Understanding Human Creativity for Computational Play

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Abstract

Play is a creative activity involving the construction, use, and modification of game frameworks. Developing computational agents capable of play with humans requires a formal categorization of the key aspects of play. We propose a theoretical framework to differentiate the knowledge, actions, and intentions employed by play agents. Play knowledge may be pre-conventional (lacking formal rules), conventional (composed of domain-specific rules), or post-conventional (including both domain specific and out-of-domain rules). Actions may exploit, explore, generate, or modify play knowledge to create play experiences. These experiences may be pursued with ego-centric (self-oriented) or exo-centric (other-oriented) intentions. We illustrate this framework with examples from research on play and relate this to existing creativity models.

Introduction

Play is a fundamental human activity with a central role in creativity and human interactions (Caillois 2001; Huizinga 2003). Fields including social robotics and virtual agents have begun to address the ways computational agents can interact with humans and integrate into our everyday lives. However, little work has been done on how these agents can intentionally engage in play. The field of game AI has focused on building agents that can realistically (or optimally) play digital games with humans or other agents, but they have no formal concepts of what it means to "play" or "be playful." For instance, game AI approaches have yet to explore how agents can be engaged within a social context to co-create a game together, as children do. Programming agents and robots with concepts of play within a social context can improve their capacities to relate to humans, increase their social acceptance, encourage human companionship and interest, and stimulate human creativity, learning, and motivation. Playing with humans requires the capacity to construct, inhabit, and modify an open-ended make-believe world as humans do. This article discusses a theoretical framework for *computational play*, categorizing types of human play as the first steps toward developing computational agents that play with humans.

Play spans a wide range of activities, most focally games. Games are systems of rules that define a set of game configurations, legal moves between these configurations, and winning and losing conditions (Salen and Zimmerman 2003). We can distinguish agents – both human and machine – through how they make use of the rules of a game. This article discusses six categories of players along two axes: one of knowledge, the other of intent. Players may possess knowledge that is: *pre-conventional* (i.e., lacking fixed predetermined rules), *conventional* (i.e., confined by a prearranged rule set), and *post-conventional* (i.e., using prearranged rules along with outside rules). Differentiating the knowledge employed by creative agents enables detailed investigation of the ways a creative domain is constructed and modified during interaction.

Playing a game is the process of choosing specific actions during a game to achieve a total trajectory through the space of game states. These actions operate on the player's knowledge and therefore may not be restricted by the known rules of a game. As such, an agent can potentially act outside the space of the rule-based play knowledge. At any given time an agent may attempt to *exploit* its knowledge to act according to game rules, *explore* the game state or rules when they are ambiguous, *generate* new game states or rules, or *modify* existing game states or rules. These different actions are used both to construct a play experience over a series of actions and to potentially alter the game itself. Agents may thus be creative in how they act within the space (exploitation), how they interact with the space and other players (exploration), or how they manipulate the space itself (generation and modification).

We contend that agents, human or computer, differ in their intentions when acting within this space of play experiences, depending on the social purposes of their actions. *Ego-centric* agents attempt to maximize their own reward when playing the game. Conversely, *exo-centric* agents seek to optimize the experience of all participants in the game. These intentions direct the creative process towards particular outcomes and provide an agent with orientation to how it acts. In both cases other players form a key context to creation of a play experience.

We define play as the combination of the knowledge of the rules of a game or play activity, the processes for using

that knowledge to enact an experience, and the goals guiding this process. In the next section will we discuss Boden and Wiggins's work on creativity. We will then elaborate the knowledge, action, and intention components of our framework and support our definitions with examples of play both from humans and existing computational frameworks. Finally, we will compare our framework to Boden and Wiggins's frameworks for creativity, contextualizing play activities within the domain of research on creativity. We conclude with research directions for developing computational systems capable of play with humans.

Previous models of creativity

Boden

Boden (2009) proposed a general framework for understanding creativity involving production of ideas that are both new and valuable. She subdivides methods for producing creative ideas into *combinational*, *exploratory*, and *transformational* modes.

Combinational creativity is defined as the unfamiliar combination of familiar ideas, performed by associating ideas that were previously only indirectly linked. This process is guided by associative knowledge rules, connecting and transferring ideas between domains. *Exploratory* creativity involves moving through a conceptual space, where the space is defined by a culturally accepted style of thinking. Generative rules define means to produce concepts that fit the defined style. Finally, *transformational* creativity is the alteration of a conceptual space through modification of the rules defining that space (Boden 2009, 24-25).

Wiggins

Wiggins (2006; 2001) provides a computational formalization of Boden's framework as a search process. He defines several sets of rules employed by the searching agent, including:

- U – the universe of possible complete or partial artifacts
- R – the rules which defined an artifact of interest
- T – the rules that define methods to traverse the space of artifacts defined by R
- E – the rules that define how to attribute value to an artifact

R is external to an agent and agreed upon among a group of agents, while T captures the individual agent's methods for searching within this space (Wiggins 2003). T generates artifacts that may or may not fall within the space defined by R and E may place value on concepts outside of the space defined by R. This means the conceptual spaces covered by R, T, and E are not necessarily co-extensive. This mismatch enables creativity through reaching novel artifacts valued by E but not within R. In response, creative systems may engage in either R-transformation or T-transformation, changing the set of rules used to represent or construct artifacts, respectively.

As a computational formalism, Wiggins's work articulates the difference between the rules used to define an artifact, the rules used to generate an artifact in the creative process, and the rules used to evaluate an artifact. Both Boden's model and Wiggins's formalization, however, focus on creativity at the level of individual isolated acts of creation. Other agents only act to define the rules for a conceptual space before a given agent acts to create artifacts within that space. This model leaves open questions for building a play agent regarding the means of co-creation among groups of interacting agents. In play the rules of a game are continually negotiated by groups of agents, while their choice of play actions dynamically responds to those of their playmates. Addressing these processes will require an understanding of the knowledge, processes, and intentions involved in play activities.

Play Framework

We model play agents as possessing knowledge of play, the capacity to engage in play actions, and a set of intentions regarding the play experience. An agent reasons about its game rule knowledge to select play actions toward particular play intentions. Play *knowledge* describes the defined rules of a particular play activity, delimiting a space for taking play actions. Play *actions* are the ways an agent may use its knowledge during a play activity, potentially acting outside the domain of game rules. A total sequence of play actions made by all players from the beginning to end of a game constitutes a play trajectory or experience. Agents evaluate potential trajectories according to their play *intentions*. We categorize play according to the kinds of knowledge employed, types of actions used, and intentions guiding agent actions.

Knowledge

Play knowledge formally consists of the set of rules that define the legal *states* within a game and the *transitions* between these states. Agents vary in the types of knowledge they possess, being pre-conventional, conventional, or post-conventional. Pre-conventional players lack knowledge of the game rules, but possess outside sources of knowledge (e.g., rules of other games, social norms regarding turn-taking among peers). This typically occurs in the context of a game not yet formally defined from the viewpoint of the play agents, but co-created by the agents through their activity. Conventional players have fully defined the rules for an activity and are restricted to the use of game-specific rules. Post-conventional players employ both the rules of the game and outside sources of rules, enabling modification of the game rules. Young children at play exemplify pre-conventional play, where rules are freely created. Professional sports exhibit prototypical conventional play, where all activity is constrained to obey the set

the set rules for the game. Post-conventional play occurs when players modify games to follow house rules, altering the rules of an activity using outside rule sources and norms.

These models of knowledge capture differences in the formal game structures that players employ: spontaneous rules and shared outside knowledge, the defining rules of an activity, or both sets of rules. In addition, different knowledge types vary in their flexibility: pre-conventional players construct a game, conventional players bar modification of game-specific knowledge, and post-conventional players use game-based knowledge while having the capacity to modify it. Playing in any of these ways involves differences in what structures are defined and how they may be modified.

Computational agents that implement these knowledge structures will require flexible schema capable of adding, removing, and modifying potential game states and transitions among these states. The computational model will need to capture the semantics of game rules, incorporating the relations of game states and rules to one another and the actions available to agents. As pre-conventional and post-conventional players both draw from beyond the knowledge of a specific activity, these computational agents will require the capacity to relate game knowledge to other outside frameworks.

Actions

Play actions differentiate how agents may use, learn, build, or modify the structure of play. Play agents reason about a given game state and the agent's game knowledge to decide how to act. Play actions can be divided into four primary categories:

- Exploitation – acting according to known game state and rules
- Exploration – eliciting information from outside (e.g., from other players or the game environment) regarding the game rules
- Generation – declaring a new game state or rule
- Modification – declaring a modification to the current game rules

Exploitation is illustrated by chess players who capture pieces according to their prescribed movements. Exploration is employed in pre-conventional or post-conventional knowledge contexts when ambiguity exists regarding the structure of the activity. During charades players may ask for a repetition or clarification of an action. Generation is used in pre-conventional and post-conventional knowledge situations to add to game structure and knowledge. Modification occurs principally in post-conventional knowledge contexts when existing game structure is altered.

Gottman and Graziano (1983) found that children playing together employ this set of actions during friendship formation. Children initially exchange information and establish a common ground activity (exploration) before escalating to play activities (exploitation). During play conflicts may arise, which are resolved through conflict resolution processes (including generation and modification) and message clarification (exploration).

A sequence of play actions made by all players defines a play trajectory or play experience. While play knowledge defines the space for play, play trajectories represent the actualized experiences. Employing play actions enables construction of play experiences. Actions are capable of manipulating both the play knowledge (via exploration, generation, and modification) as well as the play experience (via exploitation). Conventional play restricts the actions available to exploitation, remaining strictly within known states. Pre-conventional play employs exploratory actions for clarification of poorly-known states and generation to construct an activity from existing knowledge. Post-conventional play enables the alteration of game states and rules through exploration, generation, and modification. It is important to note that these actions need not be arranged into discrete phases of constructing a game and playing a game, but may be interwoven during any play experience.

Interacting with other players requires interpretation of the play actions those players take. Ambiguity in these interactions involves interpreting player actions in the context of the play activity and identifying the specific type of action performed. Research on play has identified the role of meta-communication in mediating between player actions and game meanings. Meta-communication is a form of communication where a message has different meanings with respect to different levels of an activity (Bateson 1972). In play, an action has both a real-world meaning and a meaning with respect to a particular play activity. Exploration involves clarification of this relationship, while exploitation involves conveying action information to others. Generation and modification both involve constructing new meta-communicative relationships, eitherignoring the existing game framework or working with respect to it.

Computational play agents will need the capacity to engage in this set of play actions. In playing within a game, this entails reasoning about existing game states to identify lacking information regarding game rules. Being able to engage in pre-conventional or post-conventional play will additionally require methods to generate new and relevant game states and rules, using outside sources of knowledge and existing known rules. All of these actions implicitly require the capacity for meta-communication, involving interpretation of ambiguous actions in the context of a play activity.

Intentions

Play experience intentions guide the selection of actions toward the construction of a play trajectory. These intentions capture the combination of features of a play trajectory that an agent values. Play intentions capture the focus of the set of goals employed by an agent – itself or others. Ego-centric players evaluate trajectories with respect to

Table 1. Six categories of play.

	Pre-conventional	Conventional	Post-conventional
Ego-centric	Generation of new game states and rules to structure a play experience towards personal reward	Adherence to game rules in pursuit of personal reward	Modification of game states and rules toward personal reward
Exo-centric	Generation of new game states and rules to structure a play experience towards group experience	Adherence to game rules in pursuit of group experience	Modification of game states and rules toward group experiences

desired personal play experiences, while exo-centric players aim for group experiences. Competitive sports professionals exemplify an ego-centric approach, where all actions during a play activity are chosen for the ultimate goal of winning. In contrast, a parent who intentionally makes bad moves when playing with a child exhibits an exo-centric play style, hoping to create an interesting experience for both themselves and their child. Ego-centric and exo-centric styles highlight differences in the goals players work towards during a play experience, embedding the role of social interactions into the means for enacting play.

Creating a computational play agent will require the definition of the relevant features of a play experience as well as means to evaluate any given experience with respect to these criteria. Evaluation cannot consider only the end state of a play experience, but must incorporate the full trajectory of actions. This involves accounting for the experience of both the given agent and any other playmates. When selecting actions, agents will need to calculate the impact of any choice over the remainder of a play activity with respect to all participants. This entails weighing different goals and assessing their value at different points along a total experiential trajectory. Evaluation also involves reasoning about the relationship of particular rules to the set of available trajectories in order to generate or modify game structure towards particular intentions.

Play Style Categories

The knowledge and intention axes of play styles we propose intersect to define six play style categories: ego-pre-conventional, exo-pre-conventional, ego-conventional, exo-conventional, ego-post-conventional, exo-post-conventional. We support these categories with examples of human play activities and computational models that illustrate these distinctions.

Pre-conventional play

Ego-pre-conventional play involves the construction of games that support individual interests through the use of outside knowledge. Solo play with toys is a typical example of children constructing a game for personal enjoyment (Sutton-Smith 2001). Constructive play with blocks and objects often involves invention of structured meanings applied to game states, where activities are oriented towards personal satisfaction.

Exo-pre-conventional play involves constructing activities towards the enjoyment of a group of players using outside knowledge. Children's group pretend play demonstrates this category, where a play structure emerges to support all players through iterative negotiations (Sawyer 1997; Sawyer 2002; Eckler and Weininger 1989). Caillois describes the unstructured play of taking up social roles to construct an imaginary world (2001). In both of these cases players create the structure of the activity spontaneously, without prior agreed-upon rules. Meckley (1994) describes the establishment of a play society among 12 three to four year old nursery school children over a period of five months. Here, the games and play activities gradually became ritualized from various actions the children engaged in, with particular groups coming to emphasize different norms of conduct. For example, a group of girls developed a game of playing house, where group enjoyment norms included methods to cope with disruptive intrusions from boys not part of the game.

Conventional play

Ego-conventional play involves acting solely within game rules to achieve personal play experiences (including, but not limited to, victory). Ego-conventional play is exhibited by most players in tournaments, where all actions aim toward personal victory. Game artificial intelligence (AI), in particular adversarial search techniques, exemplifies this approach as the agent evaluates actions in the service of optimizing personal score.

Exo-conventional play is the adherence to game rules while pursuing play trajectories that optimize certain group experiences. Exo-conventional play occurs when players intentionally make poor-quality moves, seeking to keep the game interesting for themselves and others by evening the odds of winning. Beaudry (2010) presents an application of Markov decision theory to a Snakes and Ladders like game, where a computational agent generates plans to avoiding creating too large a gap between its score and that of an opponent. Roberts, Riedl, and Isbell (2009) similarly argue for the application of narrative storytelling techniques to AI systems in an effort to produce interesting trajectories of actions during a game, rather than optimal end states for a game-playing agent.

Social goals can vary in guiding goal states and criteria. Caillois and Kohlberg both recognize two common exo-centric intentions employed by humans (Caillois 2001;

Kohlberg 1987). Caillois's competition (*agôn*) play category and Kohlberg's reciprocity justice operation both emphasize merit-based rewards for players. Caillois's chance (*alea*) play category and Kohlberg's equality justice operation instead emphasize fairness in games and evenness of chances. Merit and fairness are two criteria agents may use to evaluate experiences, such as Beaudry (2010) above emphasizing fairness.

Post-conventional play

Ego-post-conventional play is the modification of game rules to maximize personal reward in play. Ego-post-conventional players are exemplified by cheaters, who violate game rules for personal gains in the game. In video games this can include becoming invincible, skipping ahead of sequences that are difficult or tedious, or gaining powers to fly or move through obstacles to explore the game world more fully without its normal constraints. Other examples include stacking the deck in poker for monetary gain or covertly taking money from the bank in Monopoly™. In commercial video games, AI systems are often allowed to cheat through unfair advantages in resources or having access to information not available to human players (e.g., ignoring the "fog of war" in strategy games). The procedural particle generation system employed by Galactic Arms Race (Hastings, Guha, and Stanley 2009) is an example of an ego-post-conventional system that modifies the game weapon mechanics to match player play style preferences.

*Exo-post-conventiona*l play is the modification of game rules toward desired group play experiences. Examples of this play include human players imposing handicaps to ensure more even chances among players of varying skill (fairness) or using house rules to modify a game towards particular group interests. Young children most commonly resolve conflicts among players by adding rules to a game (Kolominskii and Zhiznevskii 1992). In pretend play, children often draw from a cultural narrative to ground their play activity, subsequently modifying the narrative to suit their particular play interests and desires (Sawyer 1997; Sawyer 2002). Meckley (see above) found children gradually increased the complexity and diversity of the games they played. As exo-post-conventional play, these children demonstrated manipulation of game rules as the group sought different sorts of play experiences.

Discussion

Play activities can be understood through the lenses of the creative frameworks set forth by Boden and Wiggins. Comparing to these models we map conceptual spaces to the game knowledge (i.e., defined game rules) and creative artifacts to the play experience trajectories. This captures the distinction between a generative space (game rules) and specific instances within that space (play experiences).

Boden's model subdivides creative activities into combinational, exploratory, and transformative types. Pre-conventional play can be seen as a form of combinational creativity, where players construct a game space by combining elements from other domains. Conventional play matches exploratory creativity, where social conventions (game rules) define the space used by individual agents. In conventional playing, agents adhere to game rules in the process of exploring the space of play trajectories defined by these rules. As rules are generative their implications are not necessarily known in advance. Post-conventional play maps onto transformative creativity, where the guiding rules of a game are modified. Boden notes that transformation requires making new creations possible and involving interactions with the outside world. Post-conventional playing meets these requirements through altering the game rule space to enable play trajectories not previously possible and using outside knowledge in creation or modification game rules. With respect to Boden's framework, types of play are avenues for interactive creation of game rules and play experiences.

Wiggins specifies both *R*-transformation and *T*-transformation as modes of creativity. *R* maps onto the game rules, *T* maps onto the play actions employed, and *E* maps onto the play intentions pursued for a given game. As in Wiggins's model, actions may result in experiences not possible within the bounds of the game rules. *R*-transformation may be involved in pre-conventional or post-conventional play activities. In pre-conventional play, agents form a set of rules for a game from a null set of rules using outside knowledge. Post-conventional play modifies the existing rules of a game by drawing from rules beyond the set defined by *R*. *T*-transformation alters the actions employed by agents, involving specific types of exploitation, exploration, and creation. Agents may alter the set of actions they employ that obey the rules of an activity, potentially restraining themselves to a particular subset of legal actions (e.g., refraining from killing enemies in a shooting game). Transforming exploration rules involves seeking different types of information from the environment, examining the bounds of rules. Altering the creative rules employed changes what aspects of the game rules may be modified and what kinds of rules may be proposed. Wiggins's framework brings to the fore two different levels of creativity in play: manipulating the rules of the game themselves and changing the experiences achieved when playing. Thus, our framework provides a model of creative activity that incorporates the role of interaction and interdependence among agents into the creative process by altering the rules forming an activity and means of playing.

Conclusions

We propose a framework to classify play activities according to the play knowledge and intentions employed by play agents. Play knowledge may be pre-conventional, conventional, or post-conventional, where game rules are not pre-

viously defined, strictly obeyed, or subsumed within a larger set of rules, respectively. Play actions involve using, clarifying, adding to, or modifying existing game states and rules. Agents may pursue ego-centric goals in playing towards personal experiences or exo-centric goals in pursuing desired group experiences. Play actions give play agents the means to construct play experiences from their knowledge toward particular intentions. The intersection of play knowledge and intent defines six types of play. The knowledge, action, and intent division we draw maps onto similar distinctions made by Boden and Wiggins in describing creative systems, while extending their work towards creativity involving interaction with others.

Future research will examine the interactions among players in different play categories. How do players categorize one another and how does this impact their play styles? Computational play agents can leverage this knowledge both in co-creating games based on the play category of a user and in playing games to create interesting play experiences for a specific kind of player.

Our categorization defines a space for future research towards computational agents capable of playing with other agents and humans to co-create particular activities and experiences. Computational formalizations of play knowledge will investigate what particular knowledge and knowledge structures agents require when involved in open-ended pre-conventional play.

Computational models of play actions will explore how agents can reason about the relationship between game states, rules, and player experiences. When should an agent seek information about the game space? What processes and information are involved in adding rules to a game? How can an agent reason about existing rules to modify those rules? How can agents and players communicate about a play activity when engaged in unstructured play? We speculate fuzzy schemas will be required to represent the ambiguity involved in meta-communication, modeling the distribution of potential game actions being performed by any given agent action.

Computational implementations of play intentions will examine what features agents must account for during play experiences and how they can be employed in evaluations. How should agents evaluate a trajectory of play actions? What goals should be used and how do they fall along the ego-centric-exo-centric axis? How can they address the open-ended nature of potential play experiences, where the set of possible game states and rules do not remain fixed? Researching these questions will enable agents that can creatively interact with humans.

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