

# Mixed-Initiative in Computer Games: Algorithmic Content Creation in Open-ended Worlds

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## Abstract

We provide a general definition of mixed-initiative for application to the area of computer games. This definition is used to provide a survey of the ways in which mixed-initiative has been applied to games up to this point, and where and how mixed-initiative could be applied to improve the quality of games in the future. The need for algorithmic content creation through mixed-initiative interactions is demonstrated, and the application of mixed-initiative interactions to the challenge of developing realistic interactions with computer-controlled agents in an open-ended role-playing game is analyzed.

## A Definition of Mixed-Initiative in Computer Games

A general definition of mixed-initiative is still a work-in-progress. For the purposes of this paper, an interaction between agents (humans and systems) will be considered a mixed-initiative interaction if the following conditions are met. Firstly, the agents must have a set of goals that motivate them to take initiative to engage in an interaction. Secondly, each agent must have the ability to initiate interactions with the rest of the agents. Thirdly, agents must be able to take actions that are not explicitly defined by other agents: an agent's own knowledge must be used to translate general requests to more detailed and specific actions. In other words, an agent must have some of its own knowledge about the world that informs its interpretation of instructions or commands it receives. Finally, an agent should have a model for determining when to take or yield initiative, this being the most basic feature of mixed-initiative systems.

This definition necessitates that for an agent to be capable of mixed-initiative interactions, it must have a well-defined form of knowledge representation.

## Mixed-Initiative in Games: The State of the Art

Mixed-initiative interactions can provide a means for solving some of the current challenges in the development of mass-market computer games. Up to this point, mixed-

initiative techniques have been applied primarily to educational games, with promising results; an example is the *Design-A-Plant* educational game described by Lester, Stone, and Stelling (1997). In *Design-A-Plant*, a mixed-initiative coach aids learners in designing plants for different environments. Our contention is that a mixed-initiative approach can benefit the art and science of computer games in general. Mixed-initiative interactions have been implicitly implemented in mass-market games in bargaining systems, helper agents, and 'simulation' games where players use mixed-initiative interactions to generate content - although mixed-initiative theories have not been applied to these genres.

Bargaining systems, such as *Freelancer*, allow the user to negotiate with a computer agent for a trade: different types of resources might be exchanged, or services might be bought. In true mixed-initiative bargaining systems, each computer agent has its own goals, and may choose not to bargain for items the user wants to trade.

'Helper agents' also use mixed-initiative approaches as exemplified in the game *Black & White*<sup>1</sup> that provides the player with a 'creature' (a giant ape, lion, or other animal) that can learn to imitate the player (Crossan and Lessard 2005). The player can give the creature general commands, such as 'provide resources to this town', and correct the creature if it misbehaves by punishing it. The creature can try to attract your attention by following your cursor around the map, or even by intentionally misbehaving. Fail to correctly train your creature, or act unpredictably so that it cannot learn from you, the creature may choose to disregard you entirely, often leaving a trail of destruction wherever it goes.

The most successful use of mixed-initiative techniques in games to date has been in games designed by Will Wright, a visionary of the computer game industry. Wright pioneered the area of player-content creation with *The Sims*, a 'simulation' of real life that allowed users to create and define their own characters through their interactions with the game world - defining their characters through their economic and social decisions

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<sup>1</sup><http://www.lionhead.com/bw/>

(Thompson 2003). By giving characters a certain degree of autonomy, *The Sims* provides the player with a choice as to how much control can be exercised over the characters. In other words, mixed-initiative approaches offer players with a variety of choices in how they played the game.

## How Mixed-Initiative Can Improve the Quality of Computer Games

The most serious problem game developers are now facing is the ever-increasing costs of game development. These costs stem from the expectation that computer game players aim for better and better game content: graphics, stories, characters, strategies, environmental constraints, contextual cues, and game play are all expected to improve with each new release. These rising costs inhibit innovation in the industry (Costikyan 2005).

Other long-standing challenges in computer games have been identified in terms of creating open-ended, non-linear plots, and agent-oriented Artificially Intelligent interactions. Open-ended plots have been created for many games, but with the exceptions of simulations (flight simulators, *SimCity*, etc..) where one can observe serious limitations: player interactions with agents in the world remain scripted, and usually, the most interesting elements of the game are still the scripted plots, simply because the open-ended activities the player can undertake are boring and predictable.

One area in which the state of AI in games has been steadily (if slowly) progressing is the automation of micromanagement in real-time strategy (RTS) games. Game playing in RTS games can be divided into two stages, micromanagement (building up resources and abilities and interacting with individual units) and macro-management (actions such as an attack that are directed against the enemy and are critical to the outcome of the game). Micromanagement is often considered tedious and steps taken to automate those functions help gamers focus more attention to the macro-management stages where more interesting interactions take place. Up to this point, automation efforts have not been mixed-initiative: AI techniques have been advanced to the level of the game's unit agents, and these agents often left a lot to be desired since they are unable to perceive higher-level strategies. As we look at the evolution of games, we find that the amount of micromanagement is gradually being reduced in each new generation of games. For example, in *Age of Empires* – the first of a series of RTS games - farms could not be reseeded and there were no queues for unit production leading to intensive micromanagement in the economy building stage and less focus on macro-management and combat. This was remedied to some extent in *Age of Kings* (*Age of Empires 2*) and *Age of Conquerors* (its expansion pack), where many tedious functions were automated – for example, building queues were added. *Age of Mythology*, its successor, automated almost all resource collection

functions, and it is predicted that as games develop, the entire focus of the game will move to further emphasize the macro-management process. For this to be possible, 'helper' agents capable of understanding more advanced tactics and strategies will be necessary, and it is here that mixed-initiative techniques hold a lot of promise. MI is needed since gamers will not want to fully sacrifice their control over their micromanagement strategies, and at the same time they will want more automation in this area. A MI automation agent would greatly decrease the cognitive load by handling micro functions and at the same time allow for adaptation to a user's macro-level activities, helping the user to concentrate on their macro-management strategies.

Finally, the idea of creating a dynamic and responsive story (or set of stories) about the game world has been around for a long time, although it has not been implemented in many commercially successful games up to this point. This field is called 'interactive fiction.' Although early games such as *Zork* presented somewhat interactive stories through a text-based interface, the rise of high-quality graphics and complexities in implementing an interactive story in a graphical environment ended commercial exploration of this field (Murray, 1997). Chris Crawford, a longtime proponent of interactive fiction, has suggested that a "little language" - a language that contains only those concepts and relationships that the game world contains - can provide players with interactive fiction: this idea seems similar to the concept of domain-specific ontology. However, mixed-initiative ideas have not generally been implemented in interactive fiction either, which generally remains tied to the idea of interactive dialog as a back-and-forth process: Crawford describes a conversation as a looping of the "listen, think, and speak" cycle (Crawford, 1993).

We contend that all the challenges that are identified here pertaining to the world of computer games can be successfully tackled using mixed-initiative approaches. Specifically, this paper proposes a way in which a mixed-initiative approach can be applied to the development of procedural content generation in an open-ended role-playing game world.

Content can be generated using mixed-initiative interactions to generate fragments of narrative, which we will refer to as micronarratives, borrowing a term from Henry Jenkin's analysis of narrative in computer games (Jenkins, 2004). These micronarratives will contain information about non-player-characters (NPCs) and the players themselves. Here, a micronarrative is essentially defined as a partial or simplified narrative. An example Jenkins provides is the process of scoring a touchdown – rather than the full narrative arc of setup, complicating incident, development, climax, and denouement, micronarratives are essentially simpler stories. Micronarratives fit well with interactivity, perhaps since they are simple to create and can be communicated quickly

to the player. These micronarratives will be communicated to the player through dialogs and other interactions between game agents and the player character (e.g. combat), and will be generated through both the players' actions, and the actions of NPCs. This provides two advantages: first, it reduces the amount of narrative content that has to be created by artists or hard-coded by programmers, and second, it increases the responsiveness of the world. Essentially, it empowers the player to author their own narrative in the game world, which can increase the player's interest and immersion (Murray, 1997).

## **A Mixed-Initiative Framework for Generating Narrative Content**

We now consider the challenges involved in implementing mixed-initiative interactions (MII) between players and the game world (including computer-controlled characters, and other objects such as buildings and terrain) in a role-playing game implemented through an open-ended world (one in which no predefined path for the player is laid out) in order to generate micronarratives about the game world, the NPCs, and the players. These micronarratives will provide the non-player characters with motivations for their actions, making them more realistic, and in combination with mixed-initiative interactions, allow the game world to respond more dynamically to the player's actions, making it more responsive and interesting. By generating narrative through interactions, the game agents will be performing networked storytelling about their world, permitting the creation of world concepts based on consensus (similar to how real-world concepts are built).

Creating a mixed-initiative interaction framework for players and computer agents/characters requires five major components: a system for knowledge representation, a system for MII, an group of Artificially Intelligent software agents which can take advantage of the represented knowledge, a method for translating those interactions into human-readable text, and an interface that permits the user to communicate through interactions without any direct knowledge of their structure. This paper will only discuss the first two components.

### **Knowledge Representation of the Game World and Micronarratives**

The underlying knowledge that provides valuable information and communication opportunities to game agents is critical to the success of mixed-initiative interactions in computer games. It should be flexible enough to represent the fundamental attributes of a game world that the computer agents are likely to encounter. It needs to represent game world facts, such as the location of important objects and characters in the game. It also needs to represent the micronarratives the agent encounters, and how the narratives were communicated to the agent: did

he/she experience them directly, or hear them from another agent? The knowledge representation will need to always provide information about the world from the perspective of a given agent, in order to ensure that each agent is receiving a unique and relevant set of information about the world. This characteristic of computer games is referred to as *sensory honesty*: not only should an agent perceive the world according to the senses they are represented to the player has having, it should also have its own internal model of the world, which may differ from reality and/or that of another agent (Isla and Blumberg, 2002). Sensory honesty becomes even more vitally important when attempting to build narrative content through MII, since the agent's biases and perceptions will persist as part of the game world's story, and any consistent flaw in the agent's sensory model will be very likely to become part of this narrative. For example, if an agent is programmed to 'cheat', and perceive events further away than they would be expected to sense, the agent may then inform a player about the occurrence of the events, even though the agent should logically be unaware of it. In an extreme case, this could extend to agents relating to the player the actions of the agents that they could never logically have met in the game world. In other words, when designing a system where emergent behavior is a goal, it is important to ensure that the system it will emerge from is consistent with the player's perceptions of that system.

Three types of information about the world will need to be represented: the state of the world, such as positions of objects and their properties, the actions that are currently being undertaken, such as movements or conversations, and the internal ideas of the agent – its stored micronarratives, goals, and needs. Temporal data would also be stored for each event, using timestamps represented by general categories, such as "just now", "a few minutes ago", "last week", "a few months ago", and so on.

There are various knowledge representation techniques that have been explored in the field of computer games. DeSmedt et. al (1999) present an ontological approach to knowledge representation for NPCs, which the authors call conversational agents. Other researchers, such as Pisan (2000), present classification as a character building and knowledge acquisition tool. Narayek. et.al (2002) discuss intelligent agent planning in computer games for character representation. Most reported research on knowledge representation in computer games is centered around the notion of game characters. Our research is focused on a) an ontological representation of the knowledge for content representation, b) mixed-initiative interactions as the key technique for communication among the agents, and c) enabling agents to build rules and relationships about their world as a group, through mixed-initiative interactions. Through ontological representation, we are able to capture the contextual meaning of the content required for dynamic creation of agents' dialogues and other interactions. The ontological representation of the content, the

micronarratives, and the relationships between the content and the narratives create a complete knowledge representation of the world, including explicit representations for the interactions. MI interactions are still a work-in-progress and will be built as an overlay of the ontology, eliminating the need for translations between interactions and the interactions' representation in the agents' representation of knowledge.

## MII in the Game World

A framework for mixed-initiative interactions in an open-ended role-playing game world will need to support not only one-to-one interactions, but also one-to-many interactions (e.g. shouting), and many-to-many interactions, whose handling will be prioritized by the agents receiving them. Fortunately, the challenges of MII-interactions between teams of agents are actually an advantage here, since if implemented correctly, agents' failures to communicate and cooperate will provide as much narrative content as their successes. For example, the challenges inherent in adjustable autonomy such as the *team decision challenge* (Scerri, Pynadath and Tambe, 2001), as well as other challenges related to the sharing of initiative can become part of the definition of an agent's behavior, since optimal helpfulness is not necessary in most situations. As a result, a character with a low tendency to give up initiative and take commands from other characters would seem more independent.

This flexibility - supporting multi-agent interactions and the handling of many such interactions simultaneously - is necessary since the game world will require these types of interactions. Ideally, the same framework will handle interactions between all game objects, even those as simple as an agent picking up an object. This will allow for the modification of behaviors of game objects through the interactions interface - for example, the knowledge structures embedded in a weapon object could be modified so that it would only fire when operated by its owner. For the purposes of this system, any game world object could be considered a potential participant (or 'agent') in the mixed-initiative interaction system. Furthermore, AI approaches can be generalized to take advantage of interactions shared across many types of game objects.

The most general case of the interaction system would be when it is in the process of perceiving input from surrounding agents (players, NPCs, etc.) Some input may trigger the creation of a context, such as a 'conversation' between a set of agents. The agent's system can then place those objects into a new context. A context could include some rules or guidelines for how interaction in that context could take place, similar to the types of interactions defined by Guinn (1996): for example, *SingleSelection* or *Continuous* modes could be indicated, either explicitly or through variable changes in behavior, such as weightings inhibiting certain interactions (e.g., social mores inhibiting possible real-life actions.) At the same time, the system

should probably be inherently agent-oriented, where interactions will be prompted by the agent's goals - an agent without goals (or currently without the means to further them) will not initiate interactions.

It should be noted that the possible 'interactions' are not limited to speech - body language and actions will also be considered. Also note that every agent can be thought of as being composed of sub-agents (arms for attacking, eyes for seeing, etc.) that inform the central or distributed MI system about interactions they observe or take part in. Of course, the granularity of agents and sub-agents is a design decision that will depend on various factors during implementation, such as the amount of processing power available per agent and the complexity of a given agent.

The degree to which a MI approach to agent interactions in an open-ended world can be successful rests in part on technological limitations: how many agents with what level of cognitive ability can a single PC support using the fraction of its resources that a game can allocate to MI? Actual implementations need to be tested in order to determine if a MI game can be implemented given these constraints (or if current hardware is insufficient, how long it will be before hardware specifications make this possible). Furthermore, the usefulness of ontological modeling to the development of complex game worlds needs to be demonstrated.

## Conclusion

We have established that MII can and should be considered in the improvement of interactivity in computer games. We have analyzed the requirements and possible architecture of a mixed-initiative system for agents' interaction with players in an open-ended game world, and proposed a set of recommendations for the design of such a system. These recommendations are as follows: firstly, that knowledge representation and interactions for agents in a mixed-initiative environment should be based upon a domain ontology; secondly, that the system should support one-to-many and probably many-to-many MII; thirdly, that it should implement as many game world interactions through the same MII framework as is possible given efficiency constraints; and finally, that the possibility of representing agents as a collection of sub-agents controlled by a centralized MI system with more authority should be considered.

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## References

- Costikyan, G. 2005. *Burning Down the House: Game Developers Rant*. Game Developers Conference 2005, San Francisco, USA.
- Crawford, C. 1993. A Better Metaphor for Game Design: Conversation. *Journal of Computer Game Design*. 6  
Retrieved from  
[http://www.erasmatazz.com/library/JCGD\\_Volume\\_6/Conversational\\_Metaphor.html](http://www.erasmatazz.com/library/JCGD_Volume_6/Conversational_Metaphor.html)
- DeSmedt, B. and Loritz, D., 1999. Can We Talk? in *Papers from the AAAI 1999 Spring Symposium on Artificial Intelligence and Computer Games*, Technical Report SS-99-02, 28-31. AAAI Press.
- Guinn, C. 1996. Mechanisms for Mixed-Initiative Human-Computer Collaborative Discourse. In *Proceedings of the 34th annual meeting on Association for Computational Linguistics*. 278-285. Morristown, NJ, USA: Association for Computational Linguistics
- Isla, D. and Blumberg, B. 2002. New Challenges for Character-Based AI for Games in *Papers from the AAAI 2002 Spring Symposium on Artificial Intelligence and Interactive Entertainment*, Technical Report SS-02-01, 41-45. AAAI Press.
- Jenkins, H. 2004. "Game Design as Narrative Architecture," in Noah Wardrip-Fruin and Pat Harrigan (eds.) *First Person: New Media as Story, Performance, Game*. Cambridge: MIT Press.
- Lester, J., Stone, B.A. and Stelling, G.D. 1999. Lifelike Pedagogical Agents for Mixed-Initiative Problem Solving in Constructivist Learning Environments. In *User Modeling and User-Adapted Interaction 9*: 1-44. The Netherlands: *Kluwer Academic Publishers*.
- Murray, J. 1997. *Hamlet on the Holodeck: The Future of Narrative in Cyberspace*. New York, NY: The Free Press.
- Nareyek, A. 2002. Intelligent Agents for Computer Games, in Marsland, T. A., and Frank, I. (eds.), *Computers and Games, Second International Conference, CG 2000*, 414-422, Springer LNCS 2063.
- Pisan, Y., 2000, Building Characters: A Form of Knowledge Acquisition in *Papers from the AAAI 2000 Spring Symposium on Artificial Intelligence and Interactive Entertainment*, Technical Report SS-00-02, 66-68. AAAI Press.
- Scerri, P., Pynadath, D., and Tambe, M. 2001. Adjustable Autonomy in Real-World Multi-Agent Environments. In *Proceedings of the fifth international conference on Autonomous agents*. 300-307. New York, NY, USA: ACM Press.
- Thompson, C. 2003. Suburban rhapsody. *Psychology Today*. 36(6):32. New York, NY, USA.