Psychosocial and Cultural Modeling in Human Computation Systems: A *Gamification* Approach

Antonio Sanfilippo, Roderick Riensche, Jereme Haack, and Scott Butner

Introduction

Human decision making is hard to capture in computation systems because it is strongly driven by insight and creativity and influenced by cognitive biases. Qualities such as the ability to focus on what is perceived to be most important and the capacity to make quick decisions by insight and intuition make human judgment uniquely effective (Gigerenzer 2007; Gladwell 2005). However, the same qualities can also be responsible for fallacious reasoning when judgment is affected by memory limitations (Miller 1956), lack of knowledge/expertise (Klein 1998), and biased judgment due to factors such as increased confidence in extreme judgments and highly correlated observables (Kahneman and Tversky 1973), positive framing (Tversky and Kahneman 1981), "groupthink" (Janis 1972; Surowiecki 2004), and premature commitment to a single expected outcome (Heuer 1999). The ability to understand weaknesses and leverage strengths in the human decision process is crucial in designing human computation systems which effectively benefit from and complement human intelligence.

In this chapter, we review some of the challenges and opportunities regarding the integration of human decision making into human computation systems and discuss ways in which challenges can be met to avail ourselves of the opportunities afforded. We discuss a *gamification* approach in which gameplay is applied to real-world problems to develop social intelligence and support analysis and decision-making through a concerted reasoning effort that interleaves human and machine intelligence. We describe a systematic methodology for integrating modeling algorithms within a serious gaming environment in which role-playing by human agents provides updates to model nodes and the ensuing model outcomes in turn influence the behavior of the human players. The approach implements a strong functional partnership between

A. Sanfilippo (✉) • R. Riensche • J. Haack • S. Butner
Pacific Northwest National Laboratory, Richland, WA, USA
e-mail: Antonio.sanfilippo@pnnl.gov

P. Michelucci (ed.), *Handbook of Human Computation*,
DOI 10.1007/978-1-4614-8806-4_65,

human players and computer models that leverages modularity and independence across participating agents and components to facilitate the connection between model and game structures. We illustrate an embodiment of this approach with reference to the characterization of transactions in illicit nuclear trafficking.

Decision Making and Risk Perception

Risk perception plays a major role in regulating human decision-making. For example, experiments performed to see how people evaluated probabilities (Kahneman and Tversky 1973, 1974; Tversky and Kahneman 1981) demonstrate that people are risk-averse with respect to gains, but risk-seeking about losses. A certain outcome is preferred over a gamble with a higher expected utility which presents the possibility of total loss, while the hope for the chance of losing nothing is preferred over a sure but smaller loss. Understanding how cognitive and cultural biases impact risk perception is therefore crucial in designing a strategy for integrating the human decision making process in human computation systems.

Psychometric approaches to risk perception (Kahneman and Tversky 1974; Starr 1969; Slovic 1987) have made significant strides in identifying cognitive factors responsible for influencing the individual perceptions of risk. Social and cultural approaches (Douglas and Wildavsky 1982) have broadened the scope of risk perception research by focusing on how the perception of risk reflects an individual's commitment to competing cultural and political views. Several promising interdisciplinary efforts are underway to integrate the psychometric and sociocultural perspectives into a unified cultural and cognitive framework of risk perception (Kahan et al. 2010; Kasperson et al. 2003).

Kahneman's and Tversky's groundbreaking experimental and theoretical work on the psychology of decision-making (Kahneman and Tversky 1973, 1974; Tversky and Kahneman 1981) paved the way to the identification of patterns of deviation in human judgment that occur under risk. Through empirical observation, Kahneman and Tversky (1974) propose that people rely on simple heuristics when exerting judgment under uncertainty. These heuristics are crucial in streamlining human decision-making so as to achieve an ideal balance between judgment effectiveness and use of cognitive-processing and information resources. However, they also lead to cognitive biases. For example, Tversky and Kahneman (1981) showed through a series of experiments that different ways of framing the same risk information can have diametrically opposite responses. In one of these experiments, subjects were asked to choose health intervention options to combat a disease outbreak expected to kill 600 people. The first choice was between program A, which would save 200 people, and program B, which would either save all the people with a 1/3 probability or no people with a 2/3 probability. Most subjects preferred the guarantee that 200 people be saved (A) rather than risking everyone dying (B). However, when asked to choose between program B and program C, in which 400 people would die, most subjects chose program B, even though the expected outcomes of programs A and C are identical in terms of casualties. The overtly expressed certain death of 400 people is less acceptable than the two-in-three chance that all would die.

Risk perception research within the psychometric paradigm has increasingly emphasized the role of affect and emotion on risk perception. The impact of fear/dread, outrage, familiarity and uncertainty/lack of control were demonstrated early on to be important determinants of risk perception (Slovic 1987). Recent work has focused on capturing the emotion components into an affect heuristic, according to which positive and negative affect is modulated by information about benefits and risks (Slovic et al. 2005).

Risk perception is also regulated by social and cultural identity factors. As individuals, we typically form judgments within a social context. Consequently, our assessment of risk is filtered through concerns about safety, power, justice and legitimacy that are germane to the social enclave with which we identify. Our perception of risk thus reflects our individual commitment to specific cultural values, as opposed to alternative ones. Following this line of reasoning, the cultural theory of risk (Douglas and Wildavsky 1982) explains variance in the perception of risk in terms of social and cultural values to which allegiance grants taking higher risks. The polemic surrounding the human-papillomavirus (HPV) vaccination is a good example of how critical one's own commitment to specific cultural values determines the willingness to accept a higher or lower risk. HPV is responsible for 70 % of cervical cancers, 80 % of anal cancers, 60 % of vaginal cancers, and 40 % of vulvar cancers (De Vuyst et al. 2009). Since 2006, when the U.S. Food and Drug Administration approved the first preventive HPV vaccine, political dispute has hindered a plan to vaccinate US girls against HPV, amid claims that the vaccine causes harmful side effects and promotes unsafe sex among teens (Kahan 2010a). Interestingly, experimental evidence (Kahan et al. 2010) shows that when the arguments pro and against HPV vaccination are conveyed in such a manner as to reduce "biased assimilation" (i.e., the propensity to credit and dismiss information so as to confirm one's own prior beliefs), opinion polarization diminishes. People react more open-mindedly towards achieving scientific consensus instead of forming risk perceptions that reflect their commitments to controversial views of ethics and morality.

While psychometric and sociocultural approaches have emphasized diverse facets of human behavior that shape how people perceive risk, both sides have long recognized that an integration of the two perspectives is highly desirable. This intellectual advancement has led to the establishment of a new approach to risk perception, known as *cultural cognition of risk*, as an interdisciplinary endeavor that draws from several social science disciplines including psychology, anthropology, political science, sociology, and communications (Kahan et al. 2010; Slovic 2006). According to cultural cognition, people form perceptions of risk which conform with the behavior they and their peers find honorable and socially beneficial. For example, people who subscribe to individualistic values are inclined to value commerce and industry and accept or doubt environmental risks ensuing from such activities, while people who subscribe to egalitarian and communitarian values tend to regard commerce and industry as sources of inequality and are more critical of environmental risks (Kahan 2010b; Kahan et al. 2006). Experimental studies have provided strong support for this hypothesis and established a new paradigm for the study of risk perception based on attitudinal measurements (Kahan 2010a). These measurements are now starting to be used to support the creation of models and simulations of risk perception (Burns and Slovic 2007). Human computation systems can benefit from the integration of these models to manage human judgment biases due to the psychosocial amplification of risk.

Serious Gaming as a Psychosocial and Cultural Aware Human Computation System

Analytical or serious gaming provides a unique opportunity to address cognitive and cultural biases in human decision-making through the use of role-playing and gameplay. These game mechanics leverage people's natural desires for competition, achievement, status, self-expression, altruism, and closure to engage people in collaborative problem solving. For example, game logics can be used as a control mechanism to compare, contrast and measure (e.g. via scoring) different problem solving strategies. Such a control mechanism is usually be represented as a set of rules implemented by a human game master or a computer model (or a combination of the two) that regulate outcomes during gameplay. Using resources allocated to each role, and the game logic and activities, human players can update model parameters and engender new model outcomes which in turn influence the behavior of the human players in the game. The approach ensures a strong functional partnership between human players and computer models that regulate or/and predict role-play behavior, while maintaining a high degree of independence and greatly facilitating the connection between model artifacts (e.g. computational agents), human players, and game structures. The outcome of this approach is a collaborative decision-making process which exploits cognitive and cultural awareness to engage human creativity and reduce the impact of biases on human judgment.

Background

Due to their great potential as an aid to understanding complex issues, role-playing games (RPG) are currently being widely tested for learning and training purposes, and to a lesser extent for analysis and decision making. In RPGs, players endeavour to enact the roles of fictional characters within a narrative, either through literal acting or through a process of structured decision-making in which the players' actions succeed or fail according to a formal system of rules and guidelines (Sanfilippo et al. 2010; Cover 2010). RPGs can be played live as tabletop, live-action, or computer games. Tabletop RPGs are conducted through discussion, while in live action role-playing games players physically perform their characters' actions (Tychsen 2006). Both tabletop and live-action RPGS rely on a game master to administer and the rules and setting of the game and referee its outcomes. Computer RPGs exist both as

Table 1 Criteria that promote a system's ability to bridge across human judgment and machine inference (Adapted from Sanfilippo et al. 2010)

Social interaction	Games that allow multiple human players to interact (negotiate, compromise, etc.) contribute more than those that do not bridge the gap between human and machine reasoning, as human judgment is often performed as a collective activity
Adaptability & flexibility	Degree of role restriction, e.g. are the players' roles solely determined by the roles in the model? Can new roles be defined in the game by grouping model parameters at will to match the player's wishes?
	Can the players specify new model rules and parameters?
	Can the game outputs be modified to fit decision making requirements?

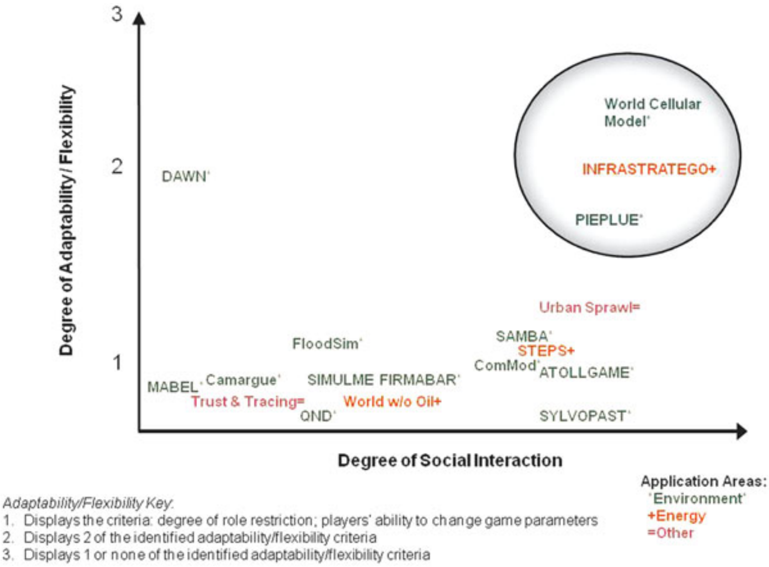

Fig. 1 Comparison of selected game systems (Adapted from Sanfilippo 2010)

multi-player games, such as massively multiplayer online role-playing games (MMORPGs), and single-player games. MMORPGs can be regarded as an implementation of tabletop or live-action RPGS, in which discussion and live performance is computationally mediated and the function of the game master is partially or fully automated.

In a recent literature survey, (Sanfilippo et al. 2010) found that approximately 32 % of 684 RPG systems examined for the period 2000–2008 address analysis and decision support. Only a small proportion of this subset focuses on how to bridge across human judgment and machine inference, with reference to criteria such as the ability of the game to facilitate interactions across human players and accommodate a player's request for a resource or outcome not represented in the game (Table 1).

Figure 1 below illustrates how a selection of the systems surveyed rank according to the criteria described in Table 1. As shown, only a few systems (those enclosed in the circle) appear to have a high degree of social interaction and at the same time exhibit some degree of adaptability/flexibility. For example, in the *World Cellular Model* (Valkering et al. 2007) multiple players interact with the goal to "survive" in a sustainable world. Players can modify some aspects of game rules through a weighted vote, include new events and drivers, and enact a game scoping stage based on previous game outcomes; however, the players' roles seem to be rigidly determined by the roles in the model. The *Infrastratego* game (Kuit et al. 2005) is highly interactive including up to 40–50 participants and players can negotiate the introduction of new rules with the game master/controller. The *Pieplue* game (Barretau and Abrami 2008) enables participatory decision making; rules are set up in advance, but new parameters can be introduced into the game.

Analytical Gaming

Analytical Gaming (AG) (Sanfilippo et al. 2010; Riensche et al. 2009, 2000) provides an environment in which analysts and decision makers can engage in interactive role-play to critique each other's ideas and action plans in order to achieve preparedness in real-world situations. AG facilitates creation and execution of games analogous to traditional tabletop simulation exercises. One application of the AG approach is to generate virtual evidence, by recording the behaviors of players, for calibrating model parameters in the absence or sparseness of real-world evidence. AG may also be configured as a collaborative and interactive interface to computer models. In constructing such environments, (Sanfilippo et al. 2010; Riensche et al. 2009, 2000) set a number of goals, including:

- Define interfaces that allow inclusion of computerized data sources (e.g., models/simulations, historic datasets) in an interactive environment.
- Define interfaces that allow display of an environmental state (informed by the aforementioned data sources) to players in ways that are naturally intuitive and realistic.
- Define interfaces by which players may interact with the environment (and by extension, other players and underlying models).
- Construct software architectures to implement these interfaces in such a way that the architectural "building blocks" are reusable across multiple distinct games.
- Leverage the use of common software architecture across multiple games to collect data regarding player actions and environmental/model states during game play, which can be used to reconstruct a history of game play(s) and to analyze the context of player actions and interactions.

As described in (Riensche et al. 2009, 2000), the abstract architecture that implements such goals includes the following notions:

- *Domain models*–the applicable computational models that we can use to drive changes in the game environment.

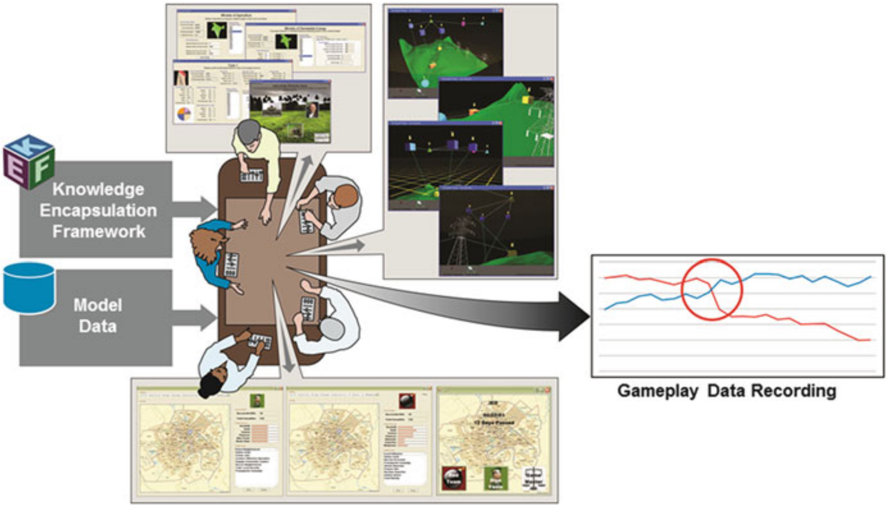

Fig. 2 Analytical gaming

- *Roles*–the roles we will ask players to assume. Identification of roles includes determining how and why a player in a particular role would be involved in the scenario represented by a game, what that player's objectives would be, and the means by which the player may influence the environment.
- *Game parameters*–the underlying data parameters that describe the state of the environment.
- *Game elements*–the user interface devices by which information is exchanged between the environment and users.
- *Handles*—the game elements which users may directly manipulate.

Figure 2 provides a graphic representation of the analytical gaming concept and its components.

Application: Illicit Nuclear Trafficking

Illicit nuclear trafficking networks are a serious security threat. These networks can directly lead to nuclear proliferation, as state or non-state actors attempt to identify and acquire nuclear weapons-related expertise, technologies, components, and materials. The ability to characterize and anticipate the key nodes, transit routes, and exchange mechanisms associated with these networks is essential to influence, disrupt, interdict or destroy the function of the networks and their processes. One of the major challenges in addressing these requirements is the lack of reliable data that can be used to develop and evaluate computational models. For example, the

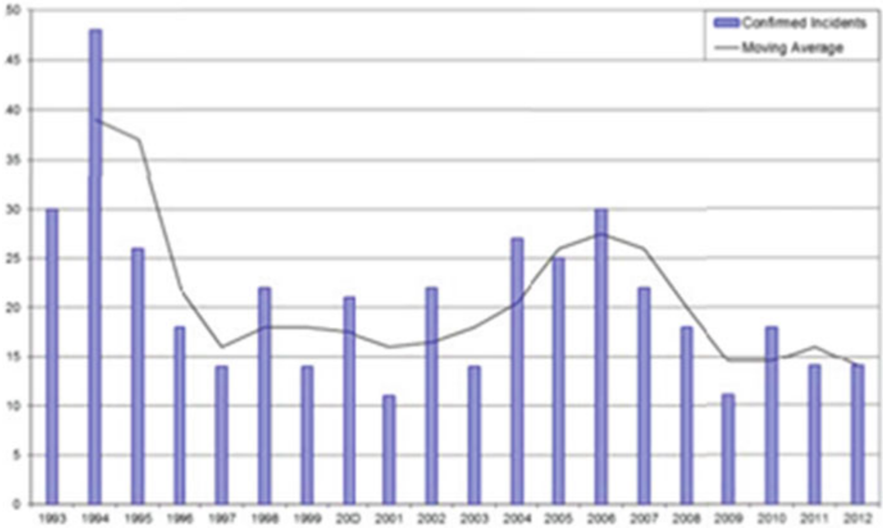

Fig. 3 Incidents reported to the ITDB involving unauthorized possession and related criminal activities, 1993–2012 (Adapted from the IAEA Incident and Trafficking Database, 2013 Fact Sheet, http://www-ns.iaea.org/downloads/security/itdb-fact-sheet.pdf)

total number of known incidents of illegal possession and movement of nuclear material or radioactive sources and attempts to sell, purchase or otherwise use such material for illegal purposes, for the period 1993–2012 is just a few hundred (Fig. 3). Consequently, the use of machine intelligence to infer and forecast patterns of illicit nuclear trafficking from historical data has limited reach. Instead of purely deductive models, we need generative models of illicit nuclear trafficking.

Sanfilippo et al. (2011) describe a prototype analytical game that provides an environment where human and machine intelligence can be jointly harnessed to meet the requirements and challenges of developing generative models of illicit nuclear trafficking (henceforth “INT game”). The INT game focuses primarily on human behavioral dynamics, in particular communications, deception, deal-making, and influencing. The game was developed using a simplified framework, where a subset of the real life contexts in which illicit trafficking occurs is selected. This methodology is akin to the practice in biological research to recreate in vitro components of an organism that have been isolated from their usual biological surroundings in order to permit a more detailed and convenient analysis than can be done with the whole organism.

Initially the game is developed as a tabletop exercise to identify and articulate game elements and their behavior. Once the structure of the game has reached maturity, it is implemented as a computer-based game. In the INT game, one player is given the objective of obtaining a set of commodities required to achieve nuclear weapon readiness (e.g. acquire uranium ore, computer and fissile core fabrication capabilities, nuclear reactor equipment, and weapon delivery systems), while some other players seek to prevent the achievement of this goal, and still other players

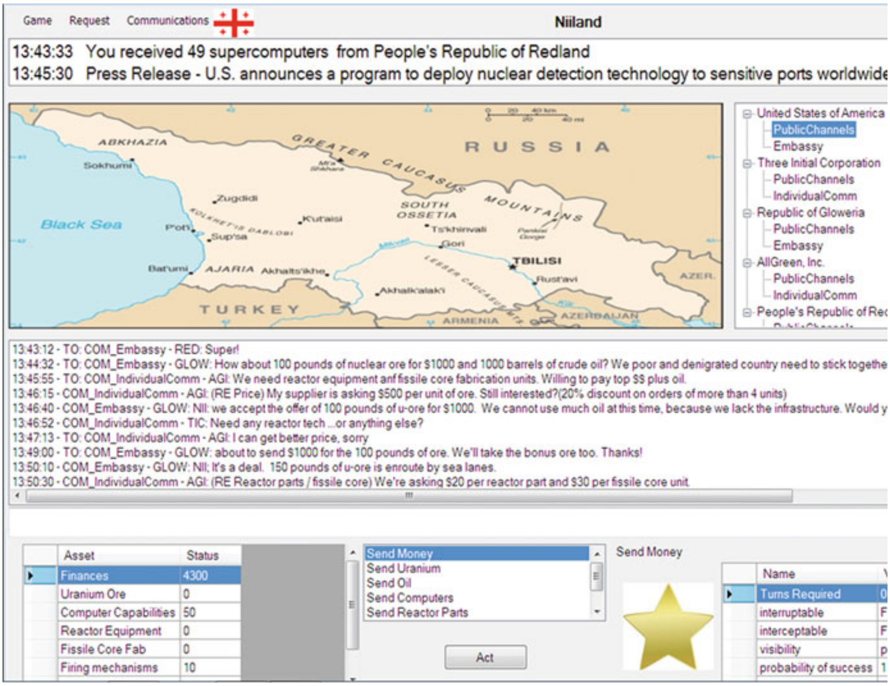

Fig. 4 A player's interface to the game (Adapted from Sanfilippo et al. 2011)

who may have nuclear commodities are motivated by other objectives such as profit within or outside the bounds of legality. Players are not told in advance who the would-be proliferator is.

Game roles include a mix of *Countries* and *Companies*. All players managed resources (*Commodities*) that were divided into three categories based on their role in the nuclear weaponization model: General Use (i.e., unrelated to nuclear weapons), Dual Use (e.g., items that could serve purposes in both nuclear energy and nuclear weapons production, and Focused Use (items that are only useful in production of nuclear weapons). Potential player actions included primarily sending of communications, attempts to intercept communications of other players, and initiating transfers of money and *Commodities*. All communications and actions were moderated by a Game Master, with whom the players could also negotiate addition of ad hoc actions.

Figure 4 provides a view of player's application screen half-way through playing a game session. The player's aim is to acquire assets (lower left in Fig. 4) which would enable the construction of nuclear weapons. In carrying out this aim, the player communicates with the other players through instant messaging to

- Use finances and other resources available to the player (e.g. crude oil) to acquire nuclear material and capabilities, and
- Cover his/her real intents to escape interception by controlling actors (e.g. the US).

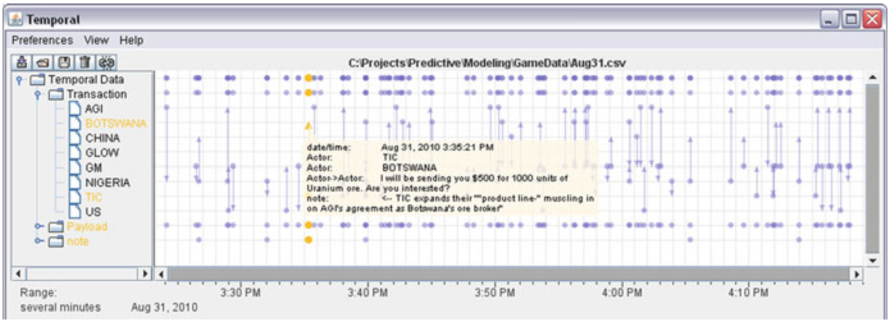

Fig. 5 Mining game results

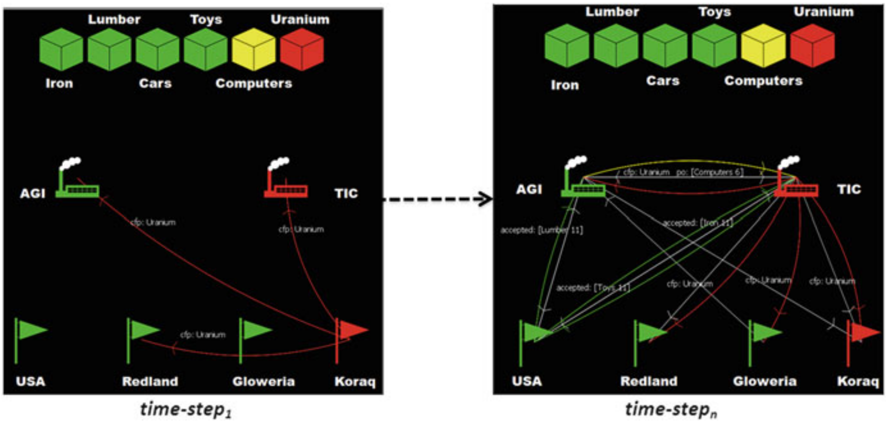

Fig. 6 Time series simulation output of an illicit nuclear trafficking agent-based model

Each player has specific roles in the game and each plays to his/her own advantages in making alliances tactically or strategically, as needed. Occasionally, in a random fashion, intelligence is leaked by the game master that reveals covert/deceptive operations. Players can negotiate with the game master authorization to perform new activities and be rewarded with new assets in the event the new activity is successfully carried out.

Every time the INT game is played, the game results are stored and analyzed to characterize the behavior of players (Fig. 5). The analysis of players' behavior is then used to calibrate an agent-based model of how the exchange of goods and know-how may play out through time series simulations with reference to developments of ongoing behaviors and the emergence of new behaviors, as shown in Fig. 6. Agent-based modeling (ABM) provides an ideal way of capturing the evolution of networking structure emerging from proliferation activities and knock-on effect from the behaviors of specific actors involved, such as the observables from the role-play activity described above.

Once the illicit nuclear trafficking ABM is sufficiently calibrated, it is integrated with the game. Model parameters, roles and activities are matched with roles, assets and activities in the game so players' behavior is both regulated by and perturbs the model's simulations as discussed in (Sanfilippo et al. 2009–2011). The emerging approach is still in its experimental stage and if successfully implemented can be instrumental in enabling analysts and policymakers to plan strategic action in influencing, disrupting, interdicting or destroying the function of illicit nuclear networks and their processes, and can be integrated with a radiation detection approach to address medium and short medium analysis and intervention objectives.

Conclusions

The integration of psychosocial and cultural processes that affect human judgment is crucial in designing human computation systems which effectively leverage and complement human intelligence. In this chapter, we have argued that gamification helps achieve such an integration. The goal of gamification is to apply gameplay to real-world problems in order to develop social intelligence through a concerted reasoning effort that exposes judgment biases and promotes creativity by interleaving human and machine intelligence. The gameplay data which results from this endeavor provide content that can be used to train and calibrate behavioral models. This is a significant achievement, especially in those domains where using historical data has limited value, either because there is not enough data available, as in the illicit nuclear trafficking problem discussed in this chapter, or because the operational context changes so rapidly, as in the cybersecurity domain. The models trained on the data generated through gameplay can be linked back to the game to increase the complexity and or level of automation of the game. This process can be repeated iteratively to develop human computation systems capable of making more complex and powerful inferences.

Partly due to its novelty, there is no shortage of challenges and opportunities for this novel endeavor. Ubiquitous access to the Internet, mobile telephony and technologies such as digital photography and digital video have enabled social media application platforms such as Facebook, YouTube, and Twitter that are altering the nature of human social interaction. The fast increasing pace of online social interaction introduces new opportunities to articulate a gamification approach to human computation systems that integrates psychosocial and cultural factors that influence human judgment. However, online behavior tends to differ from non-virtual behavior in ways that we still do not fully comprehend. Moreover, despite the great progress in understanding how humans make decision under risk, the integration of psychometric, emotive and cultural factors that impinge on risk perception is still largely unexplored. Another important question is the evaluation of game-based human computation systems. The level of human engagement elicited by these systems is certainly an important metric that can be assessed with relative ease. However, other performance metrics such as the reliability and effectiveness of the analysis and decision-making outcomes these systems generate may be harder to measure. A resolution of these challenges and the ensuing ability to reap the related benefits will largely determine the success human of computation systems based on gamification techniques.

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