# Understanding Representation in Playable Simulations

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## ABSTRACT

This paper presents a theory of how simulation games are representational. Through comparison with simple arcade games, the narration of the processes of a game is identified as a key component of interpretation, and from there a vocabulary and an interpretive framework is presented that strives to account for the as much of the simulation as possible (as opposed to particular gameplay sessions). This framework is then applied to produce an interpretation of the classic simulation game *Lemonade Stand*.

## Categories and Subject Descriptors

*K.8.0 [Personal Computing]: General – Games. I.2.4 [Artificial Intelligence]: Knowledge Representation Formalism and Methods – Representations (procedural and rule-based).*

## General Terms

Design, Theory.

## Keywords

Game interpretation, game design, procedural rhetoric.

## 1. INTRODUCTION

On the user generated news and entertainment website Reddit, a user uploaded a story titled "I've been playing the same game of *Civilization II* for almost 10 years. This is the result." In describing the state of his unusual experience with the game he said "The world is a hellish nightmare of suffering and devastation [11]." The article continues on to describe how the game's world is comprised of three factions fighting over resources, which they only use to destroy each other in a perpetual war. In short, the player had discovered a state where *Civilization II* embodied a dark sci-fi dystopia from which, only with the help of Reddit community, the player was able to escape.

Could it then be argued that *Civilization II* is *about* a dismal future? After all, this player's multi-year gameplay experience was dominated by this dark simulation. While this might be a reasonable interpretation based on this particular player's experience, most would agree that this "hellish nightmare" world is not representative of the majority of experiences with *Civilization II*, which often describe the rise to a technological utopia or a happy kingdom.

With such a breadth of possible outcomes, it would seem that in order to speak about *Civilization II*, one would need to account for all of these gameplay experiences. In his work studying the use of *Civilization III* as a teaching aid in schools, Kurt Squire provides such an interpretation by saying that *Civilization II's* sequel has "unique affordances as a world history simulation." He sings the praises of the game by saying "Civilization III represents world history not as a story of colonial domination or western expansion, but as an emergent process arising from overlapping, interrelated factors" [15]. Squire's claim about what *Civilization* accounts for and represents both the dystopian and utopian gameplay experiences by providing an account of the system that generated the experiences as opposed to any specific representation.

Another game that can be interpreted in many ways is *SimCity*. *SimCity* was one of the first games to foreground the idea that videogames can be arguments about "how the world *functions*" and is often considered the canonical simulation game. Playing *SimCity* involves taking actions such as raising taxes, building roads, or choosing where to place a power plant, in order to influence the growth of a simulated city. Over time players develop a sense of which choices create different outcomes and eventually they are able to shape cities with intention. Wardrip-Fruin describes this process where players learn a mental model of the system that governs the outcomes of interaction as the *SimCity Effect* [20].

*SimCity* was able to achieve a level of believability about its subject matter by having complex and deep gameplay, as well as being marketed as a simulation (a term typically reserved for science and public policy). This led to concern that players might accept the claims of the simulation as fact without recognizing the biases and assumptions that underlie the simulation [16]. It has been claimed by those on both the political right and left that *SimCity* ideologically biased [7]. Different understandings of the same media artifact are common, however adding to the interpretive ambiguities that arise with other forms, such as film and literature, any particular player's experience of a simulation is bound to be significantly different than another's. Videogames produce a space of possibilities, and for most, interpretations or understandings of a game will involve particulars of their gameplay session rather than a comprehensive view of what the game affords.

In simple arcade games, the processes and rules that drive gameplay experiences are evident on the surface (e.g. *when A collides with B, B will disappear*). However, in games like *SimCity* and *Civilization*, at any given time, there are many interacting variables that might be argued to have produced an effect. In *SimCity*, when a building becomes abandoned a player might believe that it is because there wasn't a park nearby, or that taxes were too high, or any other number of reasons. In most cases, changes to the game state are influenced by many factors at

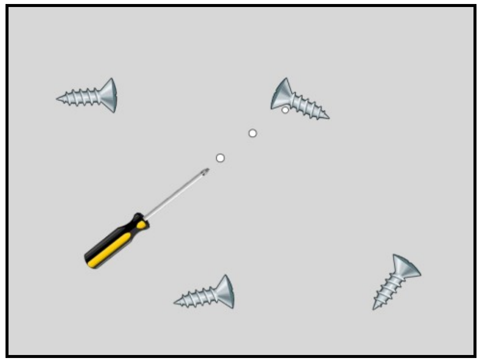

**Figure 1 - A screwdriver shooting white dots at screws might metaphorically represent a screwdriver screwing in screws.**

once. This makes it difficult, if not impossible, to confidently describe the processes of *SimCity* using simple rules about the discrete entities that appear on the screen. Instead, *SimCity* makes use of complex resource management rules where quantities of money, population, and pollution interact to produce results. In other words, the rules of the game are not directly evident to the player.

This paper explores how simulation games can be interpreted as systems that generate representations, rather than particular representations. The paper begins by teasing out a distinction between games that primarily represent through instantial assets and those that represent through simulation. Based on the theoretical foundation, a theory and vocabulary for simulation representation is presented. Next, the theory is illustrated by performing a semi-formal interpretation of *Lemonade Stand*, one of the earliest simulation games.

This paper continues an ongoing investigation into how videogames are representational in ways unique to their medium – through their processes. In previous work, a theory of representation for games involving primarily collision detection and movement was presented that understood a game as a collection of *micro-rhetorics* (patterns of game rules and beliefs about game visuals) [18][19]. This approach was found to be applicable to very simple arcade-style games, and was even robust enough to be implemented into a computational system that could generate games about subjects [17]. Like the representational theory for simple arcade games, the contributions of this paper are intended to lead to the development of a computational model of simulation representation.

## 2. IDENTIFYING THE FOUNDATIONS OF SIMULATION REPRESENTATION

In language of semiotics, the different ways we interpret simple arcade games and simulation games is a matter of which semiotic *codes* the interpreter employs to understand the game's signs. Given the indeterminate nature of a sign, it cannot be said that a signified *must* follow from any signifier. A code is a rule, or convention, that generally tells the interpreter which of the many signifieds to select from the many that are possible. For example, the appearance of a green circle on the screen of an abstract videogame could represent a green apple or a non-diegetic interface element to indicate that the player should start moving (like a form of traffic control) depending on which semiotic codes the interpreter utilizes. Codes are culturally determined and their application is a product of the individual and their beliefs about the rest of the semiotic system. If the player believed they were playing an abstract farming game about collecting food, he might understand the green circle as an apple to collect. But if he believed he was playing a racing game, was not currently moving and carried the cultural association of green with "go," he might understand it as a "green light" that indicates the being of a race. Codes determine which of the many possible interpretations to believe.

Groups of semiotic codes will often be employed in the same contexts and groupings of them have been referred to as *semiotic registers* [8]. Genre conventions often establish which semiotic register an interpreter adopts when encountering a system of signs. Applying this concept to games, Huber describes semiotic registers as "a conceptual entity produced by the player's attempt to understand and successfully play a game by organizing the signs he/she encounters [8]."

The following discussion of two hypothetical segments of gameplay will conceptually develop two registers of videogame signification. The first segment uses a thematically consistent set of visuals but seemingly incoherent mechanics. It will be claimed that it successfully signifies via an *instantial register* which relies on codes that emphasize beliefs about a game's instantial assets. The other will use an arguably incoherent set of visuals and mechanics that are able to represent *despite* the visuals. It will be argued that this segment is able to represent because of a *simulative register* that emphasizes codes about the game's processes.

### 2.1 The Instantial and Simulative Registers

Most classic arcade games can be said to signify in what could be called an *instantial* semiotic register. Understanding a game of the instantial register primarily involves beliefs about instantial assets (visuals, sound, cut scenes, etc.). Often, these games could be understood by just watching gameplay play out, and thus it can be said that the forms of representation in these games bears resemblance to those of static media.

The following description of an odd segment of gameplay will illustrate this point and help lead to the development of a simulative register:

> *A picture of a screwdriver moves around the screen and periodically white circles appear near it and move away along the angle that the screwdriver was facing at the time of the circle's spawning. Also on the screen are pictures of screws which are removed upon collision with a white circle (Figure 1).*


**Figure 2 - An editorial cartoon that makes use of multiple visual tropes.**

Given the history of space "shoot 'em up" style videogames, this might be said to represent a screwdriver *shooting at* and destroying screws. When taken as a literal visual representation, this gameplay segment is nonsensical. However, if select elements are emphasized, the visuals, and others deemphasized, the mechanics, a more sensible interpretation is possible. It could be argued that this segment is be a highly abstract, metaphorical, representation of a screwdriver *screwing in* screws.

This claim is not hard to accept if the game mechanics aren't considered. Screwdrivers are designed to screw in screws and those two entities the only entities in the game world. Even a still picture of a screwdriver and screw might be said to represent, or at least imply, this concept. However, it can also be argued that the mechanics support this interpretation through metaphor. In the details of how this metaphor functions is the distinction between the instantial and simulative registers.

Lakoff and Johnson write "the essence of metaphor is understanding and experiencing one kind of thing in terms of another [10]." Metaphors allow interpreters to transfer the qualities of one concept and apply them to another. As an example, Figure 2 shows an editorial cartoon that makes use of caricature, physical and spatial metaphor, literal signifying images and text to communicate a message about an encroaching and dividing problem of unemployment in the United States. The impending disaster is communicated through the use of a destructive entity, the saw, which is labeled "jobs." This labeling of objects to make a metaphor explicit is an established convention of the editorial cartoon and indirectly communicates using both visual and written signs. A further explanation of how this metaphor functions sheds light on how metaphor applies to the screwdriver and screw gameplay segment.

Peirce's semiotics describes three kinds of signs: iconic, indexical and symbolic. Iconic signs represent because they physically resemble what they stand for. The image of the saw blade is an example of an iconic sign. Indexical signs are those that reliably correlate with what it stands for. Understanding that the saw being behind President Obama represents that he does not anticipate the problem of jobs involves an indexical sign. The saw's placement does not directly visually resemble the image that it signifies, yet it still able to bring to mind concepts that are associated with saws colliding with people because those concepts are directly correlated with saws moving toward people. Symbolic signs are culturally determined signs that map from signifier to signified via convention. Most words are symbolic signs.

Operating as iconic signs, a picture of a saw cutting through a picture of a board will not likely arise any difficulty for an interpreter as most believe that saws can cut through wooden boards, and the image they are considering denotes this belief through visual similarity to their existing beliefs. Without being attached to the saw, the word "jobs" would be shown to be dividing the board, and an interpreter would be forced to confront the unbelievable implication that jobs cut through wood, which would no longer be able to be justified through visual similarity. The interpreter would not likely interpret it as a symbolic sign as the convention of understanding the words "jobs" in this context is not established.

The labeling of the saw with the "jobs" allows us to understand jobs in terms of a saw. Jobs are now understood as being able to cut, destroy and divide. Also through metaphor, the wooden board shaped like the United States that President Obama is standing on, is able to be cut, destroyed and divided. This symmetry between metaphors allows this editorial cartoon to convey a lot of information about abstract concepts in a single image. Metaphors function by attaching one concept, the *tenor*, to another, the *vehicle*. The tenor is the concept which features are ascribed to and the vehicle is the concept from which the features are inherited from [13]. The interpretation of the editorial cartoon described above treats the saw and board as the vehicles, and jobs and the United States as the tenors.

Returning to the screwdriver and the screw, we can use the metaphorical and semiotic language to describe why we might interpret the "screwdriver shoots at screws" mechanics as a representation of it screwing in screws. Unlike the editorial cartoon, where both the tenor and vehicle were visually represented, the gameplay segment as described is made up of visuals and game processes. The claimed interpretation of the screwdriver screwing in the screws becomes possible only by ascribing the metaphorical roles of tenor/vehicle to each of these qualities of the text, despite processes not being *visual*. In this case, the gameplay segment's tenor, the screwdriver and screws, can be said to inherit from a *procedural* vehicle.

A procedural vehicle gets its meaning from the way in which the abstract operation of the processes can be narrated. In describing the meaning of abstract machinery, Agre argues that machines have *narrative affordances* [1]. Similarly, Mateas claims "Every system is doubled, consisting of both a computational and rhetorical machine [12]." The ways in which we can sensibly, or convincingly, narrate the operation of game mechanics is constrained by shape of the computational material and cultural context of the interpreters. In other words, if there is a game mechanic where when A collides with B, B is removed from the screen, it will be unconvincing to narrate the enactment of these mechanics as something that contradicts it. For example, if A was believed to be a human head, and B looked like food, and we attempted to narrate the enactment of the mechanics as the food eating the man, it would be unconvincing as that interpretation would seem to imply that A, the head, is removed from the screen upon collision with B, the food. This is explicitly not the case and can never be the case because of the nature of the code running on the machine. This narration of the abstract processes would be unbelievable.

When we abstract away the visual representations from the screwdriver gameplay segment we have mechanics that can be described by the following game rules: *A spawns C, C moves in a straight line along the vector that A is facing when it is spawned and when C collides with B, B is removed from the screen.* Because it visually appears as though A is producing C, and some event occurs when C collides with B, solely based on this simple narration of the abstract processes, an interpreter might consider the general question "for what purpose might A be producing C in order to act upon B?"

When considered at this level of abstraction, we can now consider how the visuals relate to the mechanics. Given the thematic assignments of A as a screwdriver, B as screws and C as an abstract shape, we can reconsider the question as "for what purpose might a screwdriver act upon a screw?" To this question there is the obvious response of our claimed interpretation that a screwdriver *screws in* a screw. For this interpretation, the role C, the small white circles, plays is to establish through metaphor that A is acting upon B. For this metaphor, the interpretation that the procedural mechanics represent that A is acting upon B serves as the procedural vehicle, and the belief that A and B are screwdrivers and screws serves as the instantial tenor. Thus, screwdrivers metaphorically inherit the quality of acting upon screws.

Admittedly, this metaphor provides a weak, or possibly unconvincing, interpretation. Furthermore, the procedural vehicle that the tenor of the metaphor relies on only relates to the subject matter of screws and screwdrivers in the most general of ways (most things can be said to *act upon* others in some capacity). For this gameplay segment, an interpretation was arrived at mostly through preexisting beliefs about the instantial assets rather than through consideration of the mechanics. While it was able to be argued that the mechanics supported the interpretation, it was only after abstracting the narration of them to a point that almost any two objects could be related by them. In other words, the mechanics were not simulating any *particular* aspects of screwdrivers screwing in screws. The defining characteristics of the instantial register are that interpretations are greatly determined by existing beliefs about a game's instantial assets and processes only relate as metaphorical vehicles at high levels of abstraction.

Below, we will build from this understanding, to develop a *simulative* semiotic register that prioritizes a game's simulation. Consider a hypothetical videogame that represents part of the editorial cartoon described above:

> *The player controls a saw with a labeled with the word "jobs" and is given a goal to collide with wooden boards shaped like the United States. Upon collision, the boards split in half and fade away.*

Like the screwdriver example, this segment of gameplay can be understood using a procedural vehicle and a visual tenor. Even in denotatively describing the visuals that result from the mechanics being enacted, *A collides with B and B is split in half*, it fairly accurately describes what happens when a saw is put to wood. When images that are consistent with the narration of the abstract processes are applied, a stronger coherence is achieved and it seems more likely that an interpreter will arrive at similar conclusion: jobs are dividing the United States. This segment of gameplay is arguably able to represent as clearly as the editorial cartoon because "the elements presented on the surface have analogues within the internal processes and data [20]."

However, even when nonsensical assignments to the gameplay mechanics of A and B are made, this particular set of abstract mechanics still might be argued to represent using a similar metaphor. Consider the same gameplay segment with seemingly nonsensical visuals:

> *The player controls a cupcake and is given a goal to collide with manhole covers. Upon collision, the manhole covers split in half and fade away.*

This game appears to represent that cupcakes divide manhole covers. This statement may be nonsensical, but we still are able to grasp it because of the processes even despite the visuals.

Different than the screwdriver segment, the mechanics lend this segment a more coherent explanation of what it might mean than the instantial assets do. The codes of the simulative register involve taking the operation of the mechanics as particular representations, and beliefs about instantial assets are less essential than, or in this case ornamental to, the processes. Unlike the cupcake example, but demonstrated by the "jobs dividing the United States" gameplay segment, which simultaneously employed both visual and the procedural style metaphors, the simulative register can offer potent representations because the visuals *and* the processes can be understood as iconic signs.

These registers are not exclusive categories and can be said to be operating simultaneously and to different extents for any particular interpretation and segment of gameplay. However, each register demonstrates how types of observations can have varying degrees of significance when interpreting different types of games. Differentiating these two registers helps us pin point exactly how simple arcade games (including many newsgames and artgames) can be said to mean differently (i.e. rely on different semiotic codes) than simulation games.

Of course, the hypothetical examples above offer fringe cases of each of these registers for the purpose of precisely differentiating them. Most games that operate in the instantial register are more sensible than the screwdriver and the screw, and most simulation games are more sensible than the cupcake and the manhole cover. These simple examples can hardly be said to be simulations at all. In fact, the cupcake and the manhole cover might be thought of as the "$0^{th}$ order" simulation game as the process that is being narrated occurs directly in front of the player. Most simulation games have systems of rules that happen outside of the player's view (e.g. the precise effect of pollution in *SimCity* is not directly evident to the player). The cupcake and manhole cover example shows that the line between simulative and instantial representation is blurry.

The following will use these insights about simulation representation to build up to a theory that accounts for how simulations with more complex rules can be said to be about subjects.

# 3. INTERPRETING SIMULATION GAMES

As discussed above, regarding a videogame using the simulative register will involve paying attention to the operations of its processes and narrating, or telling stories about how they work. However, most simulation games are very complex and the operation of their processes cannot be described simply. For example, depending how someone plays a game like *SimCity,* one might walk away believing that the game was advocating for or against mass public transit if it played or didn't play a significant role in the city's growth. Simulation games are able to produce a vast space of possible outcomes, and describing the game as a representation of just one possibility would be to neglect a great deal of what the game can represent. Frasca points out that "…for an external observer, the outcome of a simulation is a narration. But the simulation itself is something bigger than narrative" [6]. However, as of now, the analytical tools for discussing a simulation as opposed to particular narratives are underdeveloped. One of the many problems is that it's not clear at what level of abstraction an interpreter should attempt to describe what the game is about. *How do you talk about what a space of possibilities is about?*

One way to better understand how the simulation operates would be to look to its code or game rules. While this would be the best way to ensure that statements about a game's processes are accurate, accuracy does not necessarily help us understand a player's experience. Furthermore, the running code of a videogame creates a dynamic environment where a space of possible operations is possible. By looking at code and rules, an interpreter is not able to foresee all possible operations in that space. As an extreme example, much of the code base might be devoted to an aspect of the game that the player never sees as they never create the conditions such that the code executes. In addition, code and rules describes a level of detail that can be argued to be *inaccessible* to players. Much like how we do not describe what we do in everyday life in terms of chemical reactions and physics, it doesn't necessarily make sense to describe gameplay in terms of code or rules.

Furthermore, describing a game in terms of its processes does not quite tell us about how it works. This level of explanation may *imply* conclusions about how it is operating, but these conclusions are the result of an act of interpretation.

To comprehensively speak about simulation games, we must have a language that enables us to speak about how they work, without in fact *knowing*. This language should be able to describe a gameplay experience while still accounting for the fact that the experience could have been different. We need a framework that can describe a game as the space of possibilities afforded by the simulation in order to understand how they are vehicles for metaphors. Below, such a framework and vocabulary is developed.

## 3.1 Simulations are Theories

It has been argued that *computer programs are theories* of what they are about. Simon and Newell write "Programs can be regarded as theories, in a completely literal sense, of the corresponding human processes [14]." Johnson-Laird elaborate on this idea in saying "There is a well established list of advantages that programs bring to the theorist: they concentrate the mind marvelously; they transform mysticism into information processing, forcing the theorist to make intuitions explicit and to translate vague terminology into concrete proposals... [9]" As computer programs themselves, simulation games can be thought of as theories of their subject matter.

Bogost states "Video games are models of real and imagined systems... when we play, we explore the possibility space of a set of rules—we learn to understand and evaluate a game's meaning [3]." Inside a game like *SimCity*, its set of rules largely determines what the game is able to represent about how public policy decisions determine the health and population of a city. These rules may have been developed to create fun and engaging gameplay, rather than to provide an accurate model of urban planning, but nonetheless it can be argued that the model can still be persuasive and shape the way players understand the world. Frasca argues that simulations are hardly neutral playing grounds where any outcome is possible and that they necessarily privilege ways of playing by design [6].

Bogost describes the theory a game embodies as a game's *procedural rhetoric* – "assembling rules together to describe the function of systems produces procedural representation, assembling particular rules that suggest a particular function of a particular system characterizes procedural rhetoric [3]." In discussing the procedural rhetoric of his *Take Back Illinois*, a game created about a political race, Bogost argues, "In playing the game, the player is not 'brainwashed' or otherwise fooled into adopting the candidates' policy position. Rather he is afforded an understanding of that position for further inquiry, agreement, or disapproval [3]." Bogost describes the *simulation gap* as the conceptual space between the player's existing mental model about what a game is about and the player's interpretation of how the game itself operates. He argues that the act of performing this comparison, exploring the simulation gap, can be educational and is one of the greatest strengths of the videogame medium [2].

## 3.2 Instances and Principles

Based on the above insights, we can now present a framework for simulation representation. Borrowing from philosophy, and emphasizing the concrete nature of a game's processes, the concept of *principles* can describe what shapes a game's theory (or procedural rhetoric). Principles are the player's perception of the general truths that serve as the foundations for how a videogame generates representations of how things function. A principle of a videogame involves both its computational structure and commitments about what those processes are about. What a game is generally about is mutually determined by both a game's instantial assets and the narrative affordances of its processes as illustrated in the analyses above.

Discovering principles of a videogame necessitates the consideration and interpretation of different aspects of the artifact than when considering static media, and the previously discussed simple games of the instantial register. Where most other media can be understood as single static narratives, videogames *generate* many narratives [6]. Understanding a game's principles does not only involve understanding what happened in a play session but also what *could* have happened. Discovering a game's principles can be difficult as players do not have direct access to the structure of the simulation. Access is limited to the individual generated narratives, or *instances*, that the simulation affords. An instance is defined as a static gameplay experience, or in Frasca's language, a particular narrative about gameplay. Interpreters construct principles through the interpretive generalization of instances.

Crawford argues that "the best measure of the success of a game is that the player learns the principles behind the game" [4]. Elsewhere, he describes a framework for how interactive systems operate and players earn this understanding: the listen/think/speak loop [5]. A system *listens* to player input, *thinks* about how this input changes its state, and then *speaks* about the new state to the player. Players also enact a listen/think/speak loop when engaging with interactive systems. A player observes the system's output (listens), considers the space of possible actions (thinks), and then chooses and performs some action (speaks). Note how a principle is not solely the system's *think* part of the loop. A principle involves commitments about what is being represented (which is not present in the computer code) and its recognition is influenced by an individual's personal history and cultural context.

An instance encompasses an interpretation resulting from one pass through this loop that begins with the system's expression of its state and ends with the player's consideration of the new state. Many instances can be in process at any point in time, and it is not the case that every pass through the loop comprises an instance. Only those cycles of interaction that are found to be significant are interpreted and considered. In other words, an instance is a moment of reflection about a segment of gameplay. By iteratively considering the relationship between the player's action, motivations, and how the system responded to the action, the player begins to construct interpretations of the videogame's principles. An instance can either support or distract from a principle. Wardrip-Fruin's concept of the *SimCity Effect* relates: "Successful play requires understanding how initial expectation differs from system operation, incrementally building a model of the system's internal processes based on experimentation" [20]. Of course, an instance that distracts an interpretive hypothesis doesn't necessarily invalidate it. With humanistic interpretation, an interpreter may or may not be wholly consistent.

## 3.3 Conclusions

Given a set of principles, the interpreter will make *conclusions* about what a game is representing. In this context, a conclusion is a generalization about what the system tends to represent. For example, after playing *September 12$^{th}$*, a game in which players target a Middle Eastern city with missiles intended to kill terrorists, for some time the city will most likely be destroyed and filled with a much higher number of terrorists and a much higher terrorist to civilian ratio. An example of a principle of *September 12$^{th}$* is that terrorists are born from civilian deaths and a conclusion could be that *September 12$^{th}$* represents a critique of the bombing of foreign nations and implies a simple solution - to stop.

If an interpreter is dissatisfied with a conclusion, his critique may take to task a principle that led to it. For example, one might argue that the terrorist to civilian ratio in *September 12$^{th}$* does not accurately represent how actual people become terrorists. This is an example of the simulation gap that exists between player's beliefs about the real world and what they perceive the game as representing.

In summary, the simulative register regards the ways that a game's operation can be narrated as salient material for interpretation. Through experimentation and grouping gameplay instances, the player constructs generalities about how the system operates, and these are called the principles of the game. These principles become the vehicles of metaphors that drive the interpretation, and ultimately provide the material that constitutes an interpretation. Finally, conclusions about what the system tends to output/represent can be asserted.

# 4. INTERPRETING LEMONADE STAND

Using the above insight that simulation games are best understood by narrating their processes and regarding these as metaphorically representational, and the framework of understanding a game in terms of its principles, this section will analyze the classic computer game *Lemonade Stand* (1979).

Gameplay in *Lemonade Stand* involves running a small business while trying to maximize profits. In the early versions of the game, as discussed here, given a weather forecast, the player chooses how many glasses of lemonade to make, how much to charge for the beverage and how many signs to buy for advertising. After these choices are made, the player is presented with a report of how many sales were made and how this affected the stand's financial standing. After this, the player is given the next day's weather forecast, and chooses again how many lemons and signs to buy and how much to charge for each glass of lemonade (Figure 3).

In every simulated day, players of *Lemonade Stand* are confronted with choices about how much of their assets to invest into that day and in what way. Each day can be considered an instance of the simulation as the game's design suggests that each day the player ought to pause and reflect upon what has happened. For example, on a sunny day, the player might choose to charge a very low price, with no signs for advertising and all of the glasses might sell. Note how *Lemonade Stand* provides a particularly clean example of instances where other games, such as *SimCity*, do not

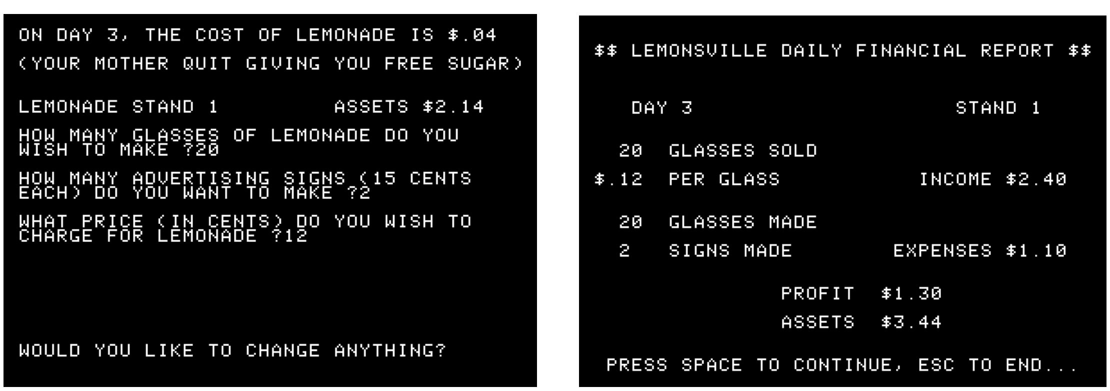


**Figure 3 - In *Lemonade Stand*, players choose how much lemonade to make, how much advertising to buy and how much to charge (left) and then see how the day's sales went.**

have such clearly delineated instances.

With *Lemonade Stand*, a day, or instance, where the weather was cloudy, given the same price and number of glasses, none of the glasses would sell. Based solely on these two instances, the player could interpret a principle of *Lemonade Stand* through a generalization of these observations: *ceteris paribus*, sunny weather encourages and cloudy weather discourages the sale of lemonade. In terms of the simulative register, this belief stands on a metaphor that people and lemonade, the instantial tenors, operate according to the processes that would have people buy more lemonade when the weather is sunny and less when it is cloudy, the procedural vehicle.

Note how as described, this principle is too general to describe *how much* more or less people want to purchase lemonade based on the weather. For instance, where on a sunny day a whole stock of ten glasses of lemonade might sell and on a cloudy day only three would, given a different stock size of twenty glasses, twelve might still on the sunny day, where four might sell on the cloudy day. The exact relationship is hidden in the code, to which the player does not have direct access. To reiterate an earlier point, the reason for speaking about the representations of a simulation game at the level of generalized principles, as opposed to particular descriptions, or instances, is that the relationship between weather and how much lemonade might sell is dynamic. An assumption of this interpretation framework is to speak about the system as a whole as much as possible.

*Lemonade Stand* is an interesting example as most of the simulation's variables appear to be directly visible to the player: the number of glasses made, the price, the number of advertising signs made and the weather. *Ceteris paribus* claims, like that about the influence of weather, can be made about each of these variables after performing simple experiments. For example, through comparing two instances where the player charged a high price for the beverage and another where a low price was charged, it will be found that more glasses of lemonade will tend to be sold as the price decreases.

While these sorts of claims help understand specifically what the simulation is claiming about people and how they purchase lemonade, simulation games can also be claimed to represent more general principles. For instance, *Lemonade Stand* involves constantly trying to maximize profits and minimize costs. The player doesn't want to make more glasses of lemonade than will sell, and doesn't want to buy more advertising signs than are necessary to attract customers. Furthermore, the player wants to sell all the glasses made, but wants to do so at the highest price possible. This relationship describes almost exactly a core introductory concept in economics: the laws of supply and demand. Thus, the game can be said to be representations of those ideas. For this reason, *Lemonade Stand* is commonly used in classrooms to introduce economics. Whatever the exact processes that compute the results of the day, adopting the general principles of supply and demand as the way to understand, or narrate, the simulation will consistently match the output of the simulation.

By identifying these principles of the simulation, other concepts from economics become relevant to the discussion of what the game represents. It can be said that what the player is constantly trying to do is achieve *equilibrium* – the state where both supply and demand are equal. Demand in *Lemonade Stand* is influenced by the weather, price and amount of advertising and supply is specified by the player in terms of the number of glasses of lemonade that are made. The player must try to avoid excess supply – where price is set too high and not all glasses of lemonade are sold – and excess demand – where price is set too low and all glasses are sold. Because demand is a function of three variables, two of which the player is in control of, another task is to determine the most efficient way to create demand. More specifically, the player needs to determine whether advertising or lower prices will attract more customers in various weather conditions. In this way, *Lemonade Stand* is a game about learning to understand the principles of supply and demand. These principles exist through the narration of the processes that *Lemonade Stand* creates through the structure of its simulation.

After identifying the economic principles at play in Lemonade Stand, an interpreter can draw various conclusions based on whether the representations match preexisting ideas about the subject matter, or simply to draw conclusions about what situations the generative principles will tend to create. For example, one could claim that *Lemonade Stand*, by reducing customer's willingness to purchase lemonade to weather, price and advertising, oversimplifies how market choices are made. Specifically, one might argue that reputation plays a key role that is not addressed in the simulation (later versions of *Lemonade Stand* do incorporate this dimension). One might also conclude, after being unsuccessful at creating profit, that *Lemonade Stand* is

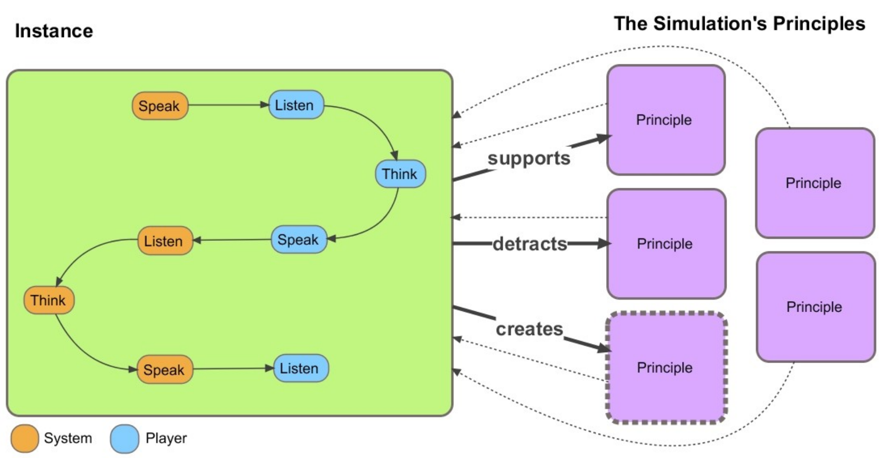


**Figure 4 - A summary of how principles can be generated from an instance.**

a cautionary message to avoid the stress of entrepreneurship in a cut throat world. On the flip side, one might critique *Lemonade Stand* for neglecting the subtle political and socio-cultural factors that influence the success or failure of a business, and claim that *Lemonade Stand* offers an overly optimistic view of how one might become economically successful. The conclusions that can be drawn from a simulation game are many and varied.

## 5. CONCLUSION

Understanding what a simulation game represents involves understanding how the game's processes function. Different than other media, interpreting a simulation game requires regarding the game's processes as first class representational entities. Through metaphor, the processes act as vehicles from which attributes, or narrations of the processes, are ascribed to the subject matter (typically represented by instantial assets).

Because a simulation generates many narrations, or instances, interpretive generalizations about the processes are required. These generalizations can be described as the game's principles. The principles of a simulation can take varying forms of generality, and can range from very specific descriptions of how the processes function, to general tendencies that arise from the specifics. However, principles cannot describe exactly how a simulation operates, as the code of the system is never revealed to the player through gameplay. Based on principles, an interpreter can make evaluations, or draw conclusions about what the principles tend to represent.

We believe that this sort of deep investigation into humanistic interpretation provides insights and domain knowledge to enable the creation of experimental game technologies and playable experiences. As evidence for this claim, previous work investigating theories of representation for simple arcade games [18][19] led to the creation of *Game-O-Matic* – a videogame generation system that enables non-experts to create games about ideas [17].

This theory of simulation representation suggests future work where the theory is implemented as a computational system. For each game, a formal definition of what comprises an instance would need to be specified. In *Lemonade Stand* an instance would be the information a single day in the game. From there, during gameplay a library of authored interpretation rules that reason over features of the instances and the established principles would be used to build a set of principles. Each rule could create a principle or support or detract from existing principles (figure 4).

This study is a step toward deeply understanding how simulation games can be representational. It is hoped that this detailed theory and vocabulary for how simulation games are representational will help enable the creation and evaluation of simulation games about complex topics.

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