Security Informatics
a SpringerOpen Journal

EDITORIAL Open Access

Technosocial predictive analytics for security informatics

Antonio Sanfilippo[1*], Nigel Gilbert[2] and Mark Greaves[3]

Challenges to the security, health, and sustainable growth of our society keep escalating asymmetrically due to the growing pace of globalization and global change. The increasing velocity of information sharing, social networking, economic forces, and environmental change has resulted in a rapid increase in the number and frequency of "game-changing moments" that a community can face. Social movements that once took a decade to build now take a year; shifts in public opinion that once took a year to take root now take a couple of months. More and more frequently, these critical moments occur too suddenly for the affected communities to succeed in countering the consequent adversities or seizing the emerging opportunities. Now more than ever, we need anticipatory reasoning technologies to forecast and manage change in order to secure and improve our way of life and the environment we inhabit.

The ability to estimate the occurrence of future events using expertise, observation and intuition is critical to the human decision-making process. From a biophysical perspective, there is strong evidence that the neocortex provides a basic framework for memory and prediction in which human intelligence emerges as a process of pattern storage, recognition and projection rooted in our experience of the world and driven by perception and creativity [1]. There is increasing consensus among cognitive psychologists that human decision making can be seen as a situation-action matching process which is context-bound and driven by experiential knowledge and intuition [2-4].

Despite the natural disposition of humans towards prediction, our ability to forecast, analyze and respond to plausible futures remains one of the greatest intelligence challenges. There are well known limitations on human reasoning due to cognitive and cultural biases. Kahneman's and Tversky's groundbreaking work on the psychology of decision-making ([5-7]; [8]) offers vivid exemplifications of patterns of deviation in judgment that occur under risk. Sociocultural approaches to risk perception [9] provide equally enlightening insights on the limitations of human decision-making.

Through empirical observation, Kahneman and Tversky [7] suggested that people rely on simple heuristics when exerting judgment under uncertainty. These heuristics are crucial in streamlining human decision-making by helping people achieve a balance between judgment effectiveness and use of cognitive-processing and information resources. However, they may also lead to cognitive biases. For example, Tversky and Kahneman [8] report results of experimental studies that show how different ways of framing the same risk information can have opposite responses. In one study, subjects were asked to choose health intervention options to combat a disease outbreak expected to kill 600 people. First, subjects were asked to choose 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 chose program A, indicating a stronger preference for 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.

Douglas and Wildavsky [9] observe that risk perception is deeply 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 decision-making process thus reflects individual commitment to specific cultural values, as opposed to alternative and possibly better ones. For example, poor water quality was known to be a persistent danger in

* Correspondence: antonio.sanfilippo@pnnl.gov
[1]Pacific Northwest National Laboratory, Richland, WA, USA
Full list of author information is available at the end of the article

fourteenth-century Europe. However, when persecution of the Jews began, the water quality issue was politicized to ostracize the Jews by accusing them of poisoning well-water [9]. The politicization of the HPV vaccination campaign [10,11] provides another good example of how ethical and moral worldviews affect risk perception and the ensuing decision-making choices in humans. "Groupthink", the tendency to override realistic appraisal of alternatives in order to achieve concurrence in decision-making within a cohesive group [12], is another group-driven mechanism that fosters cultural biasing.

In summary, our natural ability to focus on what is perceived to be most important and make quick decisions by insight and intuition [2,4,13] makes human judgment highly effective, but it can also lead to fallacious reasoning due to cognitive and cultural biases. Concomitant factors include lack of knowledge/expertise [2], and memory and attention limitations on human cognition [14,15]. If we are to help analysts and policy-makers provide better proactive analysis and response, processes and capabilities must be made available that enable naturalistic decision making while countering adverse influences on human judgment.

Technosocial and complex-system approaches to predictive analytics have arisen as promising new ways to advance the development of tool-supported decision-making methods. Significant advances have been made in the integration of predictive modeling with social and behavioral factors, in both equation-based approaches [16-18], probabilistic evidentiary reasoning approaches [19-23], and multi-agent simulation approaches (e.g. [24], [25], [26]). A new generation of approaches is also emerging where modeling and simulation is coupled with social intelligence practices, such as role playing and gaming, to stimulate collaborative decision-making [27-31]. Aided by knowledge management capabilities that automate the extraction and analysis of evidence from traditional and social media sources [32-34], these modeling and gaming methods offer a new platform for decision making that can help overcome human limitations [35]. The goal of this special issue is to record the current state of the art in this endeavor.

The papers we present in this issue address three specific challenges in Technosocial Predictive Analytics:

1. Modeling complex systems to reason about plausible futures and test response strategies;
2. Integrating data harvesting, natural language processing, data mining and content analysis technologies to support the modeling task with inputs of expertise and evidence, and
3. Harnessing cognitive technologies to enhance model interfaces and facilitate collaborative decision-making.

Richard Colbaugh and Kristin Glass present a modeling approach for analyzing the vulnerability of complex networks. Complex networks are first scaled down to simpler but mathematically equivalent finite state abstractions. These finite state network abstractions are then processed with efficient algorithms that use formal analytic methods from theoretical computer science to assess network vulnerability. The analytic conclusions are then mapped back to the original network for a comprehensive interpretation. The potential of the proposed approach is illustrated in three case studies involving the electric power grid, a gene regulatory network, and a general class of social network dynamics.

Michael Madison *et al*. describe a novel evidence marshaling solution that significantly advances the state of the art. Its embodiment, the Knowledge Encapsulation Framework (KEF), offers a suite of semi-automated and configurable content harvesting, vetting, annotation and analysis capabilities within a wiki-enabled and user-friendly visual interface that supports collaborative work across distributed teams of analysts. The framework assists analysts in distilling relevant information from traditional and social media sources to support model development and calibration, providing model transparency through knowledge and evidence reachback, and establishing data provenance/pedigree.

Roderick Riensche and Paul Whitney describe an approach to fostering collaborative decision-making based on the combination of modeling and gaming methodologies and capabilities. The approach relies on the use of formal models to inform game development, and the use of gaming techniques to generate data for modeling. They describe the development of an "Illicit Trafficking" prototype game as an exemplification of the approach. The resulting framework combines human expertise and actions with computational modeling capabilities to provide a decision-making environment that may approach the richness and diversity of the human behaviors targeted for prediction.

Kshanti Greene, Dan Thomsen and Pietro Michelucci present preliminary results from two massively collaborative problem solving (MCPS) studies that leverage large scale distributed collaboration to solve complex problems. The problem solving environments described encourage deep reasoning to emerge by combining small contributions from many individuals to solve dynamic and previously unsolved problems. Problem solvers are encouraged to decompose a complex problem into parts so as to harness the contribution of individuals with diverse skills and experiences. The paper includes a discussion of potential security applications, and the system security issues MCPS must address.

Predictive Analytics is now being increasingly recognized as a field of inquiry and capability development in

its own right. Data mining, machine learning and modeling play a predominant role in its current applications. The vision we provide extends the boundaries of Predictive Analytics with reference to modeling aims, knowledge inputs, collaborative work, human-computer interaction, and relationships across these components. We believe that these extensions are essential in developing decision-support tools that maximize the effectiveness of human reasoning. We hope that the work presented in this special issue of Security Informatics can inspire scientists and engineers to take the next step in establishing Predictive Analytics and the science of risk management and decision-making for security and other domains alike.

Author details
[1]Pacific Northwest National Laboratory, Richland, WA, USA. [2]University of Surrey, Guildford, Surrey, UK. [3]Vulcan Inc., Seattle, WA, USA.

Received: 15 May 2012 Accepted: 25 May 2012
Published: 22 August 2012

References

1. J. Hawkins, S. Blakeslee, *On Intelligence* (Owl Books, New York, NY, 2004)
2. G. Klein, *Sources of Power* (MIT Press, Cambridge, MA, 1998)
3. R. Lipshitz, G. Klein, J. Orasanu, E. Salas, Focus article: taking stock of naturalistic decision making. J. Behav. Decis. Mak. **14**, 331–352 (2001)
4. G. Gigerenzer, *Gut Feelings: The Intelligence of the Unconscious* (Penguin Books, New York, NY, 2007)
5. D. Kahneman, A. Tversky, Subjective probability: a judgment of representativeness. Cogn. Psychol. **3**(3), 430–454 (1972)
6. D. Kahneman, A. Tversky, On the psychology of prediction. Psychol. Rev. **80** (4), 237–251 (1973)
7. D. Kahneman, A. Tversky, Judgment under uncertainty: heuristics and biases. Science **185**(4157), 1124–1131 (1974)
8. A. Tversky, D. Kahneman, The Framing of Decisions and the Psychology of Choice. Science, New Series **211, No. 4481**, 453–458 (1981)
9. M. Douglas, A.B. Wildavsky, *Risk and Culture: An essay on the selection of technical and environmental dangers* (University of California Press, Berkeley, 1982)
10. D. Kahan, Fixing the communications failure. Nature **463**(7279), 296–297 (2010)
11. D. Kahan, D. Braman, G. Cohen, J. Gastil, P. Slovic, Who Fears the HPV Vaccine, Who Doesn't, and Why? An experimental study of the mechanisms of cultural cognition. Law Hum Behav **34**(6), 501–516 (2010)
12. I. Janis, *Victims of groupthink; a psychological study of foreign-policy decisions and fiascoes* (Houghton, Mifflin, Boston, 1972)
13. M. Gladwell, *Blink: The Power of Thinking Without Thinking* (Little, Brown and Company, Boston, MA, 2005)
14. G. Miller, The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychol. Rev. **63**, 81–89 (1956)
15. R.J. Heuer Jr., *Psychology of Intelligence Analysis, Center for the Study of Intelligence* (Central Intelligence Agency, Washington, DC, 1999)
16. N. Gilbert, K.G. Troitzsch, *Simulation for the social scientist* (Open University Press, Milton Keynes, UK, 2005)
17. E. Malone, C. Izaurralde, A. Thomson, L. Morgan, *Resilience, Climate Change, and Security: Modeling the Connections* (Proceedings of the AAAI Spring Symposium on Technosocial Predictive Analytics, Stanford, CA, 2009)
18. P.C. Wong, R. Leung, Lu Ning, M. Scott, P. Mackey, H. Foote, B. Bragg, J.C. Jr, W. Jiang, Yu Todd Taylor, L. Xie, Xu Jianhua, S. Unwin, A. Antonio Sanfilippo, *Collaborative Visual Analytics in Multidisciplinary Technosocial Predictive Studies* (IEEE Computer Graphics and Applications, Special Issue on Collaborative Visualization, 2009)
19. P. Sticha, D. Buede, R. Rees, *APOLLO: An Analytical Tool for Predicting a Subject's Decision making, Proceedings of the 2005 International Conference on Intelligence Analysis* (McLean, VA, 2005)
20. D. Peterson, A. Sanfilippo, R. Baddeley, L. Franklin, *Proactive Intelligence for Nuclear Nonproliferation. Proceedings of the 8th International Conference on Facility Operations-Safeguards Interface, March 30-April 4, 2008, Portland, Oregon., p. Paper No. 54* (American Nuclear Society, La Grange, IL, 2008)
21. S.D. Unwin, B.A. Fecht, Consumer Choice and Dempster-Shafer Models of Threat Prioritization for Emerging Dual-Use Technologies: Application to Synthetic Biology. Def. Secur. Anal. **25**(No. 1), 37–52 (2009)
22. P. Whitney, A. Brothers, G. Coles, J. Young, K. Wolf, S. Thompson, D. Niesen, J. Madsen, C. Henderson, *Technosocial Modeling of IED Threat Scenarios and Attacks* (Proceedings of the AAAI Spring Symposium on Technosocial Predictive Analytics, Stanford, CA, 2009)
23. T.F. Sanquist, H.M. Orr, B. Shui, C. Bittner, Lifestyle Factors in U.S. Residential Electricity Consumption. Energy Policy **42**(3), 354–364 (2012)
24. A. Chaturvedi, D. Dolk, R. Chaturvedi, M. Mulpuri, D. Lengacher, S. Mellema, P. Poddar, C. Foong, B. Armstrong, *Understanding Insurgency by Using Agent-based Computational Experimentation: Case Study of Indonesia, Proceedings of the Agent 2005 Conference on Generative Social Processes* (Models and Mechanisms, Chicago, IL, 2005), pp. 781–799
25. Xiaochen Li, Wenji Mao, Daniel Zeng, Fei-Yue Wang, *"Agent-Based Social Simulation and Modeling in Social Computing"* (Lecture Notes in Computer Science, 5075/2008)
26. N. Gilbert, *Agent-Based Social Simulation: Dealing with Complexity* (, 2004). http://cress.soc.surrey.ac.uk/resources/ABSS%20-%20dealing%20with%20complexity-1-1.pdf
27. M. Kuit, I.S. Mayer, M. De Jong, The INFRASTRATEGO game: an evaluation of strategic behavior and regulatory regimes in a liberalizing electricity market. Simulation & Gaming **36**(1), 58–74 (2005)
28. P. Valkering, A. Offermans, D. Tàbara, P. Wallman, *New tools for Integrated Sustainability Assessment: The World Cellular Water Game, Conference on the Human Dimensions of Global Environmental Change "Earth System Governance: Theories and Strategies for Sustainability* (, Amsterdam, 2007). Paper presented at the 2007 Amsterdam Conference on the Human Dimensions of Global Environmental Change "Earth System Governance: Theories and Strategies for Sustainability" on 24-26 May. See http://www.2007amsterdamconference.org/
29. O. Barretau, G. Abrami, Variable time scales, agent-based models, and role-playing games: The PIEPLUE river management game. Simulation & Gaming **38**(3), 364–381 (2008)
30. R.M. Riensche, P.R. Paulson, G.R. Danielson, S.D. Unwin, R.S. Butner, S.M. Miller, L. Franklin, N. Zuljevic, *"Serious Gaming for Predictive Analytics", AAAI Spring Symposium on Technosocial Predictive Analytics* (AAAI Press, Menlo Park, 2009)
31. A.P. Sanfilippo, R.M. Riensche, S.D. Unwin, J.P. Amaya, Bridging the Gap between Human Judgment and Automated Reasoning in Predictive Analytics, in *10th International Probabilistic Safety Assessment & Management Conference - PSAM10* (Seattle, WA, 2010)
32. A. Cowell, M. Gregory, E. Marshall, L. McGrath, *Knowledge Encapsulation Framework for Collaborative Social Modeling* (Proceedings of the AAAI Spring Symposium on Technosocial Predictive Analytics, Stanford, 2009)
33. A. Sanfilippo, A.J. Cowell, S. Tratz, A. Boek, A.K. Cowell, C. Posse, L. Pouchard, Content analysis for proactive intelligence: Marshaling frame evidence. Proceedings of AAAI'07 **1**, 919–924 (2007)
34. A. Sanfilippo, L. McGrath, P. Whitney, Violent frames in action. Dynamics of Asymmetric Conflict **4**(2), 103–112 (2011)
35. A.P. Sanfilippo, A.J. Cowell, E.L. Malone, R.M. Riensche, J.J. Thomas, S.D. Unwin, P.D. Whitney, P.C. Wong, *Technosocial Predictive Analytics in Support of Naturalistic Decision Making. Proceedings of The 9th bi-annual International Conference on Naturalistic Decision Making* (Covent Garden, London, UK, 2009), pp. 23–26

doi:10.1186/2190-8532-1-8
Cite this article as: Sanfilippo *et al.*: **Technosocial predictive analytics for security informatics.** *Security Informatics* 2012 **1**:8.