Computational Approaches to Strategic Reasoning: Maritime Strategy and Beyond

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The emergence of cyber conflict, robotics, artificial intelligence, and autonomous systems as either current or future elements of conflict pose significant issues for the craft of strategy. [1] Many believe that emerging information technology platforms – in challenging the very fundamentals of human decisionmaking and control over the rationalization of violence – will be a decisive break from all that we know. Those tasked with maritime strategy in particular must deal with the challenge of integrating unmanned aerial vehicles and unmanned sea vehicles into strategies and concepts of operation. [2]

However, the biggest challenge that the Navy and other entities face lies in thinking about strategy and decision from a computational point of view. A world in which the power of computation is increasingly inescapable needs analysts to draw broader connections between computation and existing strategic theory and history rather than merely building strategic analysis and concepts around whatever technological tools temporarily rule the day.

Hence, this paper argues for the utility of a *computational approach* to strategic reasoning. A computational approach takes familiar aspects of strategy and recasts them in terms of computational processes such as algorithms and programs for search, learning, and optimization. A computational approach also allows strategic analysis and explanation to be formalized and implemented as a computer program on a standard desktop computer or laptop.

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1 See, for example, Adams, Thomas K. "Future warfare and the decline of human decisionmaking." *Parameters* 31.4 (2001): 57, Liles, Samuel, et al. "Applying traditional military principles to cyber warfare." *2012 4th International Conference on Cyber Conflict (CYCON 2012)*. 2012, Manzo, Vincent. "Deterrence and Escalation in Cross-domain Operations." *JFQ: Joint Force Quarterly* 66 (2012): 8-14.

2 Yan, Ru-jian, et al. "Development and missions of unmanned surface vehicle." *Journal of Marine Science and Application* 9.4 (2010): 451-457, Bruzzone, Gabriele, et al. "Autonomous mine hunting mission for the Charlie USV." *OCEANS, 2011 IEEE-Spain*. IEEE, 2011, Manley, Justin E. "Unmanned surface vehicles, 15 years of development." *OCEANS 2008*. IEEE, 2008, Borck, Hayley, et al. "Active Behavior Recognition in Beyond Visual Range Air Combat." *Proceedings of the Third Annual Conference on Advances in Cognitive Systems ACS*. 2015, Callam, Andrew. "Drone Wars: armed unmanned aerial vehicles." *International Affairs Review* 18 (2015), Savuran, Halil, and Murat Karakaya. "Efficient route planning for an unmanned air vehicle deployed on a moving carrier." *Soft Computing* (2015): 1-16, Ehrhard, Thomas P., and Robert O. Work. *The Unmanned Combat Air System Carrier Demonstration Program: A New Dawn for Naval Aviation?*. Washington: Center for Strategic and Budgetary Assessments, 2007, Wadley, Jason, Gregory Tallant, and Robert Ruszkowski. "Adaptive Flight Control of a Carrier Based Unmanned Air Vehicle." *AIAA Guidance, Navigation, and Control Conference, AIAA-2003-5596, Austin, TX, August*. 2003.

Most importantly, computational approaches begin from a recognition of shared human and machine *limitations* on strategy and decision. Rationality – bounded or not – does not entail omniscience, and a computational approach promotes a view of strategy as an adaptive means of fulfilling goals in spite of them. [3] Understanding both commonalities and differences in human and machine views of strategy and adversarial behavior will not only shed light on current strategic challenges but also contribute to broader knowledge and understanding in strategic theory. [4]

The paper provides a basic proof of concept by showing how aspects of Cold War strategy – including maritime strategy and operations – may be simulated through a multi-agent model of nuclear conflict. The commercial nuclear strategy game of *DEFCON* presents a simple Cold War simulation where players – unaware of each other's dispositions – place ground units and naval fleets and then progress from surveilling each other's dispositions to progressively more escalatory levels of combat. Every game culminates in total nuclear exchange. Via an application programming interface (API) written in the programming language C++, modelers can program computer players to play automated matches.

While *DEFCON* is in many ways a very unrealistic depiction of nuclear war, programming automated players to fight each other reveals the most important finding of the computational approach. All systems – from slime molds to states – are limited in time and space in the amount of choices that can be considered and must resolve tradeoffs in goals and behaviors. All entities are capable of improving their performance through adaptation and learning, but face similar limitations and tradeoffs in what can be learned and how it is learned. [5] Programming strategy game players similarly involves tradeoffs between different goal-driven strategic behaviors and reactionary responses to unexpected events.

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3 Russell, Stuart Jonathan, and Eric Wefald. *Do the right thing: studies in limited rationality*. MIT press, 1991, Takemura, Kazuhisa. *Behavioral Decision Theory: Psychological and Mathematical Descriptions of Human Choice Behavior*. Springer, 2014.

4 For a comparative overview, see Pomerol, Jean-Charles. *Decision Making and Action*. John Wiley & Sons, 2012.

5 See, for example, Tyrrell, Toby. *Computational mechanisms for action selection*. Diss. University of Edinburgh, 1993, Maes, Pattie. "Modeling adaptive autonomous agents." *Artificial life* 1.1_2 (1993): 135-162, Tyrrell, Toby. "The use of hierarchies for action selection." *Adaptive Behavior* 1.4 (1993): 387-420, Tu, Xiaoyuan. *Artificial animals for computer animation: biomechanics, locomotion, perception, and behavior*. Springer Science & Business Media, 1999, Brom, Cyril, and Joanna Bryson. "Action selection for intelligent systems." *European Network for the Advancement of Artificial Cognitive Systems* (2006), Prescott, Tony J., Joanna J. Bryson, and Anil K. Seth. "Introduction. Modelling natural action selection." *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 362.1485 (2007): 1521-1529, Bryson, Joanna J. "Mechanisms of action selection: Introduction to the special issue." *Adaptive Behavior* 15.1 (2007): 5-9, Bryson, Joanna. "Cross-paradigm analysis of autonomous agent architecture." *Journal of Experimental & Theoretical Artificial Intelligence* 12.2 (2000): 165-189, De Sevin, Etienne, and Daniel Thalmann. "A motivational model of action selection for virtual humans." *Computer Graphics International 2005*. IEEE, 2005, Scheutz, Matthias, and Virgil Andronache. "Architectural mechanisms for dynamic changes of behavior selection strategies in behavior-based systems." *Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on* 34.6 (2004): 2377-2395.

The similarities and difference between human and machine strategy game players is often instructive; the former often internalize ways to compress or abstract the game in ways that the latter do not. What both have in common, however, is the reality of constraints, limitations, and tradeoffs in how they decide what to do next. Herbert Simon's concept of "bounded rationality" – often popularly understood as cognitive and *human* limits on reasoning and optimal decision – actually may have originally been used to describe the process of deriving approximations for military operations and logistics problems that were too tough to compute exact solutions for in the early Cold War. [6]

Computational models and simulations have often been used for operations research and analysis, wargaming, and simulation and training. In general, however, computational models are rarely if ever utilized for theory development and abstract strategic reasoning. In sum, despite the problematic Cold War origins of computational approaches, this paper suggests that the real utility of computer programs that model strategic problems is theory development and contribution to the collective knowledge base of the strategy community.

6 Erickson, Paul, et al. *How reason almost lost its mind: The strange career of Cold War rationality*. University of Chicago Press, 2013.