Modeling Interactive Intelligences

Luis O. Arata
Department of Fine Arts, Languages, and Philosophy
Quinnipiac University
Hamden, CT 06518

ABSTRACT

This paper explores modeling the adaptive mechanisms of autonomous agents. The focus is on reflexive interaction as a looping action that creates a "self."

Imitation and play are adaptive components of reflexive interactions that can provide gradual modifications of the agent's self. Little by little, the autonomous agent reinforces what seems to work and phases out other options through an internal editing process.

A performance metrics for reflexive interaction would have to depend on the task at hand within a context, rather than try to be an absolute measure. Evaluation of performance has to be flexible enough to account for multiple intelligences especially when innovation is possible.

KEYWORDS: ***reflexive interaction, open loops, modeling, play.***

INTRODUCTION

This paper explores modeling the adaptive mechanisms of autonomous agents. The focus is on reflexive interaction, which is the making of open loops that combine feedback and feedforward capabilities to interact dynamically with the environment.

Feedback and feedforward can be seen as reaction and proaction, as sensing and probing. An agent that can loop effectively the work of its sensors, probes, and tools would then have the capacity to interact reflexively with its environment. The agent's mechanism of reflexive interaction constitutes a "self."

The agent's looping action creates internal maps to translate interactions and compare them continuously to previous ones stored in its memory in order to adapt to changes. Imitation and play are components of reflexive interactions that can provide gradual modifications to the internal maps of the self in adaptive systems. The mapping process itself can be compared to the writing and editing of a text, where grammar, data, and ideas interact to form an effective map. Little by little, the autonomous agent reinforces what seems to work and phases out other options through an internal editing process.

To explore reflexive interaction, I begin with a presentation of how Rodolfo Llinás describes mapping, and Gerald Edelman's related concepts of reentry and binding. Next, I rely on Jean Piaget's model of adaptation in order to examine the function of imitation and play in an autonomous agent. These concepts come together in the model of the self that Rodolfo Llinás developed as a device that situates the agent in an environment and helps it navigate safely. Finally, I look at mobility of a reflexive agent fueled by two factors: an external changing environment and internal changes that motivate the agent to drift into what Stuart Kauffman calls the adjacent possible.

A performance metrics for reflexive interaction would have to depend on the task at hand within a context, rather than try to be an absolute measure. Evaluation of performance has to be flexible enough to account for multiple intelligences. It should not limit the freedom to develop diverse approaches in the making of agents as well as in the way agents carry out tasks especially when innovation is possible.

1. REFLEXIVE INTERACTIONS

When an autonomous agent performs tasks in an environment, change can happen to both the environment and the agent. This process of mutual change is an interaction [1]. Interaction, rather than action upon objects, complicates the dynamics of a task but it does help model more closely how events happen in the real world, so to speak.

Next, we note that interactions form a link that can create a circulation or a loop between the linked parts. This is reflexivity. The performance of an autonomous agent is affected by its ability to reflect as it interacts.

Two questions then come up. How does reflexivity work to enhance the agent's ability to perform a task? And how could this reflexivity be gauged so that it may be fine tuned with respect to tasks?

In *I of the Vortex*, Rodolfo Llinás develops a fascinating model of the self, based on interactive feedback and feedforward loops. He begins with a view of the brain as a system that does isomorphic sensory-motor transformations of the outside world. This creates representations that help the body act in the outside world.

Llinás then follows the lessons of the sea squirt. This tiny sea creature has mobile state followed by a plant-like one. During the first phase, it has a brain. But when it finally attaches itself to a surface, the sea squirt digests its own brain along with the tail that provided motility. Llinás concludes that "the evolutionary development of a nervous system is an exclusive property of actively moving creatures" [2]. The nervous system and particularly the brain are predictive instruments that allow the organism to move more safely in search of food, often in a potentially hostile environment. The brain creates working models of the environment to give the body interactive navigational capabilities. Llinás imagines that such models are very much dreams of our brain, and in the waking state those dreams are guided and shaped by the senses: "the fact is that we are basically dreaming machines that construct virtual models of the real world." In effect, what we perceive is a virtual world.

The sense of self emerges from interactions in the brain as it coordinates actions. The self is an avatar of sorts within the brain's representation of the world. Our actions follow the displacements of the avatar in the brain's maps of the environment mediated by the senses. In actual dreams, when the senses are dormant, the self moves through a recreated world made of collages of memories patched through internal logics.

Sensations, including the elusive self-awareness, are what reflexive loops feel like in order to help us navigate. Pain and pleasure are guiding sensations. Self-awareness is perhaps the most complex manifestation of this cybernetic system.

In *A Universe of Consciousness*, Edelman describes a reflexive mechanism at work in our own consciousness. It is a signaling process that takes place along reciprocal connections. He calls it "reentry." Edelman sees reentry as the key mechanism that binds all our cognitive mechanisms into a cohesive self. He considers this massively parallel function to be the uniquely distinguishing feature of higher brains. But rather than use reentry as a feature that differentiates higher from lower brains, whatever that could be, we can assume that reentry is to varying degrees a feature of any brain. This feature then can help in the more general modeling of reflexive interaction.

Reflexive neural interaction works within the complex topologies of our brain to create the sense of self out of weaving memories. Edelman suggests that memory is creative rather than replicative: “every act of memory is, to some degree, an act of imagination” [3]. Memory for Edelman is a pragmatic process that always remembers in and from the present. It is simply the ability of an agent to repeat or suppress an action. This ability seems to be at the heart of the sense of self.

When we weave together the work of Llinás and Edelman, we get a rich model of the form and function of the self. According to their combined views, then, it is the reflexivity of the self that would allow autonomous agents to carry out tasks.

The question of gauging and fine-tuning reflexivity with respect to tasks is more complicated conceptually. Llinás speculates that our sense of self and what could be called “intelligence” may well be an emergent property of how our brain wired itself as a navigational tool. He concludes that there are many possible architectures for cognition. Ours does not have to be the only one. In this case, the evaluation of intelligence may have to be done with respect to each separate architecture. In other words, there are multiple intelligences. In this case, Howard Gardner has shown that we cannot have a single measure for all of them. He believes that the notion of assessment has to be reinvented and suggests using simulations to gauge how individuals perform in more realistic and diversified situations rather than using standardized metrics for all intelligences [4]. This implies that for gauging the performance of autonomous agents with respect to realistic tasks, simulations rather than metrics should be used.

2. ADAPTATION, SELECTION, IMITATION, AND PLAY

Piaget presented adaptive behavior as a combination of accommodation and assimilation. Pure accommodation is imitation [5]. Pure assimilation is play. In accommodation, the individual seeks to copy a situation that calls for adaptation and changes following the rules of the external situation. In assimilation, the individual plays with the situation and tries changes it in order to embrace it. In other words, in imitation the individual tends to change the most in the process of copying, representing, or following external imperatives. In play, the person jiggles the external situation and changes it in order to absorb it. Piaget indicated that adaptation involves varying combination of those two extremes.

A key virtue of Piaget’s model is that it incorporates naturally the function of play. Imitation has received plenty of attention, but play tends to be underestimated or ignored altogether. Yet it is a key element in agent autonomy, interaction, and development.

A question then comes up. How do imitation and play help stimulate reflexivity in agents?

Play involves a reconfiguration of elements being assimilated. This means that there is a certain metamorphosis at work with the play elements. They are rearranged until something happens. This interaction produces a new meaningful weaving, a new order, a variation, or what could even be seen from the vantage point of a previous order as imperfection or error within the new configuration. But this imperfection becomes innovation when seen from the reconfigured perspective. Such is the creative work of play.

It is important to recognize at this point that adaptation or selection in nature do not yield an exclusive match between the selected agent and the environment. Adaptation does not produce a fittest agent. Edelman has noted that selectional or adaptive systems share a remarkable property: they can use many structurally different ways to achieve similar results. He gave this property the unfortunate name of “degeneracy.” We can call it diversification. In evolutionary terms, nature seems to play out all possibilities that yield viable results. Nature tends to favor multiple adaptive solutions. Play is what helps us try out all possibilities. Play is an engine of diversification. Its presence in Piaget's model of adaptation favors the use of multiple points of view or different approaches in the construction of autonomous agents for a given task.

Returning to the relation between play and reflexive interaction, we see that play with its tendency for overflowing boundaries, testing constraints, and diversifying, tends to excite the agent so that it has to constantly readapt. This exercises reflexivity.

But play can make or break an agent. Play needs to be bounded somehow so that it allows the agent to exercise its reflexivity without pushing it past a breaking point.

Imitation, on the other hand, is linked with representation. This helps the agent map its environment in connection with given tasks. We need to distinguish, however, between copying structures imitated, and transforming them into maps based on the agent's system of representation. Imitation for autonomous agents is then a transformation and a translation from something perceived outside of the agent to something inside the agent that allows it to interact more effectively with what is perceived. Imitation makes maps that are webs of memories. The sense of memory is the one we saw before based on Edelman's view. It is non-representational. Woven memories, although not a copy of what is perceived, do evoke it in a functional way. The agent uses the map of memories to help with navigation, placing itself in it.

We can take a closer look at the form and function of play in a created autonomous agent. How would it work? Could play have a purpose? First of all, it is important to recognize that play is interactive. It does not rest entirely on the side of the player. The player needs a partner. That partner is outside the player. This is perhaps the single most reason why play has been mostly overlooked before in its cognitive function. It has not been noticed that there is play in the environment. Natural environments give us room to play. They invite play. That may be why children play. As adults we tend to play less because we need to function in created structures that are often set in their ways and restrict play. These created structures lack the flexibility of natural environments. Our constructed environments do not allow for play, unless they are playgrounds or have been designated as toys. Our non-artistic creations come with built-in purposes. Deviations from expected uses are usually not welcomed.

How could play enter into autonomous agent design? What enhancement of the agent could it bring about? To think about play in relation to created autonomous agents we need to have an uncertain environment to begin with. If everything in the environment is determined, if rules of operation are fixed, if goals are absolute, then there is no room to play. But if rather than goals we think of tasks, if the journey is at least as important as the destination, and if the environment has the potential for surprises, then we can think about play.

Surprise is the order of the day in laboratories, for example. It is unfortunate that theorist shun Murphy's laws. Can a created autonomous agent also play when given a task in an uncertain environment? How can we design it with that type of intelligence? How do we gauge the ludic capabilities of an agent? The introduction of flexibility into designs is a first step. It is a passive response to play. The next step is to design agents that can assimilate as they play. I think we don't even have preliminary solutions modeled after these questions because play has hardly been a factor in design. But we can make some observations.

First of all, the agent has to be able to alter rules. Secondly, the agent has to have tools that can be used in unintended ways. Let's consider now Piaget's sense of play as assimilation of the environment to the individual's existing structures. For an agent, those structures have to be open, flexible, so that they can interact in unexpected ways. Secondly, the agent's tasks have to be defined in fuzzy terms so that there is room to play. Perhaps finally, operating rules can be allowed to yield new tentative combinations that could yield unexpected results. The original rules should not be discarded as new ones emerge. They all go into a widening repertory of behaviors and models.

We can say then that the agent learns through play about its own system and about the environment. Assessment of the ludic side of an agent could then be linked to the quality of what it learns with respect to very broadly specified tasks. Contrary to what is often said, play does have a non-trivial function. In a created autonomous agent this function could be the performance of self-motivated activities in an environment that invites tinkering and exploration. This generates discovery and learning new ways.

The value of play is well understood in the arts. An actor plays a role because there is room for interpretation and self-expression that can yield surprise and improve the performance as gauged by audience response. Salvador Dalí used to say that to innovate one must first master previous techniques. When we play with techniques and tools using pre-existing knowledge, then something new can emerge within that set of elements. Picasso liked to point out that painting wins in the end—not the painter. This underscores that the agent at play cannot have full control of the actions. The agent opens up and exposes itself to the environment to invite the unknown in and play with it. The writer Annie Dillard perhaps summed this best by observing that the art object "is a cognitive instrument which presents to us, in a stilled and enduring context, a model of previously unarticulated or unavailable relationships among ideas and materials" [6].

Perhaps we can use more effectively as a model for created agents Llinás' conclusion that we are dreams guided by the senses. The construction of the agent's self has to incorporate internal reflexivity. It has to allow somehow for self-creation using Piaget's sense of assimilation. Play allows created agents to have autonomy in uncertain environments. The internal structure of the agent has to be able to learn from such play and place in memory what it considers valuable. An agent's cognitive structure can be designed so that it recognizes new objects by playing with them to detect actions associated with the object and turning such associations into usable knowledge. Play, then, is a feedforward interactive behavior: it tests and tags new objects through tinkering. It has a quick trial-and-error component that can probe the environment and see what fits the agent's tasks and behaviors. Play can be seen as a form of communication with the uncertain and the unknown.

3. DISPLACEMENTS

Finally, I would like to touch upon issues of agent displacement as they relate to play. What self-motivates autonomous agents move or change? Conversely, what would prevent autonomous agents from drifting away from preset tasks? Since we are focusing on autonomy, we can exclude direct external influences such as instructions given periodically to the agent, or built-in engines.

We can imagine that two factors may affect autonomous agents. One is passive and due to the change of the external environment because this would tend to affect the agent's functioning. The other is internal change that comes about as the agent interacts in new ways with the environment. This second factor may be active if it becomes entangled with the agent's sense of self and the agent feels in control of changes.

Stuart Kauffman proposed in *Investigations* that biospheres are constantly reorganizing and innovating [7]. He noted that within this uncertain environment, autonomous agents have the tendency to propagate their systems of organization into adjacent possibilities, and create new order. Of course, such displacements and interactions would affect to some degree the agent's internal systems. The broad implication is that nature may be constructing itself through the interactions of autonomous agents. But Kauffman is not suggesting that an evolutionary vector is at work here. This process of creation is a natural drift, as Francisco Varela once proposed [8]. We can see it as the result of play from the part of agents.

Nature seems to go for viability rather than optimization. This may well be because in a complex environment it is simply impossible to optimize, particularly when there is interaction between guests and host. The way to proceed is to diversify viable options in a given environment and let them evolve. This is where the function of play becomes critical: it stimulates diversification. From a design perspective, we can call this multiple modeling. This agrees with what Llinás indicated for cognitive systems: they can have many possible architectures.

The difference between evolution and drift may well be mostly a matter of perspective. As Varela noted, Darwinian evolution favors optimization, whereas natural drift calls only for viability. But viability becomes optimization when selection criteria become so stringent that there is only one option left in the end. For practical purposes, it is better to require the less stringent test of viability. This gives the agent more room to play. Optimization needs a clear definition of a landscape in the first place, which in a natural environment is a daunting if not impossible task. Viability does not. It is self-testing, so to speak.

This suggests that performance evaluations of autonomous agents in a natural environment or any other environment subject to unpredictable changes should be based on viability rather than optimization. One possibility is to gauge the quality of play by the number of viable solutions that an agent can produce for a given task in an environment. Control or enhancement of the agent's displacements may affect its performance. Running models to tweak their parameters may help gauge such displacements and fine-tune them for specific tasks. Play control would require building boundaries that focus and restrict interactions, as well as insulate the agent from external changes. Play enhancements would come about by opening boundaries to give the agent more freedom in certain chosen directions.

Play then fuels reflexive interactions between the agent and its environment, as well as between the agent's self and its maps. These mechanisms can help the autonomous agent adapt to an environment to carry out tasks that yield viable behaviors and outcomes.

4. REFERENCES

[1] Arata, Luis O. "Reflections about Interactivity," 1999. Internet location: http://media-in-transition.mit.edu/articles/index arata.html.

[2] Llinás, Rodolfo. *I of the Vortex: From Neurons to Self*. Cambridge: MIT Press, 2001. P. 17.

[3] Edelman, Gerald M. and Giulio Tononi. *A Universe of Consciousness: How Matter Becomes Imagination*. New York: Basic Books, 2000. P. 101.

[4] Gardner, Howard. *Intelligences Reframed: Multiple Intelligences for the 21st Century*. New York: Basic Books, 1999. P. 207-10.

[5] Piaget, Jean. *Play, Dreams, and Imitation in Childhood*. New York: Norton, 1962.

[6] Dillard, Annie. *Living by Fiction*. New York: Harper & Row, 1982. P. 184.

[7] Kauffman, Stuart. *Investigations*. New York: Oxford, 2000.

[8] Varela, Francisco, Evan Thompson, and Eleanor Rosch. *The Embodied Mind*. Cambridge: MIT Press, 1991.