Agents as Actors

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1. Introduction

The purpose of this paper is to present empirically founded ideas as to the structure and design of agents that can enact interesting narratives. The paper starts with some basic assumptions about behaviors[1]. Section 3 summarizes descriptions of behaviors that can count as a part of an everyday course of event. Such behaviors, however, are often boring, and they are only the raw material out of which narratives are built. Telling stories involves other technicques concerning the presentation of the behaviors to the spectator, which includes structuring the behaviors, directing how they are enacted and deciding what the agents look like. These techniques are described in Section 4. Finally Section 5 assembles the ideas in a loose sketch for an agent design.

In contrast to most research on autonomous agents that is informed by biology and ethology, this paper mainly draws on literature, film, animation, theatre and language theory, which is a natural choice if the agent is to perform interesting actions, i.e. not only being an *agent* but also an *actor*.

2. What are behaviors?

The main point in this section is that behaviors are social units: they are classified and segmented parts of a continuous flow of actions, and the classification is based on some sign system.

The discrete behaviors can be said to be enacted by continuous actions: they are realized as continuous trajectories. When we move, our limbs do not

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[1] Since other papers in this section belong to robotics, we shall use the concepts from this field. In robotics, an *action* is a concrete continuous change of the robot's actuators, whereas a *behavior* is something that causes one or more actions to occur. The reader should be aware that most of the authors quoted in this paper would use *action* instead of *behavior*, and vice versa. We shall sometimes say that behaviors are *enacted* via actions.

abruptly jump from one position to another, but must smoothly run through all intermediate positions, and when we talk, the tongue and lips must move smoothly too. However, often these trajectories do neither contain objective boundaries, nor are there objective features that clearly distinguish one trajectory from another. Consider for example a case where a piece of paper moves from the hand to the floor.

We can say that *he lost the paper* or that *he dropped it.* We describe the same physical action but assign it to two rather different classes of behaviors. In the former case, the event was involuntarily, and he cannot be blamed. In the latter case, it was on purpose, and we can say that the loss was his fault.

Therefore, behaviors are enacted as continuous trajectories that are *articulated*[2] via some sign-system, for example a natural language, and thereby made discrete. *Communicative behaviors*[3] are specialized to accomplish this process. We have to take this into account in agents if they are to tell other agents, including the audience, about their own and other agent's actions, and if they are to enact requests from other actors, and promises issued by themselves. Such events are necessary in any interesting story, and the faculty to handle the continuous/discrete dichotomy must therefore be basic in agent design.

The position is thus the nominalistic one, that behaviors are different if we describe them as different, so our position lies within the *use-perspective* on agents as defined in Mogensen's paper in this volume. An agent is autonomous if an observer interprets it as such. However, as in books and movies, the experience is produced when observers interact with the artifact, and the structure of the artifact therefore is important too. There is a difference between the experiences afforded by Donald Duck and Shakespeare, and it therefore makes sense to make qualified guesses as to which architecture can produce which experiences, which lands us in the *construction perspective* in Section 5.

The occurrence of communicative events simultaneously induces discrete boundaries into themselves and in the actions they communicate about.

On the one hand, the movements of tongue and lips are segmented and classified by our phonemic system so that one position of the tongue is heard as an /i/, and another one as /e/. This distinction has been known for a hundred years as the distinction between "emic" and "etic" descriptions, e.g. phonemics versus phonetics.

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[2] We use the word "articulation" in the semiotic sense where it simply means converting continuous phenomena into discrete ones. The manner in which this happens is left unspecified, and does not imply a conscious effort.

[3] The term "communicative behavior" is normally called "communicative acts" or "speech acts" in linguistics.

On the other hand, non-communicative behaviors are subject to the same dichotomy in so far as they are controlled by communicative behaviors. Although our limbs move continuously, conscious and planned movement is controlled by verbal descriptions that segment and classify our actions. For example, a part of a certain continuous movement may be classified by the sentence “He is driving towards the parking lot while avoiding the heavy traffic”. This is a classification, since it rules out other descriptions, such as “He is driving home”. It is also a segmentation, since the behavior ends when the car has stopped. What happens thereafter cannot be called “He is driving towards the parking lot” but “He is heading for the supermarket”.

All behavior can to some degree be controlled or analyzed by discrete representations. People can request other people to do something (including saying something), they can discuss plans and execute them afterwards, and plans can be criticized (“This is not the way to the parking lot”).

However, the exact relation between discrete and continuous aspects is not clear. Early AI believed that behavior should be fully specified by formal representations but the idea did not have very much success and seems counterintuitive. We do not seem to verbalize all aspects of our actions.

A more realistic idea is to view plans as constraints or resources that influence already running continuous action. There is an already ongoing bodily activity, and what plans do is to *perturb* this activity in various ways.

This approach is taken in many computer games, especially in real time strategy games, where activity proceeds in a certain direction, until the player makes a change in the world, which invokes new behaviors. This can happen through direct orders to characters or by modification of the environment, e.g. by building a new house.

Apart from constraining already occurring continuous processes, discrete representations can to some degree live a life of their own, i.e. discrete representations can influence other discrete representations. This is what happens when we plan and reason logically. It may not be an innate faculty, but it certainly can be learned.

The main point, however, is that that the concept of behaviors does not make sense without some sign system that can segment the continuous stream of actions. This is the guiding principle in the next sections.

3. How are behaviors structured?

From this assumption it follows that all behavior has a discrete and a continuous aspect.

The *discrete* aspect of verbal behavior has been the main focus of linguistics in this century in two ways: one the one hand, the structure of the verbal behavior itself (the structure of the signifier) was articulated into units such as *distinctive feature, phoneme, phrase, sentence*; on the other hand, the structure of the behavior referred to was captured in terms such *as seme, sememe, semantic component, semantic field.* Most modern descriptive systems in grammar are of algebraic nature and focus on the discrete aspect of language (Van Valin & Lapolla 1997).

The *continuous* aspect — how to produce coherent and relevant sequences of sounds in real time — was for a long time banned from linguistics proper, and relegated to language psychology under the headings of discourse- and sentence plans, articulatory programs, etc. (Clark & Clark 1977: 223 ff.).

Now, not all behaviors are normally used to signify something, but (almost) all behavior can be signified, i.e. we can talk about almost all behavior (although it does not follow that we ordinarily do that or that any behavior can be discussed with anybody. Only cyclists can discuss the art of bicycling). In its role as something we talk about, i.e. in its role as *signified*, all behaviors exhibit the discrete/continuous dichotomy.

In the following we shall give an overview of research in the structure of behaviors. Section 3.7 summarizes the findings. We use the Bouncy-agent in the paper by Pirjan, Madsen and Granum to exemplify the concepts where possible.

3.1. Componential analysis and AI

The discrete aspect is treated by componential semantics and lexicography (see e.g. Goddard 1998). By analyzing co-occurrence restrictions and conducting tests on native language users, it is possible to analyze the meaning of words and sentences into smaller units of meaning. Some schools assume that there is a finite collection of building blocks out of which the meaning of all languages in the world can be constructed (Goddard 1998). For example, the meaning of *to* and *from* can be analyzed as

(1) X moved from A to B =
X moved for some time

> Before this X was somewhere (place-A)
> After this X was somewhere else (place-B).
> (Goddard 1998: 202).

Here *move, time, some, before, after, place* are assumed to be primitive. Early AI-planners were built on this type of discrete componential analysis. For example, the STRIPS formalism (Fikes & Nilsson 1971) contains three types of lists, *Condition-lists, Add-lists, and Delete-lists*. Given a goal, the planner selects a behavior with the goal in its Add-list and checks whether the conditions of the behavior are fulfilled. If they are not, the planner recursively looks for behaviors that have the unfulfilled preconditions in their add-list. The *to-from* prepositions look like this in the STRIPS formalism:

(2) Actor moves from Source to Goal =
Preconditions: Actor is at Source
Add-list: Actor is at Goal
Delete-list: Actor is at Source

Goal, Actor, and Source are variables that are instantiated when the behavior is invoked. AI mainly consists in rearranging componential analyses so that they are useful for stringing behaviors together in a means-end hierarchy.

Bouncy does not use planning facilities, but there is a few examples of componential structure. For example, the behavior *Go To Target* is composed of two sub-behaviors, *Avoid Obstacles* and *Approach Target*. Instead of being driven by a planning algorithm (resembling a context-free grammar) Bouncy is driven by the simpler finite state machine whose transitions are regulated by Bouncy's perceptions and moods. Some of the states are themselves finite state machines; for example, the "Interact" state is composed by three substates, "tease", "please" and "have the blues".

3.2. Image schemata

However, in recent years, the continuous aspects of signified behavior has come into focus in the so-called cognitive grammar (Talmy 1988, Johnson 1992). The main idea is that there are dynamic phenomena that cannot be accounted for in the discrete framework, and to capture these phenomena, the notion *of image schemata* was introduced.

An image schema is

a dynamic pattern that functions somewhat like the abstract structure of an image, and thereby connects up a vast range of different experiences that manifest this same recurring structure *Johnson 1992: 2.*

An example of an image schema is the COMPULSION schema (Fig. 3.1) where something applies a force to an object that sometimes cannot resist and begins to move along a trajectory, but in other cases can counteract the force so that the trajectory remains only potential.

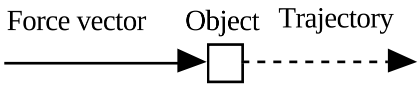


Fig. 3.1. The COMPULSION Schema

An actual compulsion schema exists as a *continuos, analogue* pattern of, or in, a particular experience or cognition that I have of compulsion. It is present in my perception of a jet airplane being forced down the runway, in my understanding of forces acting on continental plates, or (metaphorically) in my sense of being forced by peer pressure to join the PTA. *Johnson 1992: 2*

Examples of sentences based on the compulsion schema are:

- I *pushed* the dog away (physical process)
- Her beauty made a deep *impression* on me (perception)
- His argument *forced* me to change my opinion (conversations)
- You *must* do it (social)
- It *must* be true (epistemic)

As appears, the schemata structure a vast set of different domains, and they not only control perception, but also behavior (Johnson 1992: 21).

In spite of the name "image schemata", they are not real rich images (Johnson 1992: 24). In fact, they are a-modal, not being tied to any single perceptual modality (Johnson 1992: 24). Also, they are not static objects but dynamic (Johnson 1992: 29). The *from-to* meanings in (1) above correspond to the path-schema (Johnson 1992: 113).

The compulsion-schema can be formalized in various ways. A very simple one is to define a potential function with an attractor in the endpoint of the path, cf. formula (3) and Fig. 3.4.

(3) $$y = \frac{h}{x^2 + 1}$$

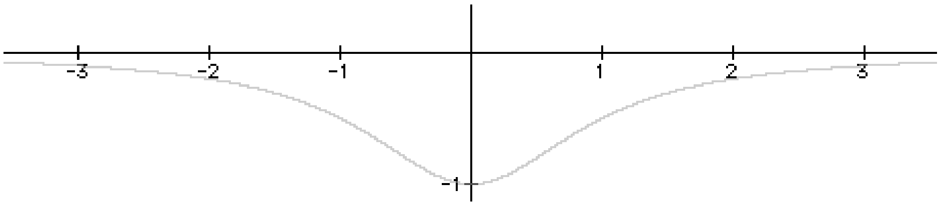


Fig. 3.4. Attractor. Formula (3) with h = -1

x measures the distance from Actor to Goal. The actor is assumed to be moved along the gradient $\frac{dy}{dx} = -\frac{hx}{\left(x^2+1\right)^2}$.

In Fig. 3.2 is shown three superimposed potentials that reflect the forces working on the bird.

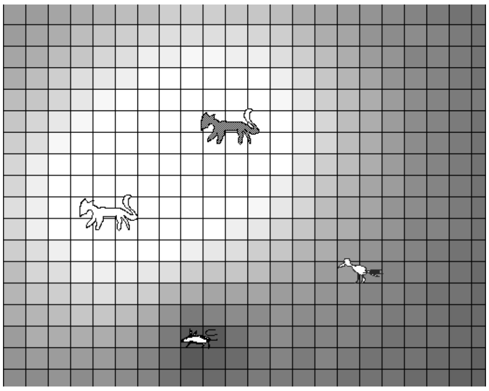


Fig. 3.2. Cats and mouse seen from a bird's perspective. The cats repel, the mouse attracts.

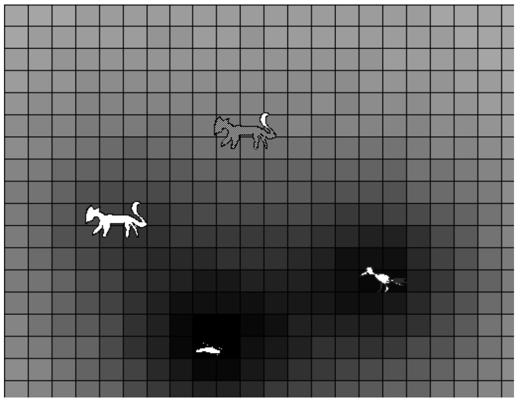


Fig. 3.3. Female cat, mouse and bird from the male cat's perspective. Darker = smaller values. The cat is attracted to all 3 animals.

The bird is attracted towards the mouse and repelled from the two cats. The height of the potentials are represented by lightness: high parts (repellers) are light, low parts (attractors) are dark. Fig. 3.3 shows the same situation, but now from the point of view of the male cat.

Maes 1989 describes an interesting hybrid between continuous and discrete behavior representations, namely activation networks based on the STRIPS formalism. The network selects one behavior among the executable behaviors that have the highest activation value. Activation values originate in the goals and in the world. For example, as shown in Fig. 3.5, unsatisfied goals (A is a Y) inject activations into behaviors that contain the goal in their add-list, and true propositions (A is at X) inject activations into the behaviors of which they are preconditions. Activations can also spread inside the network. For example, unfulfilled preconditions of a behavior (the route between X and Y is passable) spread activations to behaviors whose add-lists contain the precondition (A removes obstacle between X and Y).

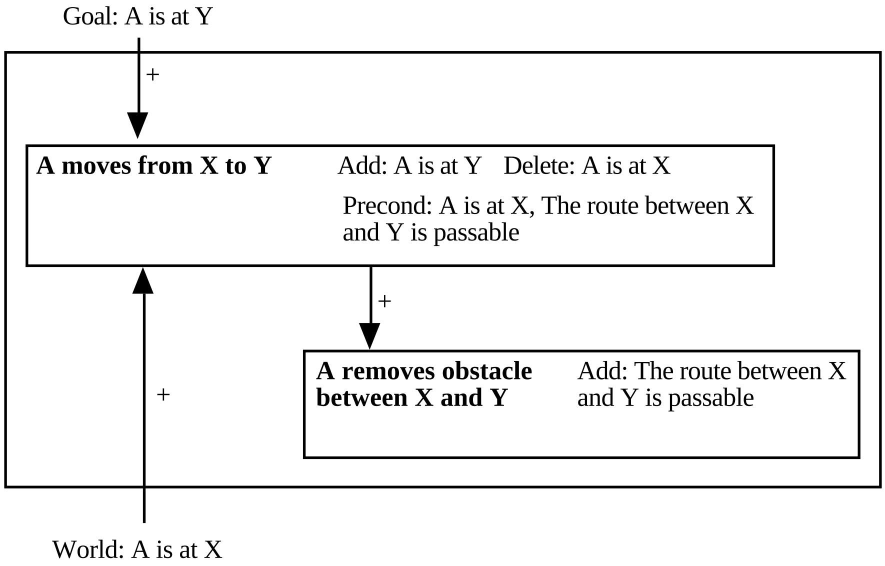


Fig. 3.5. STRIPS as activation network

Maes's activation networks are interesting because they combine the discrete with the continuous. In particular, the activation value can be used as a representation of modality, low values signifying impossibility, higher ones possibility or necessity. We will elaborate on this in Section 4.1 and section 4.4.

3.3. Talmy's force dynamics

The American linguist Leonard Talmy has elaborated a schema he calls a "force dynamic" which resemble Johnson's "compulsion schema". According to Talmy (1988), the smallest complex structure of forces seems to involve two actors and two forces. The actors are called the *agonist* and the *antagonist*. The agonist is the main character and is described as having some immanent drive towards action or rest. The antagonist tries to oppose the agonist, either by making an immobile agonist move, or by preventing a mobile agonist from moving. The force of the antagonist can be stronger or weaker than that of the agonist. This gives us the four main types in table 3.1.

	Agonist inherently resting	Agonist inherently moving
Antagonist weaker	1. The ship kept its balance despite the waves. (ship = agonist, waves = antagonist)	2. The ship kept sailing despite the strong currents. (ship = agonist, currents = antagonist)
Antagonist stronger	3. The wind made the ship drift. (ship = agonist, wind = antagonist)	4. The storm prevented the ship from reaching harbor. (ship = agonist, storm = antagonist)

Table 3.1. Four types of force dynamic patterns.

Representing meaning as gradient fields, as in Section 3.2, or as forces, as suggested by Talmy, has the advantage that meaning components can be fused in a straightforward way, e.g. by simple addition as in Fig. 3.2 – 3.3. This is necessary, since our actual actions are more often than not the result of several concurrently working schemata. For example, in robotics, the goal-seeking behavior and the collision avoiding behavior must be active at the same time, and any interesting narrative must contain conflicts where the protagonist is moved by opposing forces, cf. again Fig. 3.2 where the bird simultaneously is attracted by the mouse and repelled by the cat. In addition, use of potential fields of this kind is a standard method in robot motion planning (Latombe1991: 295 ff.) so we know it can be used to control behavior to some degree. There is also evidence that field-like forces have a neuro-physiological basis (Maclennan 1997). For concrete applications to multimedia systems, see Bøgh Andersen 1992, 1995, and 1998b.

In Section 3.6, we shall see that the notion of action fusion is not only relevant with physical actions, but also with symbolic ones.

3.4. Vendler's verb classes

Vendler (1957, 1967) classifies verb meanings according to their dynamic structure. According to him, there are four major types of proceses, namely *Activities* (play football), *Accomplishments* (drive to the parking lot), *Achievements* (win a race) and *States* (sleep, be a plumber). See also Van Valin & LaPolla (1997) for a more detailed linguistic treatment.

	Static	Telic	Punctual
Activity	-	-	-
Accomplishment	-	+	-
Achievement	-	+	+
State	+	-	-

Table 3.2. Vendler's four verb types.

The processes differ in the terms of three oppositions: static/dynamic, telic/non-telic, and punctual/non-punctual, as shown in Table 3.2.

In *activities* an action is repeated an indefinite number of times. In *accomplishments* there is also action but it stops when a certain limit has been reached (See Fig. 3.6). *Achievements* denote a momentary state-change, and *state* terms denote the continuation of a state of affairs. Vendler proves the existence of these types by showing that grammatical features, such as *ing*-forms adverbials of time and duration, and, in Scandinavian languages, the auxiliary of the past participle, depend upon them. The process type is not exclusively associated to the verb, but to the sentence as a whole: *I ate apples* is an acitivty, whereas *I ate the apples* is an accomplishment (Fig. 3.6). Like Johnson and Talmy, Vendler proves that there in fact exist definable dynamic building-blocks of processes that can be assembled to control larger narratives.

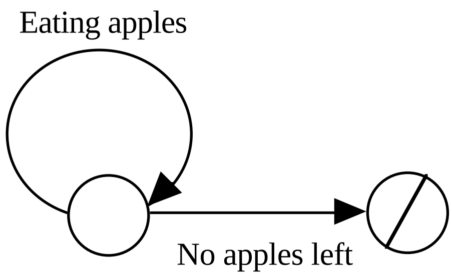


Fig. 3.6. I ate the apples

The STRIPS formalism from Section 3.1 only covers the two telic variants, the accomplishments and the achievements: it is hard to figure out what the delete- and add-lists for activities (play football) or states (sleep) should be. This is a problem since activities are important in plans too: to avoid obstacles is more like an activity since it is something one always thinks about and it should be able to work together with accomplishments such as *go to goal.* The process-type of *maintenance* described in the next section handles this problem.

Apart from mastering the goal-seeking behavior, *Go To Target*, Bouncy's repertoire mostly consists of activities and states. For example, "sleep" is a state where Bouncy does not do anything, whereas "play" is more like a non-telic activity where Bouncy keeps running and jumping around.

3.5. Lind's control behaviors

Humans are not only able to classify concrete processes, but also to handle processes of processes, such as beginning, maintaining, preventing, stopping processes.

Lind (1994, draft) suggests using Von Wright's behavior analysis for defining four basic control behaviors (T = *change*, d = *doing, acting*):

Condition of behavior	Explanation	Behavior	Explanation	Result of behavior	Explanation
pT¬p	p exists but vanishes unless maintained	d(pTp)	p is maintained	pTp	p remains
¬pT¬p	p does not exist and does not happen unless produced	d(¬pT p)	p is produced	¬pTp	p happens
pTp	p exists and remains unless destroyed	d(pT¬p)	p is destroyed	pT¬p	p vanishes
¬pTp	p does not exist but happen unless suppressed	d(¬pT¬p)	p is suppressed	¬pT¬p	p remains absent

Table 3.3. Logical analysis of four control behaviors. From Lind 1994: 269.

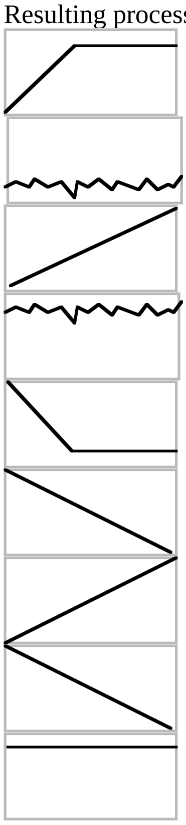
These types are important general control behaviors, and are also necessary in agent-specification. For example, the difference between production/ destruction on the one hand, and maintenance/suppression on the other, can be found in Maes 1989:

> Notice that we distinguish two types of goals: once-only goals have to be achieved only once, permanent goals have to be achieved continuously. Maes 1989: 7

Compared to Vendler's classifications, Lind's *produce* and *destroy* are accomplishments, whereas his *suppress* and *maintain* are activities without any internal endpoint. Thus, avoiding obstacles while seeking a goal can be analyzed as producing one state while maintaining another.

Inspired by Talmy, we can reformulate these analyses in terms of opposing forces. The advantage of entering time into the analysis is that we can bring the description closer to observation. For example, maintaining and suppressing a state P is not a one-event phenomenon as Von Wright invites us to believe. On the contrary, P and ¬P are unstable, so that in practice we will have repeated events where the controller tries to maintain P, but P keeps trying to vanish.

Table 3.4 shows the resulting nine control behaviors. A = controller, B = controlled.



A	B	Resulting process	Verbs
↑	↑		1. Help (produce state)
↓	↑		2. Suppress, prevent, forbid, avoid state
•	↑		3. Let, allow state to appear
↑	↓		4. Maintain, keep state
↓	↓		5. Help (remove state)
•	↓		6. Let, allow state to disappear
↑	•		7. Produce, create state
↓	•		8. Destroy, remove state
•	•		9. Let, allow state to remain

Table 3.4. Dynamic analysis of nine control behaviors.

Referring back to Vendler’s analysis we can say that accomplishments and achievements produce a state of affairs that would otherwise not have occurred, or they destroy a state of affairs that would otherwise have persisted. Activities and states maintain a dynamic, respectively static state of affairs that will cease to exist, had the actor not intervened, or they prevent a state of affairs from arising.

The two new control behaviors, *help* and *let*, are indispensable in narratives. *Help* is obvious, and *let* is used in plots where the protagonist omits a behavior and lets the situation work for him: for example, the hero may let the villain continue talking, well knowing that he is exposing himself. See Ryan 1991: 130 for further elaboration and examples.

Lin d’s control actions are useful for describing the interaction between the user and Bouncy. In some of its states, time changes the mood, but the user can influence this autonomous change. For example, when Bouncy is playing, time decreases its excitedness-value, whereas the voice of the user increases it. Thus, the user can *maintain* Bouncy’s level of excitation, or *let* him become bored. On the other hand, when Bouncy is sleeping, time does not make any difference, and the only way of changing Bouncy's state is for the user to *call* him. This is a case of *producing* behavior. The Japanese *Tamagotchi* agent derives its fascination from such control actions (Fig. 3.7).

Fig. 3.7. A Tamagotchi

3.6. Halliday's process types

Whereas the former three analyses uses the dynamic nature of the processes as their point of departure, Halliday 1994 distinguishes process types by means of the semantic roles involved in the sentences describing the processes. He sets up six main types:

- *Doings:* Actor + Goal. Material processes that imply a change of state. Moving, manipulating objects, etc.
- *Sensing:* Senser + Phenomenon. Mental processes like Perception (seeing or hearing something), Cognition (remember, know, believe, realize, notice, forget, or understand something), and Affection (fearing, liking or enjoying something; be puzzled or pleased by something).
- *Being*: processes of *attribution* (Carrier + Attribute: be sad, courageous, fearful) or *identification* (Identified + Identifier: be the leader of the team or the clever one).
- *Behaving*: Behaver. Psychological and physiological behavior (watch, stare, talk, grumble, chatter, cry, laugh, frown, sigh).
- *Sayings*: Sayer + (Receiver) + (Target) + Verbiage/Quote. All symbolic exchanges of meaning (tell, ask, say, repeat, describe, praise, flatter, request, command).
- *Existing*: Existent + (Circumstance). Something that exists or happen (exist, remain, arise, occur, happen, follow, ensue, sit, stand, hang, prevail).

Halliday is the only one dealing with *sayings*. Sayings are different from other processes in two ways:

They do not rely on cause and effect but rather on the receiver's understanding of the speaker's intention and the speaker's good-will (Posner 1993). There is no verbal way of forcing someone to do what is requested.

Also, when verbs of communication enter into planning, it is not their own delete- and add-list that are active, but the lists of their "Verbiage". For example, if I request somebody to do give me the paper then it is the delete- and add-lists of *give* (Add(give) = I have the paper) that are effective in my plan, not those of *request*. Compare the behaviors in table 3.5. A proper componential analysis of verbal behaviors can be found in Austin and Searle's work.

	Preconditions	Add	Delete
Take X	I have not X I am at X	I have X	
Give X to Y	I have X I am at Y	Y has X	I have X
Ask A to B	A can hear me A can understand me	The Add-list of B	The Delete-list of B
Ask A to take X	A has not X A is at X	A has X	
Ask A to give X to Y	A has X A is at Y	Y has X	A has X

Table 3.5. Non-symbolic and symbolic behaviors.

The six process types belong the to *ideational functions*, one of the three main functions postulated by Halliday. According to Halliday, an utterance is the result of three types of constraints: *textual*, *interpersonal* and *ideational* constraints. An single sentence must comply with all three of them simultaneously:

1. *Textual functions*. The utterance must cohere with the preceding utterances, and organize its contents in given and new information.
2. *Interpersonal functions*. The utterance must organize the relation between the speakers and their mutual turn-taking.
3. *Ideational functions*. The utterance must structure the situation referred to according to various principles: roles, foreground/background, superordinate/subordinate, etc.

Referring back to Section 3.3, we can say that these three constraints must be fused into one single utterance. Some constructions can be seen as solutions of conflicts between these constraints. For example, in English there is a rule that requires heavy clauses to go behind the main sentence, and a another one saying that all sentences should have a subject. These rules can conflict since number one removes the subject number two wants*: That she came was common knowledge* -> *was common knowledge that she came.* The contradiction is solved by the expletive *it* that can fill the empty slot left by a sentence: *it was common knowledge that she came.* Thus, behavior fusion also occurs in verbal behavior.

Apart from the degrees of freedom furnished by the choice of words and their order, language offers additional means for conveying connotative meanings, parallel to the denotational meanings of the utterance: pitch, stress, tone, and rate. These suprasegmental properties can be manipulated in some speech synthesis systems, and are of fundamental interest especially when combined with animation engines supporting coherent facial mimics and body-movements as the external traits of the agent. An example of a wave-generated skeletal animation technique for lip-syncing is shown in Fig. 4.4.

Finally, one may note that Halliday offers rather detailed descriptions of how to get from his process types "down" to actual sentences. This is useful if we want the agent to verbalize its own and other's behaviors.

Bouncy is mostly in Doings, Beings and, very rudimentarily, Sensings. However, he can react to a very limited vocabulary: two states of the data-glove, and two degrees of loudness from the microphone. He interprets combinations of these events in three ways: the user is calling, scolding or fondling him. Bouncy cannot use discrete symbols himself, although he can produce continuous indexes of his psychological state. For example, his excitedness controls his tail-wagging and the shape of his mouth. His psychological state can be defined as regions in a phase-space with three dimensions, <excitedness, sleepiness, mood>. If Bouncy were to describe his feelings, he would have to use critical limits in this space.

3.7. Summary

In the previous sections we have looked at five way of analyzing behavior, most of which was based on linguistic evidence, and we have tried to characterize a simple autonomous agent by means of the concepts. Bouncy can be characterized as an agent whose behavior primarily consists of *activities* and *states*, but rudimentarily employs a componential analysis. The user interaction mainly consists of *producing* and *maintaining* these behaviors, secondarily of *letting* developments run their natural course. Bouncy can *Do* physical actions, and use continuous *indexes* as symptoms of his psychological *Being*.

Since the classification schemes allow for other choices, we can also list abilities Bouncy does not have, but possibly should have. Adding discrete representations of behaviors of type accomplishments (Section 3.1) would enable Bouncy to produce purposeful behavior and describe it to the user. Adding Talmy's force-dynamic could introduce an elementary plot, with Bouncy trying to accomplish some goal, being frustrated by circumstances or other dogs, but eventually succeeding. Expanding the repertoire of control actions to include suppression and destruction of a state allows the user to play the role of an adversary.

However, these enhancements are not the crucial ones for entertaining agents that can produce interesting behaviors. We discuss this question in the next section.

4. How are interesting behaviors structured?

Behaviors and the characters performing them must possess special properties in order to be worthwhile looking at. Most normal behaviors are not designed to be used as signs and are therefore often boring, but theatrical and filmic behaviors have to work that way. One important feature of the characters and their behaviors is that they must keep creating expectations in the spectator.

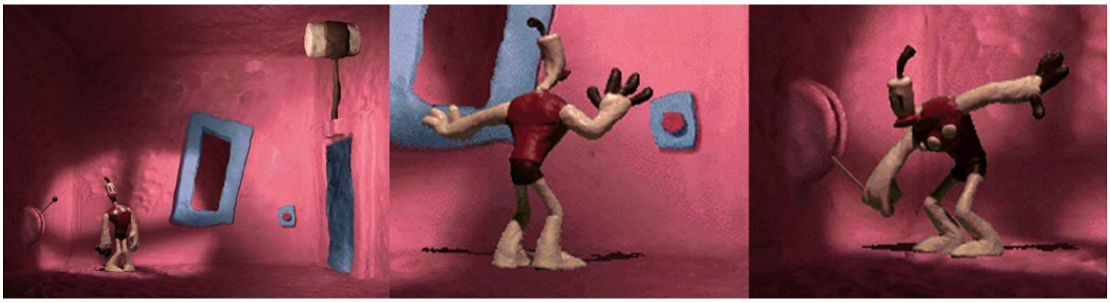


Fig 4.1. The Neverhood; Poses that create expectations

In the game the *Neverhood* (Fig.4.1) the possible behaviors are split up into a series of walks and movements, including operation of buttons and handles, which all together makes up series of small gags and puzzles.

Expectations are created by the mechanics of button pushing. What will happen when the button is pushed or the handle is drawn? Expectations are also created by the poses of the character. We can't wait to see what it "looks like" when the button is pushed, because he has such a funny way of holding his hand. Furthermore, the poses are leading us to look for or think of other possible behaviors, since one hand is almost always pointing in another direction. This is a job done by a skilled animator, where each pose is "loaded" with possibilities — in fact what every theatre or film actor is trained for. Actors often show contradictory expressions which all together builds up a complex character – f. ex. when the facial expression of a rich woman shows disgust for the working class hero but her body language shows uncontrollable physical attraction. If the actor is only able to show one intended action at a time the character becomes one dimensional.

To make the act interesting for the audience, the actor has to indicate the intended behavior rather than to show his full behavior, as Dario Fo puts it in his famous practical book on acting techniques (Dario Fo 87).

According to Bordwell 1985, the film-viewer continually creates such expectations about what will happen or has happened. These expectations has the form of schemata (a murder is possible), that generates hypotheses about what one should look for next (vulnerability of the victim); the hypotheses guide the interpretation of what is actually perceived (a knife is interpreted as a weapon, not as a kitchen utensil), and cues in the material fill out slots in already existing schemata (Mr. Schmidt turns out to be the murderer), or generate new ones (not a crime, after all, but a joke).

If expectations are not created, there will be no suspense or curiosity (in the broad sense) which again means that there will be no engagement. Expectations are created by a conscious use of modality: *the impossible, the possible, the actual*, and *success* and *failure.* If we review the various methods for analyzing behaviors above, we notice that glaring absence of any theatrical techniques. Therefore, if we use these methods in isolation we will end up with logical and causally related sequences of behaviors and outcomes that are boring because we never get the clues we need to form expectations.

This is not to say that the analyses are useless. On the contrary, if we had no possibilities of specifying behavior sequences cohering in time and causality, we would lack the raw material out of which narrative experiences are built. If we have no way of specifying the normal, logical, and expected world, we also lack the ability to create surprises, which are deviations from the normal.

In this section we shall look at semi-formalizable accounts of narrative structure and character development.

4.1. Bremond's forking paths

An early attempt to give a semi-formal account of narrative structure is found in Claude Bremond's work (Bremond 1966, 1970).

Bremond analyzed French folktales, and found the basic building block shown in Fig. 4.1.

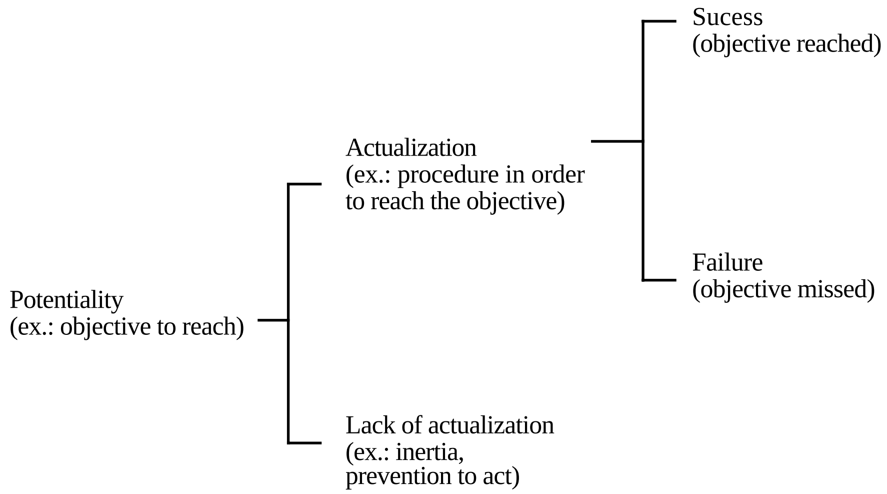


Fig. 4.1. Basic narrative building block in French folktales

The basic blocks can be assembled into larger structures, such as the *sequence*, the *enclave* and the *join*. Bremond's analysis seems limited to accomplishments and achievements. In order to use Bremond's ideas for agent design, it is necessary to specify what happens after success and failure. In the case of failure, is the behavior tried again later (the rejected lover renews his courting), or is it given up? In the case of success, is the behavior tried again once more (the successful gambler plays another game), or is one success sufficient? Furthermore, under which conditions are behaviors given up: after the lapse of some time-interval? After encountering a certain amount of obstacles?

Thus, any behavior should be specified with respect to its modality: is it potential, is it actual, does it succeed or fail — and we need to indicate what happens in these cases. What this means is that we should not only program our autonomous agent to reach a goal and avoid obstacles; the agent should also know how to behave when he is just thinking of reaching the goal, and how to display to the audience that he has given it up again (lack of actualization). In games this is often shown as linear animated "cut-scenes" where the character makes a triumphant act, such as raising a sword after killing a monster (Fig. 4.2). Another typical way of showing success or failure is by using sound-effects, playing a melody, or yelling — simple ways of showing the ecstasy of victory compared to the use of body language and facial expressions in film and theatre.

Fig 4.2. Final Fantasy VII; Cloud Strife is raising his hand and swinging the sword after a victory over two giant dogs.

To see the importance of modality, suppose the agent plays the part of a serial killer and enters the scene where the hero is placed. If the killer did not know anything about potentiality and lack of actualization, he would enter the scene, stand immobile for some time, and exit. This makes poor entertainment. However, if he knew how to express his intention to add the hero to his list of victims, tension would be created, and if he knew how to signify that he gave up the intention for the time being, a relief is produced.

The remaining parts of this section elaborate on the basic problem of turning agents into actors worth looking at. However, before we continue our discussion of narrative structure, we shall discuss the basic problem of externalizing the inner states of the agent. Until recently, there has been a tendency in academia to overlook the outer expression and concentrate on designing the inner states. But the most sophisticated exploitation of modality and intention comes to nothing if the audience cannot perceive it.

4.2. Turning agents into actors

It is not enough to furnish the agent with interesting inner traits. We have to take the step from generating descriptions of possible behaviors in possible worlds to expressing behaviors in a chosen material in a certain environment. Decisions about the agent's looks, the way it moves and how it expresses its intentions will have to be made. Finally the agent has to be modeled in a style suited for live animation by a 3D engine, This is necessarily a practical process, where the modeler will deal with aesthetic, stylistic and artistic questions as well as studies of anatomy and the physics of movement. The former approach is mainly taken by the games development industry, while the latter is taken in scientific projects, e.g. where the aim is to make precise computer generated models of facial expressions (Parke & Waters 96) or body movements (Hodgins & Wooten 99).

The process of making systematic formal descriptions of the signifiers in animation is, allthough necessary, often a controversial question in both scientific and artistic communities, since it involves exact descriptions of the artist's unique and personal use of distortion and abstraction in the visualization of the character. Furthermore, 3D-computer modeling is a recent artform learning from traditional animation, itself being another young tradition based on the conventions from film, TV, and puppetry,

To learn more about what autonomous agents could look like as actors, it is relevant to focus on the spectrum from traditional linear animation to the colorfull products from the games development industry, where any technique that seems to have some kind of potential for creating interesting, funny or entertaining characters is tried out in a pragmatic and experimental fashion.

The study of animation as an representational artform provides us with a background for understanding the various styles and possibilities in representing the characters, environments and behaviors.

In 2D-animation for film, the dominant tradition is represented by Disney where, according to Eisenstein, one important technique for giving the impression of cartoony movement, "squeeze and strech", relies on "the metamorphosis or transition of one shape into another" (Furniss 1998: 78). This is described by animation theorist O'Pray as a "protoplasmic quality", which explains our fascination of the animated figure, because it gives the spectator the awareness of the "omnipotence of plasma which contains in "liquid form" all possibilities of future species and forms" (Wright 95: 52). Furniss describes animation as the art of creating movement in a broader sense where "an object can move fluidly and rhytmically; in short incremental bursts; slowly and hesitantly (as in working against gravity); or in a multitude of other ways that all suggest meaning to the viewer" (Furniss 98: 76), including other traditions in animation such as puppet animation, pixilation, claymation, cut out and collage.

In nonlinear interactive scenarios, where the spectator is represented as an animated character who can interact with characters and objects in the world, the spectator's perception of the characters at some points seems to resemble that of the puppets in the puppet theatre more than the characters in a Disney animation. The strong sense of reality in virtual 3D worlds is often created by simulating causal relations and what theatre semioticians describe as deictic relations in the diegetic universe.

> The speaking "I", for example, can address a single interlocutor, a crowd or himself, can apostrophize the gods or some absent figure (...) can turn to the audience, and so on. He can indicate deictically his own body, the scene, the present moment, his addressee or a distant object. *Elam 91: 145*

Fig.4.4. *half-life:* The puppetlike facial expression of a guard. He is looking at you and speaks with his limited vocabulary when you push a button (Sierra On-line Inc. 98)

Sorry I'm on duty Mr. Freeman !
Sorry sir. I've gotta stay on my post !
Can we do this later ?
Sorry sir I've gotta stay on my post !
Hey, catch me later - I'll buy you a beer !

The game *half-life* (Valve 98) uses skeletal animation combined with simple game-AI techniques to increase the impression of reality created by the characters. The mouth in Fig. 4.4 is animated through a bone in the jaw, programmed to follow the waveform in the sentence. The result is an effect, which in glimpses is a rough version of the sophisticated techniques used in the puppet theatre. In addition, the character seems alive through continuous actions, such as breathing and random movements; a nod of the head, a movement with the arm, etc. Unfortunately, the behaviors that work on the level of the story are simply randomly generated sentences chosen from a limited vocabulary, which quickly destroys the illusion that the character is real. But the guard still works as a character, a fact easily explained by film and puppet theatre theory.

The relation between the spectator and the live generated character is different from that of the film, since our ability to interact with it makes us relate more directly to its materiality. The analogy is that the spectator invades the stage in the theatre and touches the actors, sets, and props.

At some point he will observe that although the world seems “real”, it is made of “dead objects”. According Metz (Metz 1974: 9) “it is often the criterion of touch, that of “Materiality”, confusedly present in our mind, that divides the world into object and copies” where e.g. touching the film screen or the puppet in the wax cabinet immediately destroys the illusion of reality.

This awareness of the character as an object is a phenomenon described in the theory of the puppet theatre as the specificity of the puppet (Kawrakova-Lorenz 230-41), “double vision” (Tillis 92: 60 - 85), and “opalisation” (Jurkowski 88: 78):

> There is still something more – the effect of what I choose to call “opalisation”, when movement fully dominates an object we feel that the character is born and present on stage. When it is the nature of the object which dominates we still see the object. The object is still the object and the character at the same time. Sometimes however this unity splits for a short while, to be regenerated after a moment. (...)
>
> “By opalesence of the puppet” I mean the double existence of the puppet, which is perceived (and demonstrated) both as puppet and as scenic character. Clown Gustaw of Albrecht Roser is a clown character, but when his strings get entangled and he asks for help, he is a puppet; furthermore he is a puppet playing upon his awareness of being a puppet. *Jurkowski 88: 78*

In the tradition of puppet theatre the object-like quality of the material, e.g. wood or clay, has been used by skilled puppeteers as an important means of expression and can serve as an inspiration for the character design and animation techniques of autonomous agents that goes beyond that of plastic Disney animation or precise naturalistic models.

The Czech artist Jiri Trnka demonstrates in his films “the ability to create expression through subtleties of movement, environment, and lighting, as well as camera angle and framing, despite the inflexibility of his puppet figures” which is a way to overcome the fact that “a wooden puppet generally has a rigid face, incapable of stretching to show a smile or speak” (Furniss 98: 163, cf. Fig. 4.5).

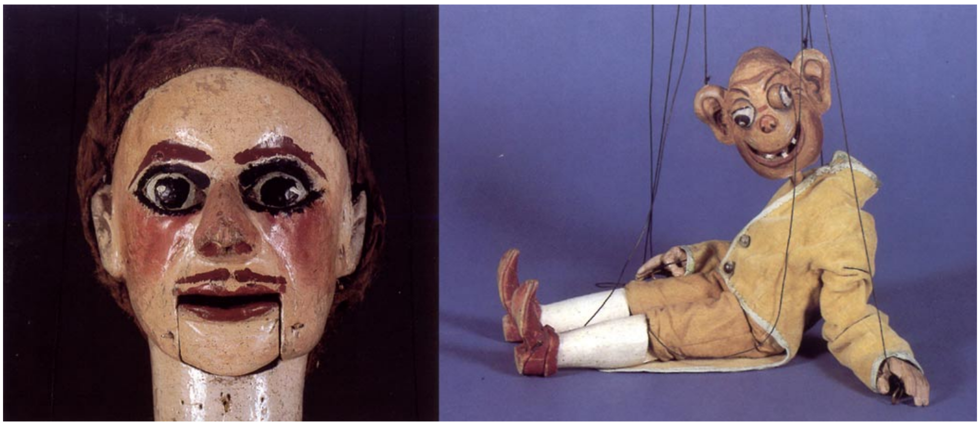


Fig. 4.5. The formalization of the possible behaviors also lies in the materiality of the character. Left; Kasper, Marionette (87 cm), Wood/Textile, Richters marionette theater 1850. Right; Chomical character, Marionette (46 cm), Wood/Textile, Czechoslovakia 1924/26, Spejbl und Hurvinek Theater – Joseph Skupa, Puppet by Gustav Nosek. (Catalog: Mobiles Puppentheater-Museum Berlin)

In computer games development, the restrictions of the material is also a major issue, especially in realtime 3D games where the chosen 3D engine sets limits to polygon count and textures. Game designer Walter Park explains some of the advantages by the character design in the game Final Fantasy VII (EIDOS 98): the use of very few polygons, large color shapes and simple surface designs in the character design gave a large freedom to use cinematographic effects (Park 99).

Fig. 4.6. Final Fantasy VII; Tifa, Barret and Cloud; Character design in 2D anime style, before the 3D modeling for the game.

The character design in Final Fantasy VII is based on the style from Japanese anime films and the simple and naive world of the fantasy tradition. The characters are archetypal and have few, but very distinct features (Fig. 4.6).

The main character Cloud Strife has an extreme long sword, spiky hair, elegant clothes and athletic stature like a prince. Barret Wallace has the heavyly built stature of a warrior, his arm is a gun and he has extremely slender hips, like an X. Tifa Lockheart has very long legs, she has feminine and girlish features and is dressed for fight as a teenage amazon.

Fig. 4.7. Final Fantasy VII. Barrett is shaking his hands for anger, because Cloud Strife will only join the resistance movement against the powerful leaders of the city as a rent soldier.

The distinct features of the characters makes them unique and they become visually recognizable, which is important for the elaborate use of cinematic techniques, with frames ranging from close-up to super-total throughout the game.

In the game the characters are to some extent able to express their emotions even though they are restricted by the edgy 3D design (Fig. 4.7).

To describe the special relation between the spectator and the live animated agent, the theory of the puppet theatre also seems relevant, because one can draw an analogy between the puppeteer playing the puppet and the engine controlling the autonomous agent

In the puppet theatre Fig. 4.8. the puppeteer serves (cf. Lund 95) as an engine for the puppet. In some cases, he is hidden from the audience behind a screen, as in the illusionist theatre, leaving the audience speculating who is behind the screen. In modern theatre forms, the puppeteer is often visible on the stage with the puppet. The presence of the actor, hidden or visible, is the source of our fascination with the puppet and the phenomenon described as “opalisation”

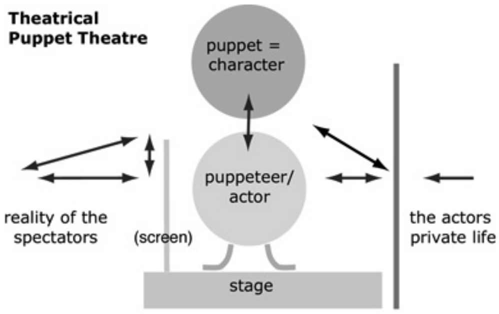


Fig. 4.8. The relation between the puppet, the puppeteer and the reality of the spectator. The screen is optional.

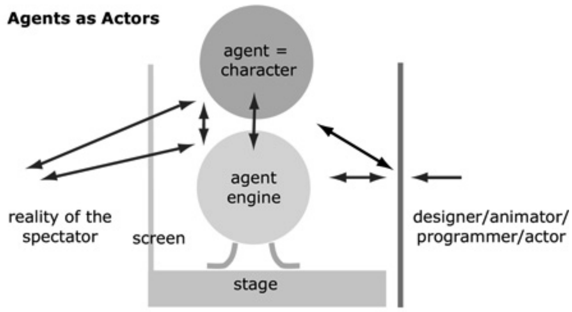


Fig. 4.9. The relation between the spectator and the autonomous agent as an actor, played by an agent engine. This model is made in collaboration with dramaturg Jette Lund

The puppet theatre is suggested as an analogy for autonomous agents in Fig. 4.9. The spectator is able to go through the screen and act in the world of the agents and sometimes event to go inside them and the agent engine. In this analogy, the agent engine has to take over the function of the puppeteer to make the characters come alive, constantly revitalizing the character when the illusion of life is broken and, for a moment, it is seen as an object. In some games, where change of agent properties is a part of the game-play and the evolving story, the spectator is also able to go inside both the character and the agent engine. We shall return to this idea in Section 4.4.

4.3. Ryan's possible worlds

Bremond is not alone in emphasizing modality as a necessary ingredient of aesthetic pleasure. According to Ryan 1991, the distinction between virtual and actual worlds is a vital ingredient in any narrative, and the notion that our experience never concerns a single state of the world, but is always circumscribed by a plurality of worlds, is quite commonplace in literary theory. In fact, Ryan claims that even the simplest text presupposes that the reader is able to imagine worlds other than the one actually narrated.

In Ryan's book, a *world* in this connection is a maximal consistent set of propositions, i.e. it is a complete and consistent representation of a state of affairs.

A *System of Reality* is a set of distinct worlds. It contains a unique central world, called the *Actual World,* in which the speaker is located. Around the central world a set of satellite worlds orbit. Four of them are modal worlds: the knowledge-world, the obligation-world, the wish-world, and the intention-world. These worlds contain the same propositions as the actual world, but they are tagged by different modal operators. Thus, the knowledge-propositions *p* are all prefixed by phrases such as “I firmly believe p to be true/false”, “I don’t know whether p”, “I believe p to be probable”. The obligation-propositions are modified by phrases like “is allowed, obligatory, prohibited”, the wish-propositions by “p is good/bad”, and intention-propositions by phrases like “I intend, plan to do p”. All four worlds can be authentic or pretended, leaving place for authentic as well as pretended beliefs, obligations, evaluations, and intentions.

In addition to the modal worlds, the Actual World is orbited by Fantasy-worlds: dreams and stories created by the inhabitants of the Actual World. Fantasy worlds differ from the modal worlds in that they are complete Systems of Reality that create a new actual world with modal satellites that substitute for the original System of Reality as long as the story lasts. Not only the worlds but also the speaker and listener are substituted and become what is known in literature theory as the *implied speaker* and *listener*.

This gives us the basic recursion that is very common in narratives: the real speaker is telling a story wherein another speaker is telling a story. In borderline cases, such as Arabian Nights, we can have up to four stories inside each other (Ryan 1991: 182).

Ryan uses the following fable to illustrate her notions:

The Fox and the Rooster

Once a dog and a rooster went into the woods. Soon it grew dark. The rooster said, “Let us stay here all night. I will stay in this tree-top. You can sleep in the hollow trunk”. “Very well”, said the dog. So the dog and the rooster went to sleep. In the morning the rooster began to crow. “Cock-a-doodle-doo!”. Mr. Fox heard him crow. He said, “That is a rooster crowing. He must be lost in the woods. I will eat him for my breakfast.” Soon Mr. Fox saw the rooster in the tree-top. He said to himself: “Ha ha! Ha! ha! What a fine breakfast shall I have! I must make him come down from the tree. Ha ha! Ha! ha!” So he said to the rooster, “What a fine rooster you are! How well you sing! Will you come to my house for breakfast?” The rooster said, “Yes. thank you, I will come if my friend may come, too”. “Oh yes”, said Mr. Fox, “I will ask your friend. Where is he?” The rooster said, “My friend is in the hollow tree. He is asleep. You must wake him.” Mr. Fox said to himself: “Ha ha! Ha! ha! I shall have two roosters for my breakfast!” So he puts his head into the hollow tree. Then he said, “Will you come to my house for breakfast?”. Out jumped the dog, and caught Mr. Fox by the nose.

Text 6.1. Ryan 1991: 144.

The two important modal worlds in this fable is the Knowledge-world and the Intention-world (Fig. 4.10).

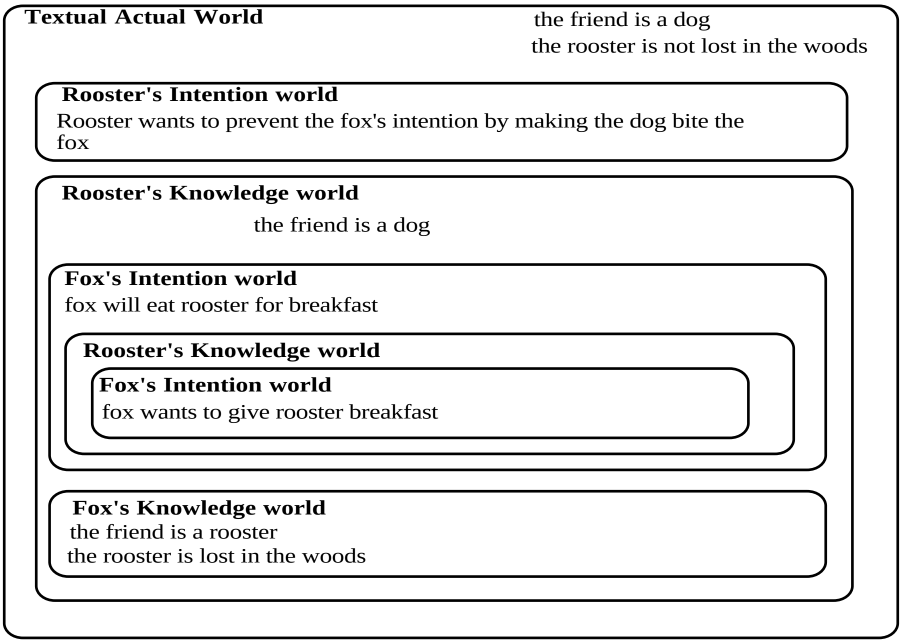


Fig. 4.10. Possible worlds of “The Fox and the Rooster”

In the Actual World of the text, a rooster and his friend, a dog, is walking through the woods. We know that, because the author uses non-modalized sentences *(Once a dog and a rooster went into the woods)* and the author controls the actual world in text. In this world, one of its characters, the fox, believes that the rooster is lost in the woods with another rooster, which we know is not true in the textual actual world. His intention is to eat the rooster and his friend. In order to achieve this, he also intends to make the rooster follow him home by getting him to believe that the fox intends to give him breakfast. Thus, inside the intention world of the fox is the knowledge-world of the rooster embedded, which again contains the intention-world of the fox, as conceived by the rooster: the fox intends to get the rooster to believe that the fox will offer breakfast.

Now, both the intention-world and knowledge-world of the fox happens to be embedded in the knowledge-world of the rooster. The rooster knows that the fox intends to eat him and seeks to accomplish this by making the rooster believe that he will get breakfast in the fox’s home. The rooster controls the fox’s behaviors by having the fox’s modal worlds imbedded in his own modal worlds.

This simple example demonstrates very clearly the importance of possible worlds in even very simple texts. If we could not reconstruct Fig. 4.10, we would miss the whole point of the story. It also demonstrates the recursive structure of systems of reality: worlds can be embedded in other worlds, and the embedding structure is a major point in the story, and, in general, in stories concerned with deception.

How should we conceive of the relation between the actual and possible worlds? According to Ryan, possible worlds are constructed from actual worlds by applying simple rules of transformation. The type of transformation defines the type of the possible world. For example, we may retain the properties of objects in the actual world but enter new objects, e.g. new characters. This gives us the realistic novel. If we keep the objects but change their properties we get fables like the one above. We know roosters, dogs and foxes from the actual world, but they have acquired the ability to speak and think. At the other end of the scale, we can change the laws of nature, logic and language. This yields nonsense literature like *Alice in Wonderland.*

The general rules for building these worlds is that we change the features dictated by the genre and keep the rest as it is:

> we reconstrue the central world of a textual universe in the same way we reconstrue the alternate possible worlds of nonfactual statements: as conforming as far as possible to our representation of AW. Ryan 1991: 51

The example given here is extremely simple and Ryan's book shows that real fictional works are much more complicated.

The ability to create worlds and enter them seem to be a spontaneous faculty of humans. This ability lends credibility to Ryan's notion of worlds: when we discuss a fictive person we do not keep within the confines of the sentences of the novel. Instead we enter a new system of reality and explore and discuss this textual world under the constraints of the transformation that created it. For example, if we have entered the world of Agatha Christie, we know that we are entitled to natural explanations of the riddles, and feel cheated if the murder turns out to have supernatural causes. On the other hand, violation of natural laws are accepted in the fantasy genre, and we accept the power of the ring in Tolkien's "The Lord of the Rings". The reading process itself can also be characterized as "entering a world". When we become absorbed in a book or a film, we withdraw from the actual world, cease to hear and see our surroundings, forget our worries, and live for a short while in the fictive world.

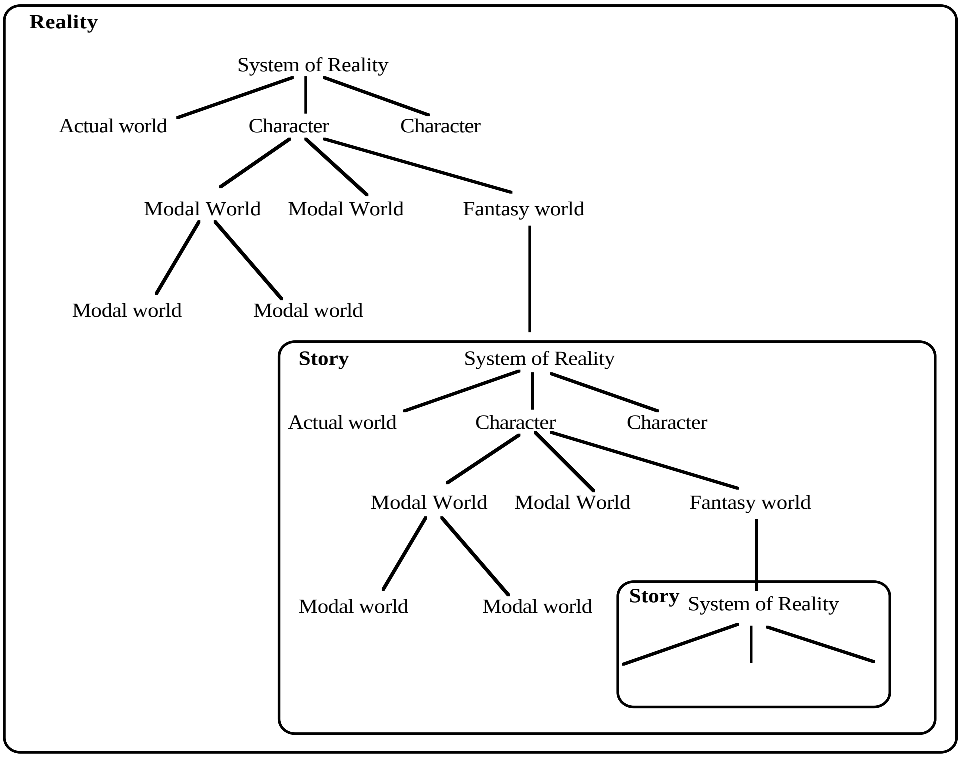


Fig. 4.11. Adapted from Ryan 1991: 123. Ryan does not seem to allow nested modal worlds, but I think that her own examples indicate that this is indeed possible.

This evidence from literary analysis thus shows that our interpretation of a work of art involves a basic tension between the actual world presented and a — possibly infinite — set of possible worlds that work like a huge set of projectors illuminating the present and actual by means of the dim hues and shapes of the potential. In addition, meaning seems to be recursively structured (Fig. 4.11).

4.4. Representing and editing the Intention-world

Modal worlds are different from the textual actual world in the following important respect. In the textual actual world actions are represented as trajectories of values of object properties; for example, the movement of an agent is represented as a trajectory of his three spatial coordinates. In fact, objects can be represented as a phase-space with as many dimensions as the object's degrees of freedom, and any change of the object is a trajectory in this phase-space. However, in the modal worlds, it is not these physical properties of the objects that change, but rather properties of the object's actions. Thus, modal worlds can be represented by trajectories in phases-spaces whose dimensions are probabilities, obligations, or intentions and whose objects are actions. Actions are *reified* when they enter into the modal worlds.

> The relationship between the trajectories (episodes) of the semantic system [i.e., the actual world] and the symbols of the logic system [i.e. the modal world] seems strange: what exists as process in the semantic system, shows up as an object in the logical system. The same phenomenon lives as an process in one system, but as an entity in another. *Andersen 1998a: 177*

This sounds all very abstract, but we can in fact use Maes 1989 from Section 3.2 as a very concrete example. We remember that her system worked by injecting activation values into the behaviors, always choosing an executable behavior with the highest value. The activation value is a modal value which can be interpreted as degrees of possibility — or degrees of intention if we think of the agent in anthropomorphic terms. For concrete applications of these ideas to multimedia systems, see Bøgh Andersen 1998b.

A closer reflection reveals that the idea of reification is not so counter-intuitive after all. The purpose of the modal worlds is not to execute behaviors, but to analyze possibilities and plan behaviors. Therefore, what is manipulated in these worlds are not the objects of the actual world, but rather relationships between actors and behaviors. Should I do this behavior now? Who should do this behavior?

In organizations, planning and execution of behaviors are often done by different departments, and it turns out that planning departments in fact do tend to reify behaviors when they describe work. In Andersen 1997: 348 the manager says: “We are going to gain a step by trying to merge data input with completion”. “Data input” and “completion” are names of work processes. “Completion” is a nominalisation of the verb “complete”, and the processes described do not involve change of work objects, but change of work processes (“merge”).

In Maes’s system, there was only one agent, but it is natural to extend her ideas to cover assignment of a set of behaviors to a set of agents. One possibility is to reuse the dynamics from the actual world while replacing objects by actions and physical dimensions by modal dimensions. We will then obtain a representation that describes the intention-worlds of the actors, and this intention world will in fact closely resemble what is known as a thematic analysis from literature theory. Consider for example the *Lord of the Rings* by Tolkien. There are four main characters, Sauron, Frodo, Gollum and Sam. The main theme is whether someone is to claim the right to the “ring that rules them all” or whether the ring should be destroyed. Sauron and Gollum want to claim the ring, Frodo and Sam to destroy it, although Frodo is tempted to claim it, and in fact does so in the ending. In fact, Gollum, not Frodo, becomes the agent of "destroying the ring" in the end, although not intentionally.

Fig. 4.12 shows how to represent this in a dynamic modal phase-space.

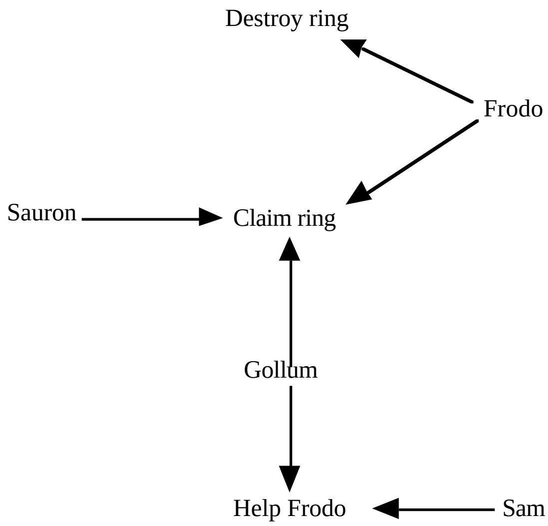


Fig. 4.12. Thematic structure of "The Lord of the Rings"

Fig. 4.12 depicts intentions by means of forces attracting agents to behaviors. Frodo is torn between destroying and claiming the ring. In the beginning, the destroy attractor is the strongest, but in the final chapter the temptation to claim it grows the strongest. Gollum is divided between claiming the ring and helping Frodo to get rid of it. Only Sauron and Sam are "pure of heart": Sauron never wavers in wanting to claim the ring, Sam never in helping Frodo. Important parts of the novel can thus be described as changes of the forces attracting agents to behaviors.

Other forces must be added in order to complete the picture: for example, we need to represent "prevention" from Section 3.5 since Frodo and Sam want to prevent Sauron from claiming the ring, and Sauron and Gollum to prevent Frodo and Sam from destroying it.

The first person shooter game *half-life* is a good illustration of how a varied use of agent-behavior relations enhances the game. Here three groups of people with different intentions fight against each other. There is you, represented as the young scientist Mr. Freeman and your colleagues, there are the bad monsters from the underworld, and there are the soldiers conspiring against mankind, wanting to use the monsters for evil purposes.

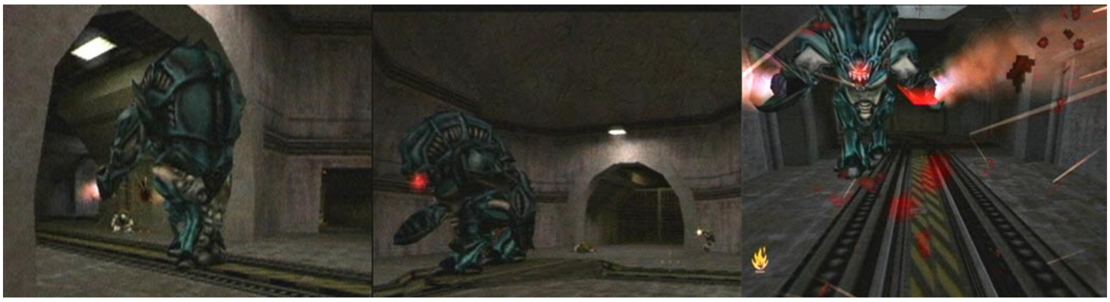


Fig. 4.13. *half-life;* The monster is attacking 2 enemy soldiers. One is already dead. The monster discovers you and starts hunting you instead. (*Sierra online inc. 98*)

In the episode of the game depicted in Fig. 4.13, both you and your enemy are threatened by the same monster. The monster attacks two enemy soldiers, but when it discovers you, it starts hunting you. Thus, the agent-behavior association <Monster - Hunting enemy soldiers> changes to <Monster - Hunting player>. However, the intentions of the characters cannot change which makes the conflict between the characters very simple and the story one dimensional. But imagine that your former enemy changes his mind and comes to help you because you were nice to him in an earlier episode of the game, i.e. the association <Monster - Hunting player > could change to <Monster - Helping player>.

Episodes like the one in Fig 4.13 is an example of how the characters can change intentions in their choice of behavior. Furthermore it shows that intention is important in the creation of conflict — a necessary ingredient in any narrative.

There are different levels of <Agent -Behavior> associations. Consider an episode from the same game where a group of soldiers are attacking: they have the same overall intention to kill you, but carries it out in different ways. Thus, agents can be associated to the same intentional behavior, but to different embodiments of the intention.

It is possible that representations of modality as shown in Fig. 4.12 could be converted into a design tool for editing the system. The first argument is that the intention world is already a representation where agents can analyze and plan their behavior. The only addition needed is to allow the user/designer to do the same.

Fig. 4.14. *half-life;* Enemy soldiers seem intelligent by acting out collaborative skills. The pictures in the second row show close ups of the soldiers covering the frontrunner.

In games like *half-life* and *Final Fantasy VII,* the characters still function, a l-though the spectator can destroy the illusion of reality for a moment by "touching" or entering the characters as shown in Fig. 4.9. In the *Final Fantasy VII* the characters have different types of powers referring to their types of weapon. In an episode the main character Cloud is entering a weapon shop, where the owner tells him how to use the different weapons. This is staged by a displaying a tutorial for editing the actual weapons, completely outside the world of the characters (in terms of Fig. 4.9, this means contacting the agent engine), after which we enter the story world again.

The second argument is that the editing process in general seems to involve a modal process of reification where actions are turned into objects:

> The notion of instrument can be seen as a reification operation: a command such as scrolling a document is turned into an object, the scrollbar. Reification is used widely in user interfaces to turn concepts into objects that can be represented and operated upon *Beaudouin-Lafon unpublished: 5*

Star Craft gives a simple example of how to associate actors to behaviors: the soldiers to the left in Fig. 4.15 are represented in 3 ways, shown in close-up to the right; as a video image, who speak simple one-liners, as dots on the map, and as little figures.

Fig. 4.15. *Star Craft.* In real-time strategy games behaviors are often shown as icons in a menupanel. The circle with the x means *patrol*, and the circle with the x and the dot means *hold position. (Blizzard Entertainment 97)*

Their behaviors are presented as ongoing and continuos in real time, shown as small animated movements of the figures and dots, and as facial movements in the video image. When the soldiers are selected as individuals or as group, they can be given orders to do a behavior by pushing the yellow buttons in the menu panel, the buttons representing reified behaviors.

4.5. Staging behaviors

Another important issue is the distinction between plot and story. The *plot* denotes the sequence of events as they are presented in a novel or film, whereas the *story* denotes the sequence and the causal relationships of the events as they are assumed to have happened in the fictive Actual World. The behavior analyses described in Section 3 are useful for constructing the story, but have nothing to say about how to design the plot.

Story and plot differ in time scale: the time of the story is the narrated time, whereas that of the plot is the narrating time. In a few instances the two times can coincide, but normally they are different. The narrating time is often shorter than the narrated time, and in e.g. crime stories, the sequence of events are reversed: first the discovery of the crime is narrated, and as the plot unfolds, we regress back in narrated time until we are confronted with the beginning, the perpetration of the crime. The interplay between plot and story is a main means for creating entertaining sequences of behavior (Bordwell &

Thompson 1997: 89), and this means that the agents should not only be aware of the laws of the fictive Actual World, but must also know when to present the information to the user. Creating the plot is a difficult task, since it demolishes the spectator's picture of the events as they happened in the story by hiding important events, changing the temporal order, showing ambiguous events that might lead to different conclusions etc. The spectator must work his way from the behaviors presented in the plotline to the level of the story to fully understand the overall meaning of the performed sequences of behaviors:

> It is only at the level of the *fabula* or story that the series of distinct actions and interactions of the plot are understood to form coherent *sequences* governed by the overall purposes of their agents *Elam 1991: 123*

The agent must not only create the story, but also the plot.

Besides being able to cause or prevent a villainy, the agent must know the right time to disclose the act to the user, in short: agents must turn into actors, in the literal sense of the word, and always feel the gaze of the invisible audience in their backs. This statement has consequences when we turn to determining which properties should belong to the agent. In order to participate in building the story, the agent must simulate certain physical, mental and social properties, but as an actor, he should be able to control the stage too: camera angle and camera position, darkness and light, color schemes, effect-sounds, and music.

Consider first the requirement from Section 4.1-4.2 that the agent must be able to express modality: not only that a behavior is in the progress, but also that a behavior is impossible, possible, or abandoned. This can of course be represented by dialog, either diegetic or as asides to the audience. But more subtle means are to be preferred: suppose our villain actor enters the stage with the goal “I want X dead”. Many behaviors may have this goal on their add lists: *drown, stab, shoot, push,* etc. Now the villain discovers a knife on the scene and his planning mechanism determines that a precondition of “stab”, namely “I have a knife” can be instantiated, i.e. the villain is building the next step of a causally connected story. The user, however, does not know this computational state of the agent.

If the agent decides on a plot that requires the user to know his state of mind, the state has to be expressed. In order to do this, the agent must not only be able to move to the knife and grasp it, but also to influence the stage so that his state is communicated. This can be done in many ways: a spotlight can hit the knife; the lightning can darken; the effect-sounds can cease and give place to an ominous silence; the music can change, etc.

If on the other hand, the agent decides on a plot that requires the user to be ignorant of the villain’s acquisition of the knife, then the agent may cause the scene to cast a shadow on the weapon or he may move the camera to another place.

In both cases, properties of the stage must be controllable by the agent, and belong to his degrees of freedom, on a par with his possibilities of locomotion and speech.

A fundamental question is thus whether we should build the whole story world first, and then let the agents to act in it, or should we build the top of the iceberg, which is modeling the things to be shown in the plot-line only.

5. Putting it all together

In this section we shall put the material from the preceding sections together in a loose, although well-motivated, sketch.

The evidence presented above indicate that we need at least three layers of processes:

1. *The world of reflection, behavior, communication and scheming*. Discrete processes are necessary for representing our ability for systematic reflection and scheming, both with respect to our behaviors (planning moves and counter-moves) and speaking (planning rhetorical structures). The act of speaking presupposes an ability to imagine what other agents believe and intend and what they believe I believe they intend. Therefore this layer must contain recursive structures of the form shown in Fig. 4.11.
2. *The world of bodies, their movements and urges*. This existence of this layer is documented by the existence of the process-chunks identified by Vendler, Talmy, Johnson and others. It mediates between the layers of discrete and continuous processes, between behaviors and actions: on the one hand, it contains standardized and labeled schemata of processes that can be converted into discrete representations; on the other hand, these chunks are made of dynamic material that can be assembled into processes that can actually physically control actuators and sensors.
3. *The physical world of actions, mass, energy, velocity, etc.* This is the world in which the former two layers must ultimately be realized. Don Juan’s intrigues of seduction must ultimately be realized as caressing movements of arms and hands, and ingratiating sounds produced by his silken tongue. The transition from (2) to (3) must involve some kind of

> arbitration mechanism which must include the possibilities of fusing several action-lumps into one. Apart form the practical necessity of fusion (avoiding obstacles while striving for the door), fusion is necessary in order to generate ambiguous trajectories, be they physical or verbal actions, which again is mandatory for any plot of deception (Section 4.2). The deceiver always has two behaviors which must be realized simultaneously in one and the same action sequence: the real one and the faked one.

As shown in Table 1, there are two versions of this hierarchy, non-symbolic and symbolic processes, where the latter are a subclass of the former. Because of the symbolic processes, all processes, including the symbolic ones themselves, must live the double life of discrete and continuous phenomena, since symbolic processes cannot avoid articulating themselves and other actions into discrete elements. Without this doubling we would be able to tell stories about animals, but not fables about anthropomorphic foxes and roosters.

The interactions between the components of is unfortunately a matter of philosophical speculations, except that there is no top-down control: although I may be wrestling with a difficult chess problem, my body is still capable of executing the action schema of finding its way to the pub while avoiding by-passers, even if it receives absolutely no support from the analytical compartment — that may be completely taken by surprise by finding itself with a mug of beer in its (?) hands.

	Signs			
	Non-symbolic process		**Symbolic process**	
1. Discrete. The world of reflection, behaviors, communication and schemes.	Planning and scheming. (Componential analysis STRIPS, Maes).		Discrete sentence representation (Syntax, Rhetorics).	
2. Discrete + Continuous. Fusing behaviors into actions	Image and action schemata (Talmy, Johnson, Vendler,).		Textual, Interpersonal and Ideational functions (Halliday)	
	Fusing	Defusing	Fusing	Defusing
3. Continuous The physical world of actions, mass, energy, velocity, inertia, collisions and gravitation.	Actuator: *Acting*	Sensor: *Seeing.*	Actuator: *Speaking and writing.*	Sensor: *Listening and reading.*

Table 1. The agent.

An attractive idea, consistent with the notion of agents (Maes 1994) is that all components are themselves semi-autonomous agents that can be influenced by other components but handle the information according to their own logic. In addition, there is psychological evidence pointing in that direction (Engelkamp & Zimmer 1994).

Although Table 1 may contain sufficient processes to generate normal, every-day life-like courses of events, this is not what we are striving for. We want the agent to turn into an actor and generate interesting events, and this requires the agent to view the course of events, consisting of actions and utterances — signifieds and signifiers — as a signifier itself, produced for the benefit of an audience that are to extract pleasure from it (Table 2). Thus, the course of events turns into a story and must be presented as a plot to the on-looker.

Unlike everyday events, the mental reflections must become perceptible signs that enable the audience to make guesses about the character's long-term designs, his emotional make-up and his possible developments; the action schemata are no longer selected to merely produce the most efficient way from departure to destination, but must be contrived in such a way that the audience can enjoy suspense and surprises; and the actual physical trajectories of the actuators must replace efficient violence by sensual ballet-like brawls.

Signifier		Signified
Signified	Signifier	
Reflection	Rhetorics	Guessing the character's long term designs
Action schemata	Communicative schemata	Enjoying suspense and surprises
Physical trajectories		Enjoying movements of bodies and rhythm of lines.

Table 2. The actor

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