17th ICCRTS

“Operationalizing C2 Agility”

Title

Exploring the Potential of Computer Games for Decentralized Command and Control

Topics

Modeling and Simulation (Primary)
Approaches and Organization (Alternate)
Architectures, Technologies, and Tools (Alternate)

Authors
Walt Scacchi, Craig Brown, and Kari Nies
Institute for Software Research
and
Center for Computer Games and Virtual Worlds
University of California, Irvine
Irvine, CA 92697-3455 USA

Point of Contact
Walt Scacchi
University of California, Irvine
Irvine, CA 92697-3455 USA
949-824-4130, 949-824-1715 (fax)
wscacchi@ics.uci.edu

Abstract: This report describes results from a research study investigating how computer game (CG) concepts, techniques, and tools can be employed to create an online environment that supports experiments in Decentralized Command and Control. We refer to this project and the CG we have prototyped collectively as the DECENT project and system platform. DECENT is a platform for exercising and assessing the potential of a game-based virtual world approach to decentralized C2, as well as to compare our efforts with others closely related. Overall, we find this effort gives rise to very promising results that point to additional opportunities and system extensions for new ways to consider the potential of decentralized approaches to C2 that merit further systematic investigation and experimentation. This report provides description of the approach to prototyping and initially evaluating some of the potential of DCC systems based on CG technologies.

Overview

Decentralized Command and Control (DCC) is emerging as a new strategic thrust [DoD JOAC 2012]. DCC is envisioned as a new approach and model for how to organize and experience command and control systems, mission planning and scheduling processes, and physically decentralized user practices, using low-cost or free, open source software technologies. DCC are anticipated to operate as virtual enterprises that are physically distributed butge logically centralized. They are used at the edge of a multi-site organization, and thus can engage participants in different locations.

This report describes results from a research study investigating how computer game (CG) concepts, techniques, and tools can be employed to create an online environment that supports experiments in DCC. We refer to this project and the CG we have prototyped collectively as the *DECENT* project and system platform. DECENT is a platform for exercising and assessing the potential of a game-based virtual world approach to decentralized C2, as well as to compare our efforts with others closely related. Overall, we find this effort gives rise to very promising results that point to additional opportunities and system extensions for new ways to consider the potential of decentralized approaches to C2 that merit further systematic investigation and experimentation.

We also find that a number of computer games also suggest system features applicable to C2, as well as distributed individual/group problem-solving, using popular card games. Again, these may be candidates for further systematic study that can shape how next-generation C2 systems can be designed to support/embrace future workforce interests, skills, and capabilities.

Last, we also report on topics that essentially have little/no published research study or results that are central to the continuing development of VW technologies for C2 applications. Principal among these are topics surrounding the security of VWs intended for experimental studies or future applications to the C2 domain. VWs are still very early in their technical development, and far from ready for deployment in actual application settings. Nonetheless, these technologies do merit ongoing study and investment as they offer new categories of affordances that can enable/support both centralized and decentralized approaches to C2 in ways that legacy C2 technologies and approaches cannot. Decentralized game-based virtual world approaches may offer the potential to substantially reduce the cost and dramatically shorten the time to design, build, and deploy C2 systems that embrace new generations of low-cost, mobile technologies that future C2 workforces may expect, whether for use in physical or virtual/cyberspace worlds. So much remains to be studied, and time for appropriate and realistic research investments is now at hand.

Developing a DECENT Prototype

In the effort described here, we have prototyped a computer game and virtual world (CGVW) environment we call the DECENT project. Our efforts here represent a substantial departure from current C2 practice, and thus does not seek to primarily provide an incremental improvement to centralized C2 efforts. However, our research is informed by such efforts, like the C2 Rapid Deployment Continuum (C2RPC) highlighted in Figure 1, as they are critical to enhancing and demonstrating upgrades to current C2 operations which have high consequence [Garcia 2010, Gizzi 2011].

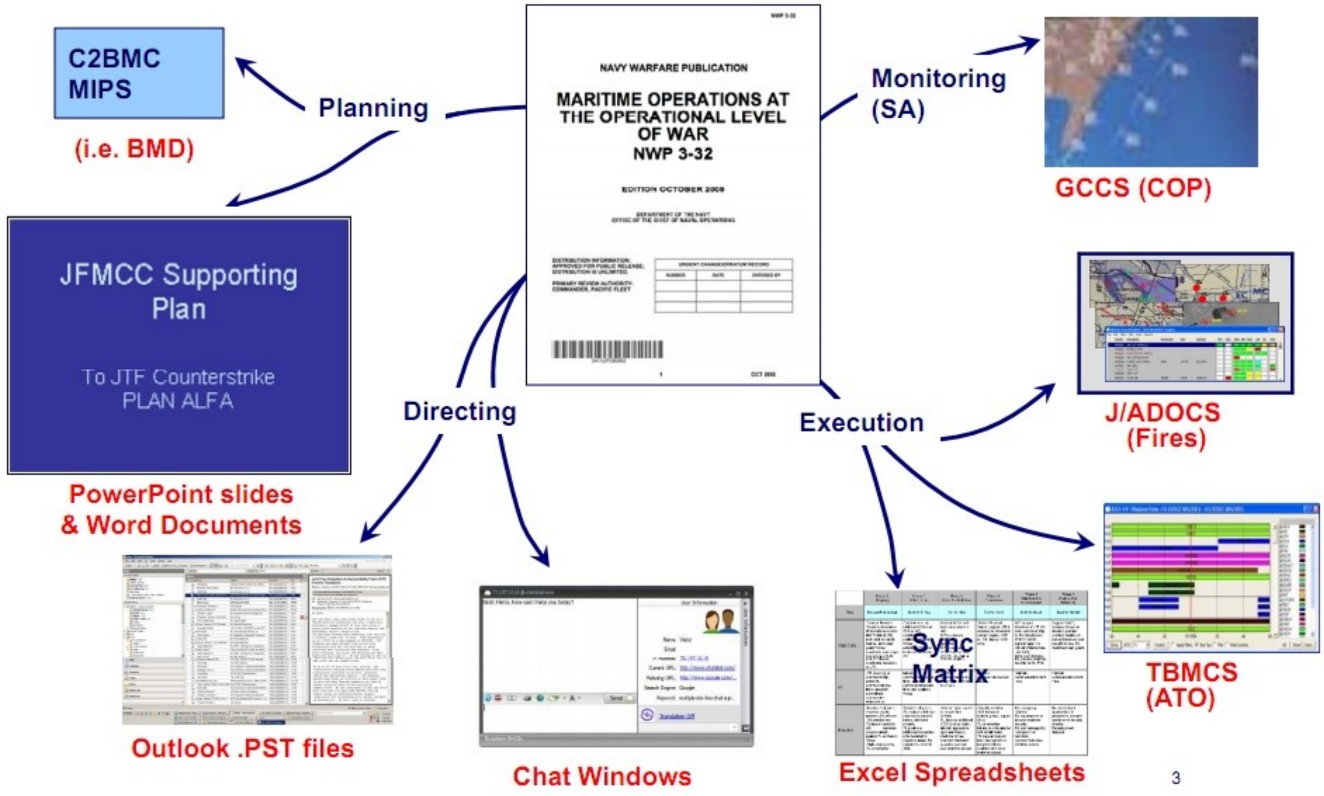


Figure 1. Common information objects and software applications that may be involved in C2 operations/tasking, as identified in publicly accessible C2RPC [2010] materials.

In such settings, C2 operations/tasks entail the creation, update, and sharing/presentation of information reports for C2 decision-making purposes, which may include resource schedules expressed as timelines or spreadsheets, for example.

However, as our efforts represent a basic research investigation, we can pursue more risky pathways and edgy alternatives that may or not yield significant advances. Furthermore, our attention is directed to technologies that enable network-centric, decentralized "edge" approaches to C2 [Albert and Hayes 2003]. Consequently, our goal is to advance scientific and technical knowledge for how decentralized C2 might be put into practice in the future, especially with regard to future workforces who may have grown up playing computer games and/or exploring virtual worlds.

To help motivate our approach, we first choose to characterize a sample of computer games that have influenced our efforts for what might be possible with future C2 systems, and how such systems might enable people using the C2 system to be physically dispersed, for different reasons, yet still be capable of performing C2 missions, processes, and practices. We begin with our sample of games.

Computer game concepts

Computer games are computational systems for individual, group, or team interaction with game elements or other players. As computational systems, they may be designed to model, simulate, or "mirror" activity or other systems found in the physical world, or in imaginary/fantasy worlds. Game play activity may be sedentary, with seemingly little physical activity beyond computer mouse or keyboarding actions, or physically demanding, where computer play requires physical activity in diverse physical settings, or with complex devices. Most depictions of C2 activity may be closer to sedentary activity by individuals and work groups/teams, than to highly physical activity.

Modern computer games are complex systems (sometimes a system of systems) involving many components, sometimes from different vendors or contractors. Popular 3D action games represent software systems involving hundreds of thousands of lines of source code, with others larger or smaller. Common game system software components include game engine (the run-time environment controlling and coordinating all computational aspects of the game), the user interface (providing the ways and means for the user/player to interact with the system), networking (for wide-area game play with remote players), databases/repositories (accommodating persistent game play across multiple play sessions), graphics and animation, artificial intelligence, and other components. Game hardware components vary from personal computers, game consoles, hand-held game devices (e.g., PlayStation Portable, Nintendo DS), smart-phones, wired/wireless networking, backend servers, and more. A growing number of commercially successful game systems also are deployed for consumer use with full software development kits (SDKs) that allow the adventuresome and technically skilled user/player to modify the game, game object, rules of play, and more, including total conversion of a commercial game into another not recognizable from examination of the source game [Scacchi 2011].

Computer game play takes place within a visually (or textually) rendered game space that depicts a the world of objects and players (as in-game avatars) that can be manipulated, navigated, or engaged according to the rules of play built into the game system. The game space establishes game look and feel, as well as an overarching storyline and/or backstory that serve as a narrative backdrop intended to increase the immersive experience of the players. The game's rules of play controls game engine, mediates user interface display/interaction, as well as database transactions, and propagation of data/events to others in the game space. The rules of play may be pedantic, requiring completion of preliminary levels or play skill mastery before moving on to more challenging play scenarios; may be goal-oriented towards attaining some specified or implied final game state/objective; or may be fully emergent and open-ended to indicate that the purpose of the game is unbounded play or pursuit of fantasy. Game play rules are computationally realized and designed as “game play mechanics” to indicate the progressive play entails mastery of skills and achievements that recur across extended periods of game play. Putting these elements into an examples, in a card game like draw poker, the card table/surface denotes the play space for card dealing, holding, reviewing, and returning; the play mechanics entail how/when cards are dealt to players and how/when betting occurs; and game play rules determine how card holdings are scored and ordered across players. Finally, as the number and diversity of computer games is broad, it is common to refer to similar games as falling into widely recognized game “genres” like first-person shooters, combat simulators, real-time strategy, card/board games, role-playing games, etc. with 10-25 popular computer game genres [VideoGameGenres 2012].

C2 Gameplay in DECENT

Instead of only simulating possible C2 situations using a virtual world for C2 [Scacchi, Brown, Nioes 2012], we have chosen to use a gameplay metaphor that most users will have at least some familiarity with: seven card *Texas Hold'em* poker. This metaphor was chosen from amongst many options due the surprisingly large number of similar choices required by both.

In DECENT, one proctor controls the bulk of the gaming simulation, as seen in Figure 2. A simple interface allows the proctor to act as the poker dealer, and is responsible for shuffling the deck between hands, dealing each team their cards, and manipulating the public information cards. The proctor should be someone versed in the rules of Hold'em, and must maintain objectivity to ensure fair play. At the end of each hand, the proctor is also responsible for resolving the pot and ensuring all side-pots are dealt out appropriately.

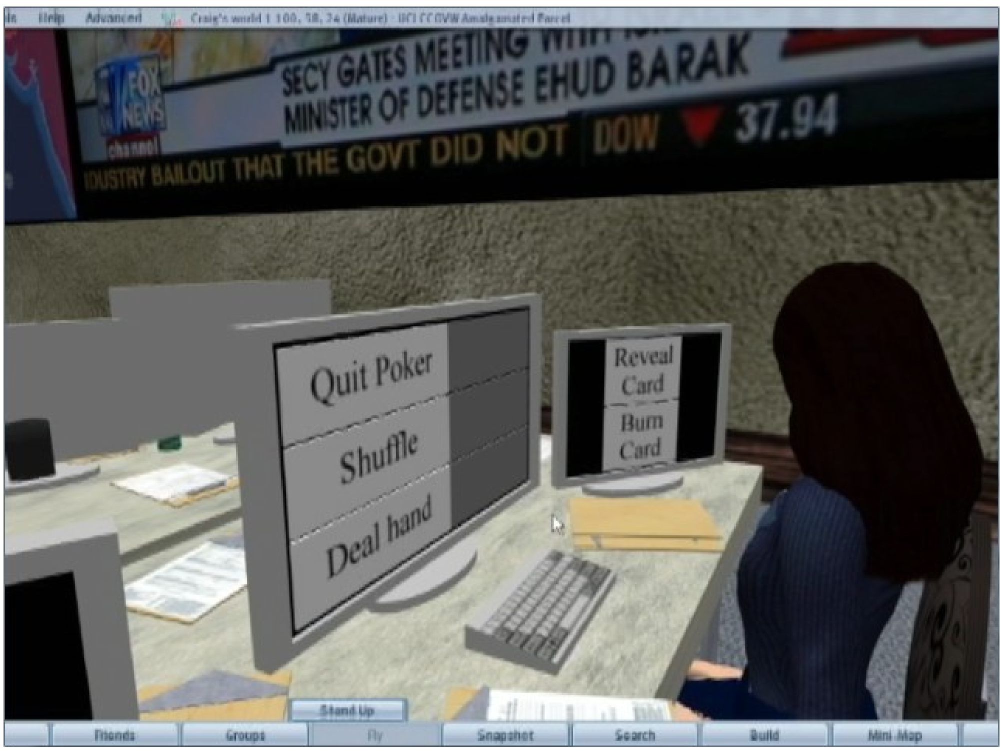


Figure 2. Proctor at the dealer seat.

Two to six teams, representing separate military groups, compete in DECENT to see who is best suited to undertaking the current mission. Each team is completely autonomous, and can compete from any physical distance as long as they are connected to DECENT through a computer with an internet connection.

Figure 3. Teams discuss tactics for the current hand.

Team members interact amongst themselves, coming to a consensus on how to dedicate their resources and when to abandon a given situation, as seen in Figures 3 and 4. As DECENT is implemented using OpenSim [2012], it handles all of this with OpenSim's built-in communication tools. Interaction between teams is cautioned against (but not automatically forbidden), as sharing information non-openly may skew the odds of the gaming simulation.

Figure 4. Variable sized teams competing against each other.

Both C2 and Texas Hold'em make use of public information, viewable by all and specific to no single party. C2 has this in the form of large information displays, either showing the most important information that must available at all times or organizational information necessary to coordinate tasks. Hold'em uses public information in the form of community cards, available to all to make the best five-card poker hand possible; these are commonly known as the flop, the turn, and the river, as indicated in

Figures 5 and 6 (a-d). In addition to public information, C2 and Hold'em both make use of private information. In C2, this can be anything from specialist data to communications to the stream of a soldier's helmet-cam. In Hold'em, it is each player's hole cards, the two cards only that player may use to make his or her five-card poker hand the best at the table.

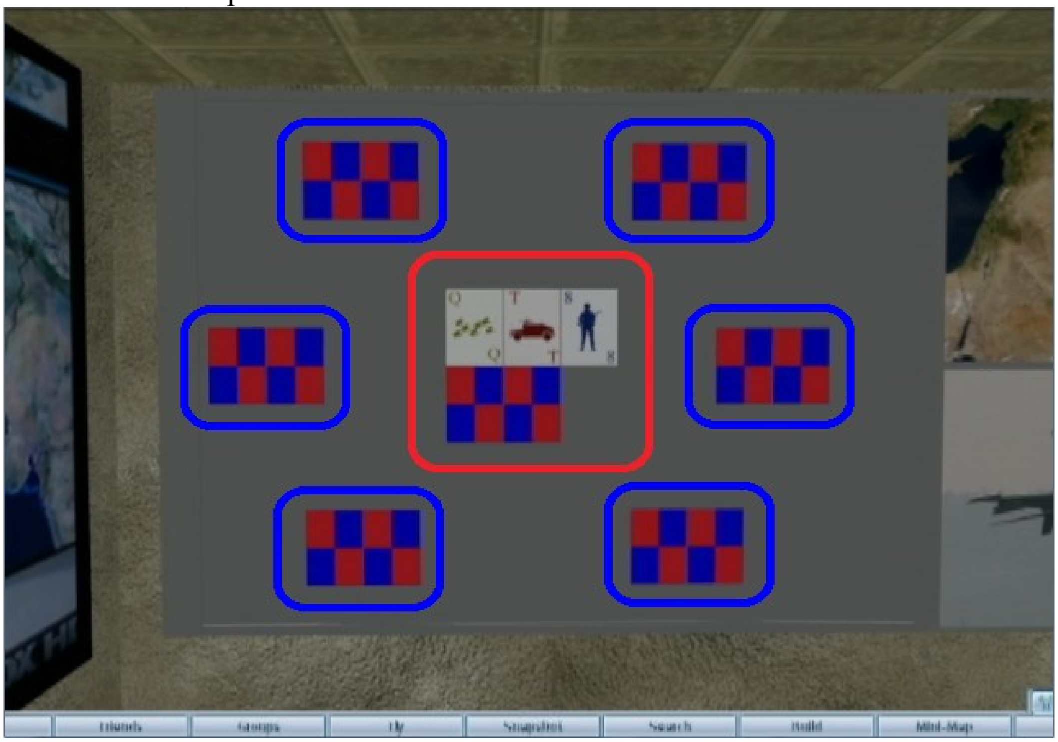
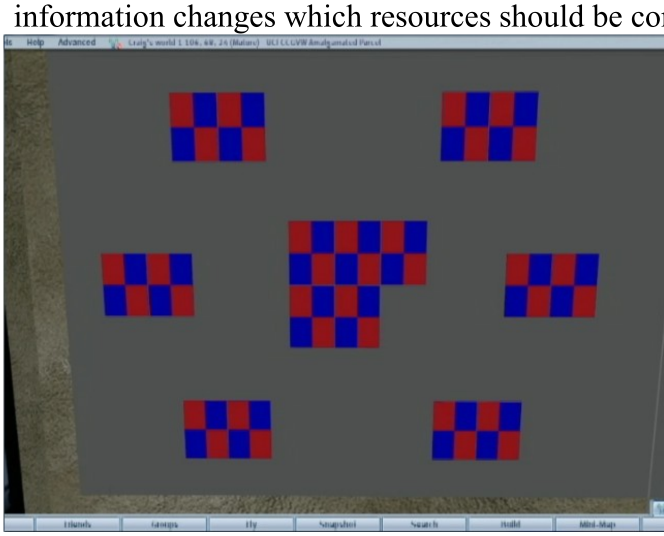
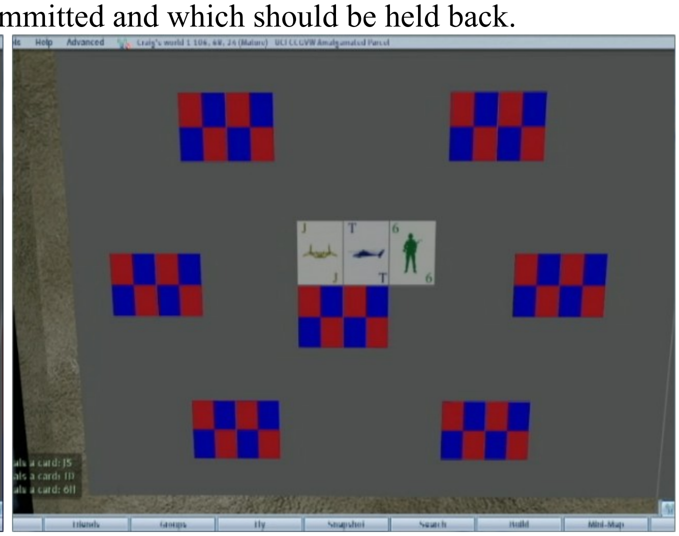


Figure 5. The public cards are circled with red; the pairs of private cards (face down) are circled with blue.

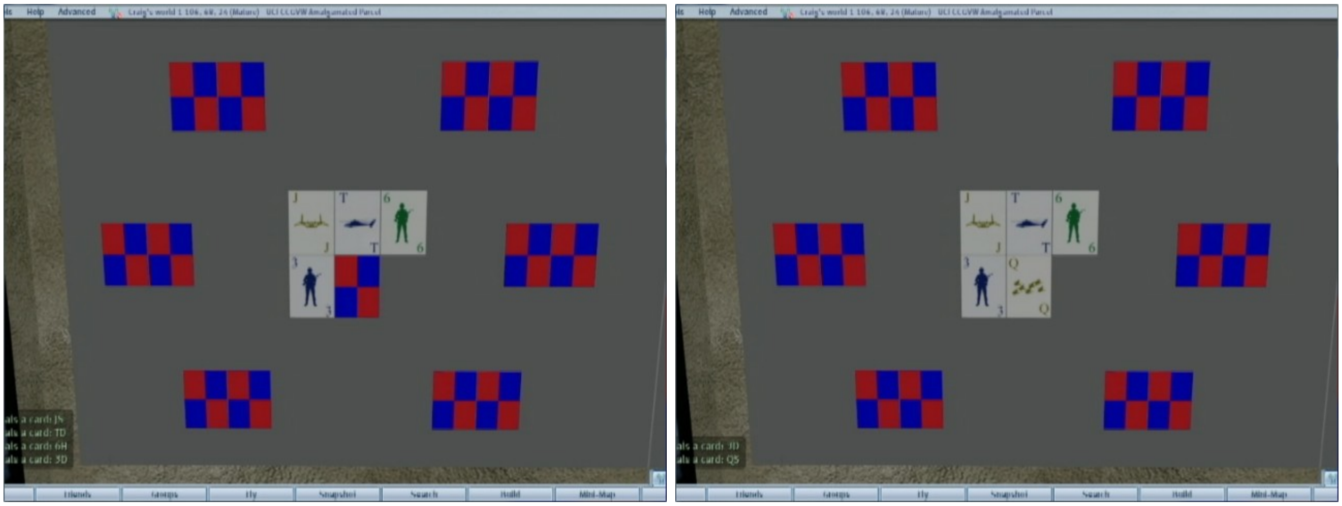
In addition to the sharing modes of information exchange, both games share similar resource and timing restraints. New information is revealed over time, and the information revealed this way affects each group's situation, changing who has the advantage. C2 reveals information in real time, and that information changes which resources should be committed and which should be held back.



(a) Pre-flop



(b) Flop



(c) Turn **(d) River**

Figure 6 (a-d). Information about different resources revealed as cards in the shared information display are incrementally revealed.

Hold'em reveals the public information cards at set intervals, but this still requires the team to re-evaluate its position, and the strategic values of its cards. The ability to re-evaluate one's standing and adapt to new information is critical in C2, just as one's ability to recognize when a new card improves or devalues an existing hand in Hold'em.

Features in Development for DECENT

DECENT Mission Cards

As the prototype continues to evolve, we are adding more constraints to the DECENT C2 game world, such as a deck of specialized mission cards. These cards act as additional constraints and modifications on the traditional Hold'em game, modifying the fundamental way each team's hole cards can be valued, and acting as additional ways for making the Hold'em analogy fit the environment of military C2. This allows us to increase the variability of play while still maintaining the fundamentals of Hold'em.

Some mission cards will give an advantage to certain military branches (the equivalent of traditional poker suits), while some will require or prohibit the use of specific card values. In addition to varying the DECENT's play, this also allows users with more flexible thinking skills to show their ability to adapt to different situations. Learning to value one's hole cards becomes much more difficult when the mission cards vary which cards are best. The mission cards will help to discover the most capable and flexible C2 thinkers.

In order to ensure that users who have not yet become accustomed to the game of Hold'em are not confused by this addition, DECENT can be played with or without these mission cards; the proctor may simply choose not to deal out a mission card. When played without the Mission Deck, DECENT's gameplay is exactly that of Hold'Em. Due to the static nature of the rules of Hold'em, we suggest that this only be done when teaching users the basic rules of Hold'em, and that the Mission Deck be added as soon as possible.

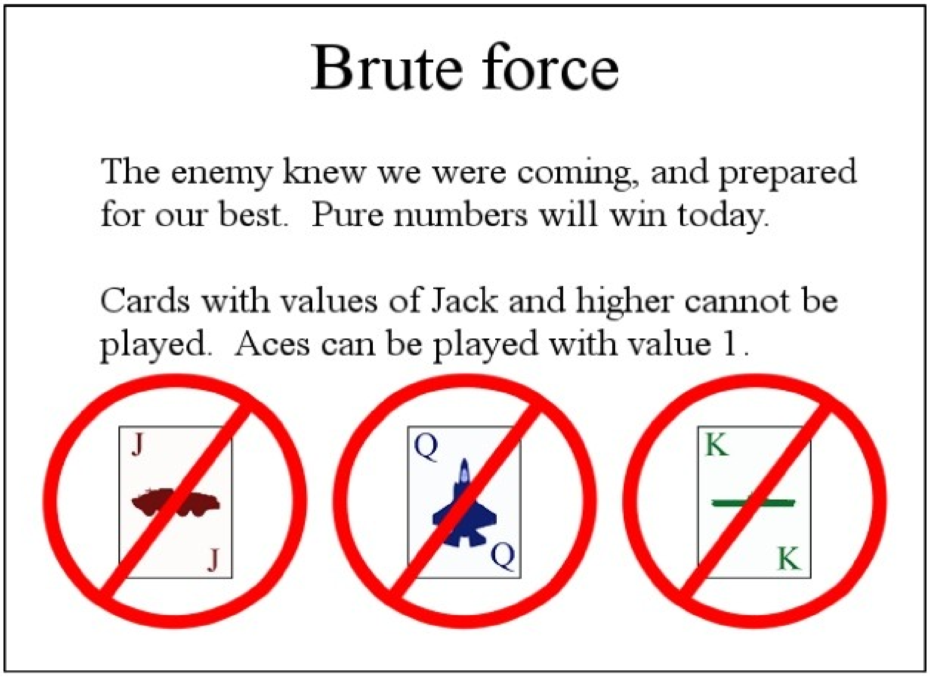


Figure 7. Example mission card: Brute Force.

Because mission cards are an additional element, not normally found in Hold'em, the structure of the gameplay must be modified when using them. Players get their cards, then a round of betting occurs. In traditional Hold'em, this would be followed by the flop (three public cards being revealed), but DECENT adds a mission step before the flop. After the first round of betting, the top card of the Mission Deck is revealed and made publicly available to all players. The mission card, itself, is placed in the public card area, below the flop and to the right of the river. To avoid any possible confusion between the playing cards and the mission card, we have made the mission cards twice the size of any other card. After the mission card is revealed, there is another round of betting, so that players can reevaluate their position, given the mission at hand. Play then continues as normal, with the flop.

In case the initial set of mission cards do not provide enough variability, or the users simply want new mission cards, additional mission cards can be made and added to the Mission Deck by an administrator (in OpenSim/SecondLife, this would be whoever owns the parcel of land). The most important thing when creating new mission cards is to change the odds of getting any given hand without making that change too significant. For example, the Brute Force mission card shown in Figure 7 invalidates all face cards, but does not actually cause a significant change to the odds of any hand. In effect, Brute Force just makes 10's the highest card and Aces the lowest card, while making Jacks, Queens, and Kings dead cards.

When making the visual component of a mission card, the current mission elements are as follows:

Mission Card Title in Bold
Flavor text, a description of the mission
Rules text, how the mission affects the game's rules
Image, an image which represents the rules text

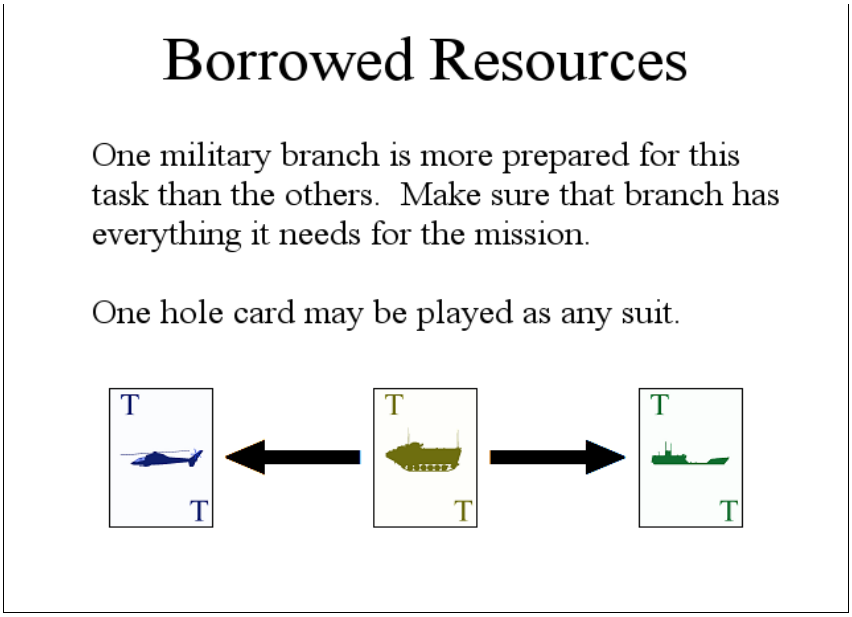


Figure 8. Example mission card titled Borrowed Resources, with narrative flavor text followed by rules text, and then an image of the rules text.

Figure 8 provides another example of a mission card whose elements constrain what resources can be utilized in further play, which can be compared to those seen in Figure 7.

Extending DECENT C2 functionality

There are three areas of interest that we have begun to explore in order to extend the function and scope of our DECENT prototype. First, we are exploring how to more efficiently create, tailor, and personalize the appearance and behavior of in-world avatars. This extension is influenced in part by related efforts with the ELICIT environment at NPS that explore how and why to tailor software agents to emulate specific people in a C2 operation [Wynn, Ruddy, Nissen 2010]. Such capabilities allow us to model people assigned different roles or decision-making responsibilities, as depicted in Figure 9.

Second, we have been extending DECENT to model and simulate other C2 domains, such as for space commands. Our objective here has been to explore what kinds of new modes of interaction with modeled and simulated objects (or clusters of objects) may arise. For example, for a game-based VW for space C2 (not shown in the paper), we model and simulate space debris fields that surround the Earth, and represent hazards/threats to the post-launch trajectory and orbital placement of new satellites, as well as potentially serving as a hiding space for other satellites or space-born threats. This capability allows DECENT users to place or "fly" their avatars into the modeled space debris field at different elevations and proximity, which allows for near-object visual inspection, its field of view, its current orbital trajectory, and more. Furthermore, these DECENT models have been programmed to interoperate with the data importing and *spherecasting* (i.e., decentralized, net-centric control of shared spherical displays) capabilities providing by NOAA's *Science on a Sphere* visualization systems (http://sos.noaa.gov/), used for visualizing global weather and remote sensing data sets.

Figure 9. Personalized models of C2 user-controlled avatars used in DECENT studies

Extending DECENT to support the full range of modern CGVW capabilities and affordances for decentralized collaboration

Recent studies, such as those found in Bainbridge [2007, 2010] and Scacchi, *et al*. [2011], as well as emerging ventures commercializing emerging CGVW technologies, reveal a diverse and growing set of socio-technical affordances (i.e., new ways and means for net-centric, decentralized collaborative work) are both supported and being used in practices including:

- *Group presentation, communication, conferencing, and social interaction* – virtual meetings of many different kinds that incorporate a sense of place at a distance, along with relevant work media (interactive reports, documents, presentations, 3D models, etc. -- many examples in Second Life), often as an alternative to currently available solutions provided by WebEx, GotoMeeting, and Skype-based online meetings.
- *Prototyping and review* – interactive design, construction, and modification of virtual objects, composite systems, or mirror worlds as potential enterprise products or services that can be used in proposals or design presentations.
- *Training, education, rehearsal, learning* – providing game-based VW simulators where people can enact simple/complex behaviors to understand how best to use/service a simulated device (e.g., see projects the Discovery Science Center and Intel [Scacchi 2010], also see examples from the *Little Big Planet* 2 game portal).
- *New product demonstration* – virtual product showroom, often with modeled/simulated interactive controls for selecting or customizing product features/attributes, such as color, appearance, accessories, etc. (see EONReality.com for online case studies).
- *Identity role-playing, team building, and other social processes* – often training centered VW but focusing on role-play, especially with attention to workplace diversity issues (cf. FutureWork Institute for identity role play, IBM efforts on team building).
- *Multi-media storytelling and avatar control/choreography* – creating video-audio animations

(recordings) or live virtual action (live broadcast) of game-based VWs for the purpose of illuminating narratives, telling stories through "machinima" for such purposes.

- *Mirrored worlds and memorialization* – creating game-based VWs that seek to strongly represent, primarily through visual means, some aspect, venue, or enterprise facility also found in the physical world. One reason for this may be to recreate or commemorate places that may no longer exist. Another reason may be to help new users more readily acclimate during their initial immigration from familiar physical worlds, to seemingly familiar virtual worlds, so as to enable follow-on activities like training or role-playing. VWs that mirror physical worlds may also include support for control devices that affect action in the corresponding physical world place, and vice-versa using augmented reality techniques.
- *Game development and/or modding* – software development kits or modding tools [Scacchi 2011] specific to a game engine (CGVW run-time environment) that streamline game-based VW development using engine-specific content development tools (e.g., *Unreal Development Kit* for the Unreal 3 engine from Epic Games), rather than general-purpose programming tools or interactive development environments (e.g., Microsoft's *Visual Studio*).
- *Socio-technical process discovery* – ethnographic, virtual ethnographic, and computational (text data mining) approaches to discovering socio-technical processes emerging within game-based work or play activities.
- *Enabling human behavior transformation* – game-based VWs designed to enable reflection, modification, and evolution of human behavior through repeated system-based training or usage settings, most clearly observed in CG for improvement of human health, ability, recovery, and self-managed care.

Affordances such as these can all support new ways and means of conducting collaborative research, development, and education in C2 domains, and thus collective represent a new engine for innovation and advancement, as well as to the creation, sharing, and enactment of new kinds of scientific knowledge.

Conclusions and recommendations for future study

This report seeks to describe and document the results of a small-scale one year research study that investigates how virtual world concepts, techniques, and tools can be employed to support experimental/prototyping efforts for command and control applications. We reported on our efforts to investigate and prototype a CG-based virtual world we called DECENT as a platform for exercising and assessing the potential of a CG-based approach to decentralized C2, as well as to compare our efforts with others closely related. Overall, we found this effort gave rise to very promising results that point to additional opportunities and system extensions for new ways to consider the potential of decentralized approaches to C2 that merit further systematic investigation and experimentation.

We also found that a number of computer games also suggest system features applicable to C2, as well as distributed individual/group problem-solving, using popular card games. Again, these may be candidates for further systematic study.

Last, we also reported on topics that essentially have little/no published research study or results that are central to the continuing development of CG technologies for C2 applications. Principal among these are topics surrounding the security of CGs intended for experimental studies or future applications to the C2 domain. VWs are still very early in their technical development, and far from ready for deployment in actual application settings. Nonetheless, these technologies do merit ongoing study and investment as they offer new categories of affordances that can enable/support both centralized and decentralized approaches to C2 in ways that legacy C2 technologies and approaches cannot. Decentralized CG-based virtual world approaches may offer the potential to substantially reduce the cost and dramatically shorten the time to design, build, and deploy C2 systems that embrace new generations of low-cost, mobile technologies that future C2 workforces may expect, whether for use in physical or virtual/cyberspace worlds. So much remains to be studied, and time for appropriate and realistic research investments is at hand. In the near-term, such research is likely to still be considered risky, but the longer-term benefits may most quickly arise and be demonstrated through such near-to-mid term research investments. This is the future opportunity now at hand.

Acknowledgements

The research described in this report was supported by grant #N00244-10-1-0064 from the Center for the Edge, Naval Postgraduate School, Monterey, CA. No endorsement, review, or approval implied.

References

Albert, D.S. and Hayes, R.E., (2003). *Power to the Edge: Command and Control in the Information Age*, Command and Control Research Program, Washington, DC, http://www.dodccrp.org/files/Alberts_Power.pdf

Bainbridge, W.S. (2007). *The Scientific Research Potential of Virtual Worlds*, Science, 317, 472-476, 27 July 2007.

Bainbridge, W.S. (Ed.) (2010a). *Online Worlds: Convergence of the Real and the Virtual*, Human-Computer Interaction Series, Springer-Verlag London Limited.

C2RPC (2010). Command and Control Rapid Deployment Continuum Overview, http://www.afcea-sd.org/wp-content/uploads/2010/12/YoungAFCEA_C2RPC.pdf

DoD JOAC (2012). Department of Defense, *Joint Operational Access Concept*, Version 1.0, 17 January 2012, http://www.defense.gov/pubs/pdfs/JOAC_Jan%202012_Signed.pdf

Garcia, P. (2010). Maritime C2 Strategy: An Innovative Approach to System Transformation, *Proceedings 15th International Command & Control Research & Technology Symposium*, Paper 147, Santa Monica, CA.

Gizzi, N. (2011). Command and Control Rapid Prototyping Continuum (C2RPC) Transition: Bridging the Valley of Death, *Proceedings 8*th *Annual Acquisition Research Symposium,* Vol. 1, Naval Postgraduate School, Monterey, CA.

OpenSim, (2012). *The Open Simulator Project,* http://opensimulator.org/

Scacchi, W. (2010). Game-Based Virtual Worlds as Decentralized Virtual Activity Systems, in W.S. Bainbridge (ed.), *Online Worlds: Convergence of the Real and the Virtual,* Human-Computer Interaction Series, Springer-Verlag London Limited, 225-236.

Scacchi, W., (2011). Modding as an Open Source Approach to Extending Computer Game Systems, in S. Hissam, B. Russo, M.G. de Mendonca Neto, and F. Kan (Eds.), *Open Source Systems: Grounding Research,* Proc. 7th. IFIP Intern. Conf. Open Source Systems, 62-74, IFIP ACIT 365, (Best Paper award), Salvador, Brazil, October 2011. Also in *Intern. J. Open Source Software and Processes*, (to appear, 2012).

Scacchi, W., Brown, C. and Nies, K (2012). Exploring the Potential of Virtual Worlds for Decentralized Command and Control. *Proceedings 17th International Command & Control Research & Technology Symposium,* Washington, DC, June 2012.

Scacchi, W., et al. (2011). *The Future of Research in Computer Games and Virtual Worlds*, NSF Workshop Report, February 2011.

VideoGameGenres (2012). http://en.wikipedia.org/wiki/Video_game_genres

Wynn, D., Ruddy, M, and Nissen, M., (2010). Command & Control In Virtual Environments: Tailoring Software Agents To Emulate Specific People, *Proceedings 15th International Command & Control Research & Technology Symposium*, Paper 019, Santa Monica, CA.