hsinchun Chen, *University of Arizona*
Yulei Zhang, *University of Arkansas*

Hundreds of thousands of people from different physical locations can join virtual worlds whenever they want to interact with each other and create objects in a computer-based simulated environment, typically in an interactive 3D format. The rich social media data generated in virtual worlds has important implications for business, education, social science, and society at large. Similarly, massively multiplayer online games (MMOGs) have become increasingly popular and have online communities comprising tens of millions of players. They serve as unprecedented tools for theorizing about and empirically modeling the social and behavioral dynamics of individuals, groups, and networks within large communities.¹⁻³

Some technologists consider virtual worlds and MMOGs to be likely candidates to become the Web 3.0. In such a “brave new world” of diverse online virtual civilizations, we believe AI can play a significant role, from multiagent avatar research and immersive virtual interface design to virtual world and MMOG Web mining and computational social science modeling.

Avatar Data Collection Example

Virtual worlds will become another type of important world in people’s lives in addition to the real world where they physically live. The Gartner Group estimated that 80 percent of active Internet users will have a “second life” in the virtual world by the end of 2011 (www.gartner.com/it/page.jsp?id=503861). Second Life (<http://secondlife.com>), developed by Linden Lab and publicly launched in 2003, is currently the most popular 3D virtual world. Since its inception, the number

of Second Life residents has grown dramatically, with 2.2 million residents in December 2006 and 8.3 million by August 2007.

Collecting social media data is difficult, however, because most virtual worlds do not provide easy data collection functions for regular users. Most of the data collected by virtual worlds and MMOGs are proprietary content and are not available for academic research. In an earlier study, we explored a technical framework to collect avatar-related data by using a combination of bot- and spider-based approaches.⁴ To demonstrate our proposed framework, we conducted a case study on *Second Life* exploring behavioral differences between male and female avatars. Figure 1 shows the proposed framework, where we use the bot-based approach to collect avatar behavioral data and the spider-based approach to collect avatar profile information.

The bot-based approach uses LibOpenMetaverse, a software library for communicating with the Second Life server. LibOpenMetaverse lets each bot conduct data collection on a much larger scale than the basic Linden Script Language (LSL). By logging onto the Second Life server using LibOpenMetaverse as clients, we used avatars as bots to automatically collect other avatars’ behavioral data in a given region. We sent a bot to a given region where it collected both the behavioral data and the avatar identifiers (such as names) at the same time. The avatar names help the spider-based approach collect the avatars’ profile data. The spider-based approach consists of three components. *Avatar profile spidering* collects the profile pages of all the avatars whose behavioral information had been gathered using the prior bot-based approach. *Profile data parsing* generates avatar

data fields including avatar name, birthday, and picture as well as a short self-introduction. Lastly, *avatar personal data* are used to infer avatars' other personal characteristics, such as gender and virtual age.

Following the proposed integrated framework, we conducted a case study to examine the differences in virtual world actions (such as flying, running, and walking) between the two virtual genders—that is, the self-reported gender in virtual worlds. Avatar names, self-introductions, and profile pictures were parsed out to three avatar gender coders. Only the avatars whose gender information, either male or female, was able to be clearly decided without any disagreement or confusion among all three coders were kept. Independent group t-tests were conducted to compare the action differences between the two genders as well as two age groups.

Table 1 shows the analysis results. For flying (p-value = 0.015), running (p-value = 0.023), turning left (p-value = 0.010), turning right (p-value = 0.046), and walking (p-value = 0.005), male avatars were significantly more likely to perform these actions than female avatars. Female avatars were significantly more likely to stand as compared to male avatars (p-value = 0.012). Male avatars seemed more likely to hover and stride, but the results were not statistically significant. Overall, male avatars tended to perform more “active” actions than female avatars.

These findings are consistent with real people in the physical world, where males are in general more physically active than their female peers. Our future research will involve examining other behavioral and avatar characteristics in virtual worlds, including virtual world experience, age, education level, social network formation, and interaction

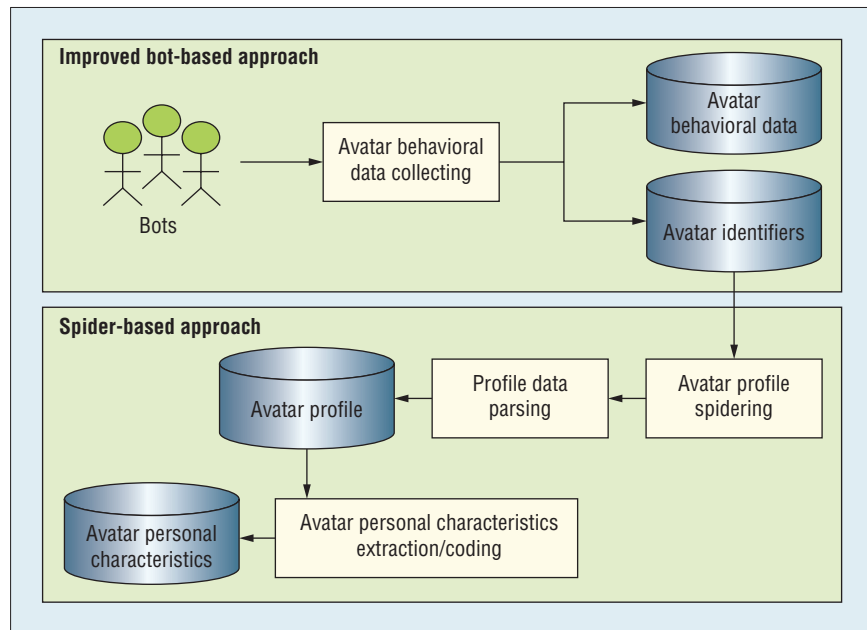


Figure 1. Proposed framework for avatar data collection. The bot-based approach collects avatar behavioral data, and the spider-based approach collects avatar profile information.

Table 1. Results of the virtual world gender analysis.

Avatar action	Male N = 537 (mean/standard deviation)	Female N = 797 (mean/standard deviation)	T-test (t-stats/p-value)
Flying	0.020 / 0.044	0.015 / 0.037	2.16 / 0.015*
Hovering	0.042 / 0.062	0.036 / 0.069	1.51 / 0.065
Running	0.020 / 0.045	0.016 / 0.040	2.00 / 0.023*
Striding	0.018 / 0.028	0.016 / 0.025	1.23 / 0.109
Turning left	0.099 / 0.071	0.090 / 0.071	2.33 / 0.010**
Turning right	0.095 / 0.071	0.089 / 0.073	1.68 / 0.046*
Walking	0.143 / 0.105	0.129 / 0.099	2.62 / 0.005**
Standing	0.775 / 0.161	0.795 / 0.160	-2.26 / 0.012*

*Significant at 0.05 level. **Significant at 0.01 level.

patterns. All these data can be readily obtained (some with further processing) based on our proposed bot-spider framework for virtual world avatar data collection.

In This Issue

This issue includes two articles with additional research examples from distinguished experts in social science and computer science. Each article presents a unique research framework, computational methods, and selected results. In the first article,

“Secondary Avatars and Semiautonomous Agents,” William S. Bainbridge presents semiautonomous agent assistants that have been incorporated into recent MMOGs. Although the AI behind these agents is basic, their behavior in groups and complex situations can provide insights into how future intelligent systems might function in many realms of activity. Bainbridge reports results from extensive explorations of two popular game worlds, Dungeons and Dragons Online (DDO) and Star Trek



Figure 2. A primary avatar and six secondaries in Dungeons and Dragons Online. The game lets players rent secondary agents to help with game play when friends and other human players are unavailable.

Online (STO). Both MMOGs emphasize team play, and AI assistants serve as substitutes for human beings when the player's friends are not online or are unable to participate. The author believes that for more advanced future virtual world and MMOG research, scientists will need to participate actively in the design of virtual worlds, incorporating their experiments while helping the game creators innovate.

In the second article, Kyong Jin Shim, Nishith Pathak, Muhammad Aurangzeb Ahmad, Colin DeLong, Zoheb Borbora, Amogh Mahapatra, and Jaideep Srivastava report research results from their multiyear research project on MMOGs. The University of Minnesota group adopts knowledge discovery as a core mechanism to analyze MMOG logs and build models of social interactions in games. They constructed combat, mentoring, and trust networks based on data from Sony's popular MMOG *Everquest II*. They also provide an excellent summary of their ongoing research in performance and learning, player churn analysis, and identifying undesirable behavior in MMOGs.

The authors argue that the close collaboration between social scientists and computer scientists is creating an emerging area called "computational social science," where computation is used as an integral mechanism in social science research. Given current trends in virtual-and-real-world interactions, this area of research will increase in importance and impact.

Acknowledgments

This material is based on work supported in part by grants DOD HDTRA-09-0058, NSF CNS-070933, NSF CBET-0730908, and NSF IIS-0428241.

References

1. W.S. Bainbridge, ed., *Online Worlds: Convergence of the Real and the Virtual*, Springer, 2010.
2. W.S. Bainbridge, *The Warcraft Civilization: Social Science in a Virtual World*, MIT Press, 2010.
3. J. Srivastava, tech. reports, Dept. of Computer Science and Eng., Univ. of Minnesota, 1998–2009; www.cs.umn.edu/research/technical_reports.php?page=author&author_id=68.
4. Y. Zhang et al., "An Integrated Framework for Avatar Data Collection from the Virtual World: A Case Study in

Second Life," *IEEE Intelligent Systems*, vol. 25, no. 4, 2010, pp. 17–23.

Hsinchun Chen is the McClelland Professor of Management Information Systems and the director of the Artificial Intelligence Lab at the University of Arizona. Contact him at hchen@eller.arizona.edu.

Yulei Zhang is a visiting assistant professor in the Information Systems Department at the University of Arkansas and a PhD candidate in management information systems at the University of Arizona. Contact him at ylzhang@email.arizona.edu.

Secondary Avatars and Semiautonomous Agents

William Sims Bainbridge, *National Science Foundation*

Recent massively multiplayer online (MMO) games are prototyping methods through which users can interact with multiple semiautonomous agent assistants.^{1–3} Although these agents use simple AI, their behavior in groups and complex situations can provide insights into how future mixed-initiative systems might function in many realms of activity. Here I report results from extensive exploration of two game worlds, Dungeons and Dragons Online (DDO) and Star Trek Online (STO). Both emphasize team play, and AI assistants serve as substitutes for human beings when the player's friends are not online or when other players are unavailable.

Hirelings in DDO

AI assistants in DDO are mercenaries, called *hirelings*, who must be rented, either with virtual coins earned by completing missions inside DDO or with points bought in an online store with real dollars. Figure 2 shows my avatar, Sagittarius, standing

on a footbridge over the Menechta-run desert with three agents on each side—five hirelings who cost US\$2 for a one-hour rental, plus his pet hyena. These are secondary avatars, in complex ways under the user's control.

For each hireling, there is a hot bar holding 10 icons, and clicking one either gives a specific command or sets the agent's general behavior. Four of these are actions that only the particular hireling can perform. For example, a cleric might have one icon to give significant healing to a selected wounded ally and another to give minor healing to all members of the party. All hirelings also have six icons that perform these actions:

- toggle between stand still or follow the primary avatar;
- summon the hireling to the avatar, even over a long distance;
- set the hireling to behave autonomously;
- engage defensive mode, responding only if it or the primary avatar is attacked;
- engage passive mode, doing nothing; and
- interact with a target.

The last of these might, for example, have the secondary avatar pull a lever in one of the many dungeon mazes, when two widely separated levers must be pulled simultaneously to open a gate. The hireling follows the primary avatar to one lever, is told to stand still, and the user right clicks the lever to select it as the hireling's target. The primary avatar then walks to the second lever and activates it, while the player clicks the hireling's icon to tell it to interact with the first lever. These combined actions open the gate, something that one avatar could not do alone.

One mission carried out in the ruins of Threnal illustrates how complex the action of a simulated team can become. Buried deep beneath the Earth for 500 years, the Library of Threnal has just been entered by archeologists. An ambitious man named Coyle is seeking an ancient manuscript that could give him magical powers, but he has kept secret this reason for entering the library. In DDO, he is represented as an autonomous nonplayer character, as are two assistants who accompany him. They stand in the library's central book repository, responding as waves of monsters of different kinds enter from random directions. As soon as Coyle sees a monster

DDO and STO are fantasy games, but they offer a glimpse into the real future that many people will inhabit.

he attacks it, and his assistants follow his lead. Unfortunately, this will result in his quick death, and the goal of the mission is keeping him alive for 15 minutes.

Sagittarius rented five hirelings—two cleric healers and three warriors with different attack modes to fight the different monsters. On ordinary missions, he often instructs all his hirelings to support him in defensive mode, which means they heal him and attack only enemies who have harmed him. This time, he gave the three warriors instructions to act autonomously, which means they immediately attack enemies they detect. Thus, when monsters approached, six members of the

team attacked them: Coyle, his two assistants, and three of the hirelings. The two cleric hirelings stood passively watching the battle, only reacting when Sagittarius took damage or when given specific instructions. Sagittarius set his attention on Coyle and, whenever Coyle took damage, instructed one of the clerics to heal him. In the pause after one attack and before the next, Sagittarius would rapidly use the clerics plus his own limited healing abilities to restore the health of any members of the team who needed it.

The nine-member team included three agents who could not be controlled at all, three secondary avatars who were set to function autonomously but could have been controlled, and three characters (counting the primary avatar and two secondaries) under the player's direct control. Given that groups of attacking monsters came from random directions, and the behaviors of the AIs were influenced by their exact locations in relation to the others, even simple programming produced a remarkably complex result.

Secondary Avatars in STO

STO chiefly takes place in outer space, as fleets of spaceships battle each other, but some "away missions" take crews of five avatars to a planet's surface or inside a ship. A mission begins when the player's ship enters a solar system, and STO automatically assembles players into teams if they have not already teamed up with friends and if other players are starting the mission at roughly the same time. When this does not happen, the team is completed by secondary avatars conceptualized as officers from the bridge of the player's ship.

By the time he became an admiral, my avatar Rho Xi had 10 of these bridge officers but only used the

Table 2. Characteristics of five secondary avatars in Star Trek Online.

Character	Ability	Description
Thuvia, Andorian female tactical officer	Suppressing fire	Slows down and reduces the damage caused by an enemy.
	Leg sweep	A short distance attack with a high chance of knocking back any nearby foes.
	Photon grenade	Throws an explosive grenade at the target.
	Fire on my mark	Reduces the enemy target's resistance to damage.
Marx, Ferengi male tactical officer	Overwatch	Increases nearby allies' resistance to damage, and impedes nearby enemies.
	Lunge	Leaps at the target, delivering a melee attack and possibly knocking it down.
	Focus fire	Lowers the damage resistance of the target with each attack from allies.
	Ambush	Increases damage from next attack, best used while in stealth mode or not under attack.
Tonga, Trill female engineering officer	Shield generator fabrication	Creates a fixed position generator that recharges personal shields for allies in the immediate area.
	Reroute power to shields	Strengthens the target character's shield against damage.
	Shield recharge	Restores lost personal shield energy to you or an ally.
	Fuse armor	Snares, roots, and then holds the target, reducing its mobility.
Flash, Human male engineering officer	Medical generator fabrication	Creates a fixed position generator that heals injured allies in the immediate area.
	Phaser turret fabrication	Creates a fixed position weapon platform that fires at nearby enemies.
	Chroniton mine barrier	Deploys five mines, which explode when hostiles get close.
	Cover shield	Creates a broad shield that deflects attacks from a particular direction.
Azura, Vulcan female science officer	Neural neutralizer	Placates nearby enemies, discouraging them from attacking.
	Vascular regenerator	Rapid recovery from serious injury.
	Medical tricorder	Quickly heals injury to your avatar or an ally.
	Nanite health monitor	Scans nearby allies to determine if they are seriously injured, then heals wounded.

five listed in Table 2, typically leaving one or the other engineer behind when beaming down on an away mission. Each secondary avatar has four special abilities, in addition to using whatever weapon it carries, and the descriptions are adapted from STO's wiki (http://stowiki.org/wiki/Bridge_officer_abilities).

Operating STO secondary avatars involves much end-user programming, although not generally conceptualized as such because it is done by clicking or dragging icons. The user decides which of several possible abilities each bridge officer will have and what weapons, armor, and special equipment they will carry. In action, the hot bars for the four secondaries have icons representing their abilities, and clicking one during battle removes it from the list of actions the secondary can

perform, putting the emphasis on others.

Unlike the situation in DDO, a STO player can tell each secondary to go to a particular location within the field of view or send all four to the same spot. When encountering a group of enemies, the user can leave the secondaries free to respond to the situation autonomously, control each one in detail, or have them all attack the same enemy officer to remove him from action quickly and then respond autonomously as the combat unfolds. Visually, the result is exceedingly complex, especially when engineers set up equipment that then functions autonomously.

Implications of Secondary Agents

DDO and STO are fantasy games, but they offer a glimpse into the real

future that many people will inhabit. Their AI systems possess primitive machine learning, as the secondaries concentrate on the enemies that have done most damage to them. The systems also appear to be hierarchical because secondaries often choose at random among the actions available to them, but they respond correctly when approached or attacked by an enemy or when they notice that a team member needs healing.

In the future, our lives might incorporate many semiautonomous agents, and we may set the degree of autonomy of any secondary avatar as events require. DDO and STO place a great premium on a good user interface because decisions must be made quickly. Future use of agents might take place over longer periods of time and thus provide more scope for advanced machine learning. On the

team level, if not that of the individual agent, these games already represent highly intelligent systems. Thus, they have become both a laboratory for research on human-multiagent interaction and a training ground for the future users and creators of such systems.

Among the interesting research questions is when it will be advantageous to conceptualize an agent as a secondary avatar, possessing some degree of personhood. In terms of human-computer interaction, giving an agent a person's appearance might be helpful for inexperienced users, but sophisticated users might do better with agents represented through a variety of metaphors that best express their different functions. Researchers can initially study such questions by observing how users of different levels of sophistication operate diverse resources inside existing game worlds. For more advanced research, scientists will need to participate actively in the design of virtual worlds, incorporating their experiments while helping the game creators innovate.

Acknowledgments

The views expressed in this essay do not necessarily represent the views of the National Science Foundation or the United States.

References

1. W.S. Bainbridge, *Online Multiplayer Games*, Morgan and Claypool, 2009.
2. W.S. Bainbridge, ed., *Online Worlds: Convergence of the Real and the Virtual*, Springer, 2010.
3. K.E. Merrick and M.L. Maher, *Motivated Reinforcement Learning: Curious Characters for Multiuser Games*, Springer, 2009.

William Sims Bainbridge is a director of the Human-Centered Computing Program at the US National Science Foundation.

Analyzing Human Behavior from Multiplayer Online Game Logs: A Knowledge Discovery Approach

Kyong Jin Shim, Nishith Pathak, Muhammad Aurangzeb Ahmad, Colin DeLong, Zoheb Borbora, Amogh Mahapatra, and Jaideep Srivastava, *University of Minnesota*

Observing and analyzing a phenomenon at unprecedented levels of granularity not only furthers our understanding of it but also transforms the way it is studied. With the mass adoption of the Internet in our daily lives and the ability to capture high-resolution data on its use, we are at the threshold of a fundamental shift not only in our understanding of the social and behavioral sciences, but also the ways in which we study them. Massively multiplayer online games (MMOGs) have become increasingly popular, with tens of millions of users.¹ They serve as unprecedented tools to theorize and empirically model the social and behavioral dynamics of individuals, groups, and networks within large communities.

MMOGs are online spaces providing users with comprehensive virtual universes, each with its own unique context and mechanics. They range from the fantastical world of elves, dwarfs, and humans to space faring corporations and mirrors of our world. Large numbers of users interact and role-play via the in-game mechanics. With their increasing popularity, researchers are realizing that MMOGs are a means to fully observe an entire isolated universe. Each action is logged, and the level of granularity and completeness with which information is collected is

unmatched by any real-life experimental setup. The data collected provides an excellent means of studying human social behavior with respect to the complete context of the environment for a large population.

Because MMOGs usually consist of a thin-client architecture, all player actions are captured in the click-stream logged at the server. Along with the players' behaviors, the games often also store a brief record of their real-life profile. And it is common for popular virtual worlds to have hundreds of thousands of players generating copious amounts of data at any given time. A key challenge is developing methods that can analyze relationships while scaling to terabytes of data. The data also have a temporal component that is often an integral part of the analysis and introduces further relationships. Thus, while providing an exciting new tool for social science research, the virtual worlds also present a set of difficult and novel computational challenges.

Our research uses knowledge discovery as a core mechanism to analyze MMOG logs and build models of social interactions in games and understand how users' relationships are affected by the variety of environmental factors present in each world. MMOGs provide mechanisms to foster social activities among users, letting them form groups, guilds, corporations, and so on and tackle collaboration-oriented tasks, such as raiding a dungeon for gold. Data collected from these mechanisms provide an excellent means of studying human social behavior with respect to the complete context of the environment. Such research is infeasible for real-life activities because it is impossible to track and record complete information on a large population. Knowledge discovery

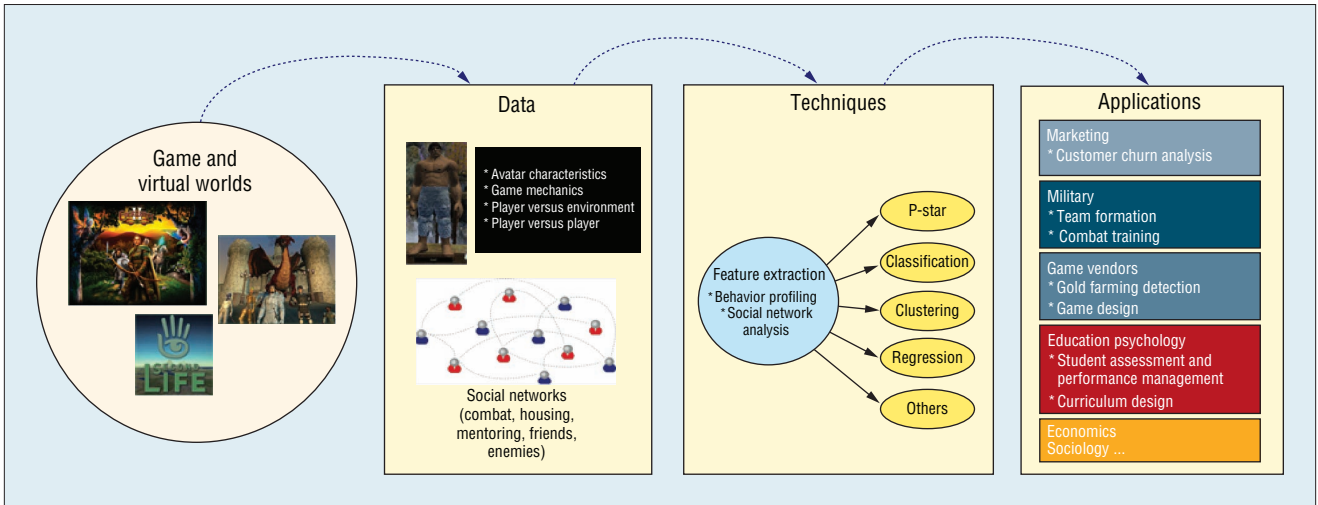


Figure 3. Data obtained from massively multiplayer online games (MMOGs) can be used for various scientific and commercial purposes. Scientific purposes include data-intensive empirical studies of various social science theories and models, including organizational behavior, team dynamics, competition and cooperation, mentoring and teamwork, and performance and achievement. Commercial applications include predicting player churn, identifying undesirable behavior, and social-influence-based recommendations.

is a key computational approach to realizing this promise, and in the process, it creates opportunities to push the frontiers of knowledge discovery itself.

Game Data and Social Networks

Our research focuses on data from Sony’s popular MMOG *EverQuest II*. Figure 3 provides an overview of the overall approach to our project.

The data primarily consist of avatar characteristics, player demographics, and in-game behavior. *Avatar characteristics* provide data on players’ virtual avatars in the game. This includes the avatars’ gender, race, faction, health and damage statistics, and more. *Player demographics* include real-life age, gender, geographic location, and so on. Survey results from a small sample of players are also available that include their responses to multiple facets such as feelings toward the game and other game users, psychological fitness, and real-life behavior outside the game.

The most unique data are the *in-game behavior logs*, which contain each user’s game activities. Anytime a significant event occurs—for example,

when a user kills a monster, completes a quest, forms a group with other users, or engages in trade—a record is created in the in-game behavior logs. The behavior logs are time-stamped and can be parsed to uncover a wealth of information.

For our research, the most important information gleaned from the logs is about user relationships. Players can socially interact with each other using various methods provided by the game mechanics. They can form groups to tackle monsters, go on quests together, trade with each other, express different levels of trust, create and join guilds, mentor other players, and so forth. Each of these can be represented as a social network among players, which we can then study to understand how they are impacted by and affect both the players and the environment. The following are examples of the types of relationship networks that we can construct from game logs.

- **Combat network.** Team formation is a common occurrence in many MMOGs because the games are designed to encourage social interactions. For instance, certain quests

require multiple avatars with different sets of skills. Team members must rely on each other while playing their respective set of capabilities and abilities during combat. Studying the formation of task-oriented groups is an important first step to understanding the dynamics of team collaboration. Team formation is highly influenced by the common interests of players during challenging tasks. Combat team performance is positively correlated with group size (to a certain extent) and group level. More than 12 million teams form monthly, making games such as *EverQuest II* an excellent venue for studying human and organizational behaviors.

- **Mentoring network.** Mentoring occurs in MMOGs when an experienced player helps a novice player gain skills. Mentors move down to the level of their apprentices to teach them combat skills, transmit knowledge about different aspects of the game, and perform one or more tasks with the apprentices. Mentors gain achievement points from successfully completing tasks with their apprentices. Apprentices also gain XP points (plus bonus

XP for participating in mentoring) from, for instance, killing monsters. More importantly, they attain valuable lessons and experience by interacting with their mentors. Skilled and knowledgeable mentors will help their apprentice pick up the game quickly and efficiently. A player can have multiple mentors in a session and can interact with one mentor at a time.

- **Trust network.** Trust networks are difficult to study because mapping trust relationships in the real world is difficult. Online interactions, however, provide a unique opportunity to study such relationships. In some MMOGs such as *EverQuest II*, for example, players can buy virtual houses and grant other players varying levels of access to them. Thus, trust in these games is described with respect to a commodity. Analyzing these trust networks reveals that their properties are similar to trust networks in other domains.

Interestingly, networks generated by in-game processes are closely analogous to the real world. For example, money transactions are similar in the game world and the real world. In contrast, role-playing networks differ from any real-world networks because this is a unique in-game phenomenon.

Applications

As Figure 3 shows, data obtained from MMOGs can be used for various scientific and commercial purposes. Scientific purposes include data-intensive empirical studies of various social science theories and models, including organizational behavior, team dynamics, competition and cooperation, mentoring and teamwork, and performance and achievement. Commercial applications include predicting

player churn, identifying undesirable behavior, and social-influence-based recommendations.

Performance and Learning

In recent years, researchers have found games and virtual worlds to be a sound venue for studying human behavior. In particular, in learning sciences and educational psychology communities, systematic studies of player performance and social interactions captured in game logs have led to a better understanding of learning, collaboration, social participation, literacy, and learning trajectory at the individual and group levels.



The estimated worth of the MMOG market currently stands at US\$6 billion, with little expected future letdown in growth.

In addition, the military has widely used simulation-based training in virtual environments. Traditionally, human instructors are tasked to abstract from individual soldier behaviors to the team behaviors and goals. One challenge with this approach is that the interpretation is subject to the instructor. Another challenge is that human instructors cannot capture information about rapidly evolving events or low-level information. Therefore, efficiently and effectively determining what teams are doing as well as how and why they are doing it remain challenging tasks. A systematic

study of individual player characteristics, team composition and characteristics, social interactions among team members, and game environments can reveal a great deal about the recipes for success in achieving various game objectives.^{2,3}

Player Churn Prediction

The estimated worth of the MMOG market currently stands at US\$6 billion, with little expected future letdown in growth.¹ Activision-Blizzard's game *World of Warcraft* has the largest market share of any MMOG by far at roughly 60 percent, and the revenue potential has attracted several new game makers to this market segment. With increased competition, game companies are especially concerned with customer acquisition and retention.

Using Web-mining techniques,⁴ we analyzed players' in-game behaviors. When combined with subscription-related information, we gained significant insight into the mechanics of player engagement and their likelihood to churn.⁴ Game developers can use this knowledge to improve marketing and retention strategies as well as to tweak game mechanics to enhance player engagement.

As part of churn analysis, we try to understand different player motivations. Two key indicators of player engagement in MMOGs are their individual involvement and achievements as well as their level of in-game socialization with other players. Churn-prediction models built on a combination of these factors have greater predictive power than those that are not. MMOGs have different business approaches ranging from subscription-based to free-to-play models. The churn analysis and prediction models also vary based on the nature of the underlying subscription model.

Identifying Undesirable Behavior

Gold farming refers to the illicit practice of gathering and selling virtual goods in online games for real-world currency. Gold farmers are especially frowned upon by game developers because they disrupt the economic balance of a game's virtual economy, go against the ethos of fair play, and might make certain areas of the game difficult to access for legitimate players. Consequently, game administrators actively seek to ban gold farmers from their games.

The problem of gold farmer detection can be posed as a binary classification task using in-game features such as the amount of time played, sequence of play, associations with other players, and offline characteristics such as language, location, and gender.⁵ We can further divide gold farmers into four subtypes:

- *gatherers* accumulate gold (virtual currency),
- *bankers* are low-activity accounts that hold gold in reserve,
- *mules* (or *dealers*) are one-time characters that act as a link in the chain to distance the customer from the operation, and
- *marketers* (or *spammers*) advertise the company's services.

Different in-game and network features must be used to detect each type. Not all gold farmers are labeled as such. Thus, administrators must use labeled propagation techniques to identify other potential gold farmers.

Trends and Controversies

Games fulfill many needs for humans at multiple levels and thus have been popular since the dawn of time. The Internet medium, with its new capabilities, lets game developers and players exercise their imagination in new ways. Online games have clearly

proven to be highly engaging, given the increasing rate of adoption and the amount of time people spend playing them. This has opened up new avenues for studying social sciences, as this article illustrates.

As the science's success becomes increasingly visible, commercial efforts will not lag far behind. There is already talk in commercial forums, such as the annual Game Developer Conference (GDC, www.gdconf.com), of the need to use game analytics commercially. Thus, one of the major trends expected for this research is to transition into the industry. Next, the success of commercial analytics will lead to game developers



Online games have proven to be highly engaging and opened up new avenues for studying social sciences.

inserting more data collection hooks into the system and building more personalized games. Subsequently, we might also see personalized recommendations and product placements in the games on a regular basis—for example, see www.xconomy.com/san-francisco/2010/09/30/npario-shows-ea-how-to-track-and-target-consumers-across-web-mobile-social-internet-tv-and-game-consoles.

Any major change is not without controversy, and this area is no exception. On the commercial side, there are issues of privacy violation and ruined game experience. For the social sciences, the controversy is even more fundamental. The approach we describe

here is an example of data-driven modeling, which is a hard sell at best to a community trained in and used to hypothesis-driven model building.

The close collaboration between social scientists and computer scientists is creating an emerging area called *computational social sciences*, where computation is used as an integral mechanism to do social science research. Given current trends of user behavior, this area can only increase in importance. Emerging experiences show that our proposed approach can aid in the process of classical model building. However, the computational and social science communities' mode of thinking has sufficient gaps that such collaborations are unlikely to arise easily. We sincerely hope to be proven wrong on this prediction, to the benefit of both communities. ■

Acknowledgments

The Virtual World Exploratorium project is a major collaborative effort involving numerous educational institutions, industrial partners, and sponsoring agencies. The academic institutions are Northwestern University, University of Southern California, University of Illinois at Urbana-Champaign, University of Chicago, and University of Toronto. The data for this research has been provided by Sony Online Entertainment, Linden Lab, and Kingsoft. This research has been sponsored by the US National Science Foundation, the Army Research Institute, the Air Force Research Laboratory, and the Army Research Laboratory through a Network Science Collaborative Technology Alliance (CTA) award.

Although this article focuses on computational aspects, our ideas have been shaped by cross disciplinary interaction with colleagues from all partnering institutions, and we owe them all a debt of gratitude. The ideas and positions expressed herein, however, are solely the authors' and do not represent the official positions, either stated or implied, of the sponsoring agencies. More information about this project can be obtained from <http://vwobservatory.com/drupal>, and all publications are available at www.vwobservatory.com/filesare.php.

References

1. A. Bagga, "The Emergence of Games as a Service," industry report, ThinkEquity, 2009.
2. K. Jin Shim, R. Sharan, and J. Srivastava, "Player Performance Prediction in Massively Multiplayer Online Role-Playing Games (MMORPGs)," *Proc. Pacific-Asia Conf. Knowledge Discovery and Data Mining (PAKDD)*, vol. 2, LNAI 6119, Springer, 2010, pp. 71–80.
3. Y. Huang et al., "The Formation of Task-Oriented Groups: Exploring Combat Activities in Online Games," *Proc. IEEE Int'l Conf. Computational Science and Eng.*, vol. 4, IEEE CS Press, 2009, pp. 122–127.
4. J. Kawale, A. Pal, and J. Srivastava, "Churn Prediction in MMORPGs: A Social Influence Based Approach," *Proc. IEEE Int'l Conf. Computational Science and Eng.*, vol. 4, IEEE CS Press, 2009, pp. 423–428.
5. B. Keegan et al., "Dark Gold: Statistical Properties of Clandestine Networks in Massively Multiplayer Online Games," *Proc. IEEE 2nd Int'l Conf. Social Computing*, IEEE CS Press, 2010, pp. 201–208.

Kyong Jin Shim is a graduate student and research fellow in the Department of Computer Science and Engineering at the University of Minnesota. Contact her at kjshim@cs.umn.edu.

Nishith Pathak is a graduate student in the Department of Computer Science and Engineering at the University of Minnesota. Contact him at npathak@cs.umn.edu.

Muhammad Aurangzeb Ahmad is a graduate student in the Department of Computer Science and Engineering at the University of Minnesota. Contact him at mahmad@cs.umn.edu.

Colin DeLong is a graduate student in the Department of Computer Science and Engineering at the University of Minnesota. Contact him at delong@cs.umn.edu.

Zoheb Borbora is a graduate student in the Department of Computer Science and Engineering at the University of Minnesota. Contact him at zborbor@cs.umn.edu.

Amogh Mahapatra is a graduate student in the Department of Computer Science and Engineering at the University of Minnesota. Contact him at amahapa@cs.umn.edu.

Jaideep Srivastava is a professor in the Department of Computer Science and Engineering at the University of Minnesota. Contact him at srivasta@cs.umn.edu.

cn Selected CS articles and columns are also available for free at <http://ComputingNow.computer.org>.

IT Professional

TECHNOLOGY SOLUTIONS FOR THE ENTERPRISE

CALL FOR ARTICLES

IT Professional seeks original submissions on technology solutions for the enterprise. Topics include

- emerging technologies,
- cloud computing,
- Web 2.0 and services,
- cybersecurity,
- mobile computing,
- green IT,
- RFID,
- social software,
- data management and mining,
- systems integration,
- communication networks,
- data center operations,
- IT asset management, and
- health information technology.

We welcome articles accompanied by Web-based demos. For more information, see our author guidelines at www.computer.org/itpro/author.htm.

WWW.COMPUTER.ORG/ITPRO

