

Saying and doing at sea.

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Abstract: based on empirical field work in the maritime domain, the paper suggests a common model for semi-otic and instrumental activities, and shows how it can be used to analyze maritime maneuvers, communication, instruments and automatic systems.

1 The problem

This paper offers ideas for describing semiotic as well as instrumental actions, plus their interrelations. The motivation for this is empirical, namely field-work in the maritime domain conducted at the Center for Man-Machine Interaction (website <http://www.cs.auc.dk/~pba/ElasticSystems>). We visited a number of different ships, and made 60 hours video-recordings of work and communication on the bridge of Sally Maersk, a large container ship sailing from Gothenburg to Algeciras.



Fig. 1.1. Sally Maersk approaching Algeciras

A characteristic feature in these recordings is that instrumental actions directed towards maneuvering the ship and semiotic actions with the purpose of informing the crew and coordinating work were intertwined and in some cases could systematically replace one another.

Intertwined instrumental and semiotic actions are a consequence of the conscious demands of verbalization we encountered on some of the ships we visited. A crew member must say what he is doing in order to maintain the situation awareness of his colleagues. In particular, there is a very frequent pattern, the *ready-steady-go* pattern, where each action must be accompanied by an order or report. When the pilot was to disembark, it was verbalized in this way (the utterances stretched over some time):

- *Preparing*. Captain to Pilot: What time do you estimate to disembark?
- *Starting*. Pilot: I'm on the way.
-
- *Executing*. Officer reporting: Pilot on his way down the gangway.
- ...

- *Finished*. Officer reporting: Minus pilot, pilot vessel clear.

But instrumental and semiotic actions can also *replace* one another. For example, in open waters the officer of the watch would control the ship's course instrumentally by means of a "rudder knob" or the autopilot, whereas near harbors the captain would give rudder commands to the helmsman at the helmstand in order to change course. Furthermore, although some actions were primarily instrumental, they had an important semiotic side-effect. For example, changing the position of the machine-telegraph not only controls the physical speed of the ship, but also informs the bridge team of the intended speed. More examples can be found in Andersen (2000, 2001), cf. also Goldkuhl 2001: 2.

These observations motivate the following basic constraints for a useful theory:

- 1 Semiotic and instrumental actions are not different in kind but are rather end-points on a continuous scale.
- 2 Semiotic and instrumental actions influence one another.

In the following I shall sketch a descriptive framework and give authentic examples from our fieldwork.

2 The morphology of instrumental and semiotic activities

We start by suggesting a possible morphology of instrumental and semiotic activities.

2.1 Case theory

In order to characterize the activities I shall use *case-theory*. *Cases* describe the roles sentence parts can play in a sentence and are an old invention, since they go back to the case-inflexion of classical Latin grammar. They were revived by the American linguist Charles Fillmore (Fillmore 1968, 1977) that redefined them as pure semantic units, and allowed prepositions and word order to mark cases as well. Cases have been used by John Sowa (<http://users.bestweb.net/~sowa/cg/cgstand.htm>) in his work on a conceptual graph standard. In this paper we use the cases to describe the roles which participants can play in an activity, and we shall define activities by means of the case-roles they involve, in a manner similar to Halliday 1994. Cases predict the linguistic forms the utterances will take, and have a relation to corresponding action categories, but probably not in any straightforward fashion.

Still, case theory seems the best choice when we are interested in investigating the relation between what we do and what we say.

Agent	The volitional cause of an event
Experiencer	The experiencer of an event
Force	The non-volitional cause of an event
Theme/Object	The participant most directly affected by an event
Result	The end product of an event
Content	The proposition or content of a propositional event
Instrument	An instrument used in an event
Beneficiary	The beneficiary of an event
Source	The origin of the Theme of a transfer event
Goal /Destination	The destination of an Theme of a transfer event
Purpose	The purpose of the event
Time	The time of the event

Place	The place of the event
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Table 2.1. Case roles. Adapted from Jurafsky & Martin 2000: 609.

In the following we analyze actions as they occur in the crew's own interpretation, in order to ensure that the following abstractions have psychological reality. We shall be concerned with four main types of activities (cf. Halliday 1994, chapter 5):

1. *Instrumental activities* involve an animate *Agent* that intentionally applies an *Instrument* to an *Object*.
 - Shall *we* (*Agent*) keep *her* (*Object*) *in the forward spring and a stern line* (*Instrument*).
 - Can *we* (*Agent*) berth *her* (*Object*) *without a tug* (*Instrument*)?
 - Now look here, it is the *positions* (*Object*) that are added *with a ball-point* (*Instrument*) there.
 - Yes ... and I suggest that *we* (*Agent*) don't *use the mooring boats* (*Instrument*), *we* (*Agent*) can go alongside and *use heaving lines* (*Instrument*).
 - And stop the *stern thrusters* (*Object*) *captain* (*Agent*).
2. *Non-human events*. A variant of the previous pattern does not have an *Agent* but a *Force* (either natural force or artefact) in subject position. It often lacks *Instrument* but can have an *Object*.
 - Yeah, the *wind* (*Force*) in there tries to push *us* (*Object*) this way.
 - As long as it is out of the load program, right, then *it* (*Force*) goes up immediately.
 - But it is easy of course, if we are in no hurry, then you can just put it in "Nav" Mode, then *it* (*Force*) sails by itself (*Officer* about automatic system).
 - As *she* (*Force*) goes full speed at shallow water, then *she* (*Force*) creates a *water wave* (*Result*) (*Pilot* about fast ferry: *she* refers to the ship, not the captain of the ship).
 - The *wind* (*Force*) is pushing *us* (*Object*).
3. *Communicative activities* have an animate *Agent* (*Speaker*) that uses a medium (*Instrument*, *Location* or incorporated in the verb) to communicate some *Content* to a *Beneficiary* (*Addressee*)
 - Yes, it is the skipper, M, *you* (*Agent*) can tell the *purser* (*Beneficiary*) *that we add an hour during the morning* (*Content*).
 - Because they listen in *on walkie-talkie* (medium, *Location*), those that are awake.
 - Could we go to *channel zero six, zero six* (medium, *Location*), over?
 - But *I* (*Agent*) tell *it* (*Content*) to *D* (*Beneficiary*), I don't know if he has tried it before.
 - *You* (*Agent*) tell *them* (*Beneficiary*) *a lot* (*Content*), right?
 - *I* (*Agent*) said to *him* (*Beneficiary*) *that as soon as you were finished steering, you would come down so that we could get it in* (*Content*).
 - (*Phoning*) Yes it is A...*I* (*Agent*) am *phoning* (*Medium*) to *hear the ETA of the pilot at Maas* (*Content*).
4. *Interpretative activities*. The last activity is interpretation of instruments and warnings; it involves a *Representation* of some sort, an indication of the *Reference* of the representation, and a *Comment* on the interpretation. Case-theory is generally bad at

describing processes that are not actions, so I had to invent special categories for this kind of activities. Here are some authentic examples:

- B: yes, but um...*it* (Representation) points to *eighty eight* right now (Reference), *the course, it is eighty nine* (Comment)
- B: Do you remember this one, E, *it* (Representation) keeps blinking "fault" (Reference)...*what the hell can be wrong then, after all, it looks like it has printed...*(Comment)
- B: Now look here...it is the positions, there is written *something* (Representation) with a ballpoint there, this *tank* (Reference), was it the one, "empty not cleaned". A: Yes. B: *In the loadstar, it figures only as an empty tank, there is no IMDG instruction* (Comment). (IMDG = International Maritime Dangerous Goods code)
- (Looking at the turn rate indicator, Representation). Yeah, there is no *turn rate* right now (Reference), so *we are just angling in very slowly* (Comment)
- Yeah..., what does *it* (Representation) point to on this variable...time variable...*15* (Reference), yes I think so, they are probably lying about there ... *but something is wrong* (Comment), what if I switch to the aftermost transducer (switches over)
- X: *bridge alarm* (Representation). B: There is no *error* (Reference) in it, *it was a remote control failure in main engine* (Comment)
- (*DSC alarm*, Representation, "Digital Selective Calling system"). C.: *What* (Reference) is it they serve up ... *there is nothing wrong with it...no* (Comment). B: No, *it is just "all all ships call"* (Comment)
- B: Try and look here, now, um, now I gave it the next five ones, right, look, now *it* (Representation) came up to "RPM limit", and that means, *the torque, it is, it is about being at bit on the high side...for the reason that it does accelerate a bit too fast, right ...*(Comment).

2.2 Two types of mediation

Based on these patterns we can make essentially two abstractions. (1) The instrumental activities seem to belong the basic pattern proposed by activity theory (Raeithel 1992), a Subject (Agent) is changing some Object by means of a Mediator (Instrument). (2) In the interpretative activities, according to Peirce, a Representation (Peirce: Representamen) stands for an Object in some capacity or respect (Interpretation, Peirce: Interpretant). Peirce's *Object* corresponds to the label *Reference* and his *Interpretation* to the label *Comment* above. In both traditions, the basic figure of thought is depicted by a triangle (Figs 2.1-2.2).

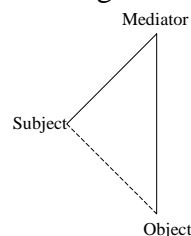


Fig. 2.1. The Activity Theoretic triangle

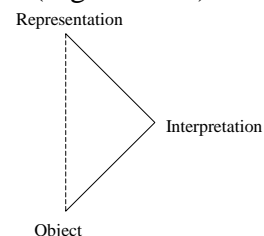


Fig. 2.2. The semiotic triangle.

Because of our data, we need to combine the two triangles in one construction, but how do we do this?

Meaning processes were in fact early added to activity theory by Vygotsky, Bakhtin and others (Raeithel 1992: 97). One way of combining the triangles is to equate the Representation with the Tool (Mediator) asserting that

Tools and machines have “external effects” while language and other signs are directed “internally”, and thus realize self-regulation (Raeithel 1992: 96)

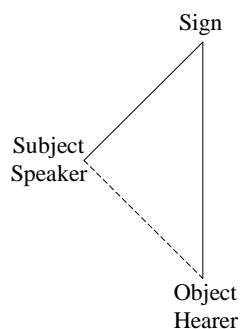


Fig. 2.3. The hearer as the object of semiotic action



Fig. 2.4. The conveyor tube model of communication

However, against this solution (Fig. 2.3), which is reminiscent of the conveyor tube model of communication (Fig. 2.4), speaks the fact that the impact of a hammer on a nail cannot really be compared to the reaction of a human interpreting a sign:

A sign does not have the direct causal force of a tool, rather it must be “picked up” by the second subject, accepted as meaningful and legitimate, and turned into some action by its/her/his “own” force. (Wells 2002: 48.)

The point here is that communication is much more indirect than material actions: you can force the nail into the wood, but you cannot similarly force an opinion into your conversation partner, except in degenerate cases like brain-wash.

As an alternative model, I propose that conversation is a kind of co-construction where the participants take turns to construct a shared text. The semiotic Object of conversation is not the other participant, but rather the topic of the conversation (but of course the other participant may happen to be the topic).

Second, it is not the coparticipants who are the object of the “speaker’s utterance act” – except in the sense that the utterance is directed to them; rather, the object is the issue, problem, or topic that is the focus of their joint consideration. (Wells 2002: 50)

A speaker can of course make clear to the listener that he intends him to believe or do something; but the outcome solely depends upon the goodwill of the listener.

Another important difference between instrumental and semiotic mediation is that communication generates social structures which instrumental actions *in themselves* do not.

Material tools and semiotic signs play different roles in activity...As the recipient of a semiotic action, the addressee is more likely to produce a rejoinder or to perform a relevant material action himself or herself than to be transformed in any significant material way. (Wells 2002: 49)

There is nothing inherently social in hammering a nail into a piece of wood; a “next turn” is undefined for a bystander. In opposition to this, a question creates a pressure for the listener to produce an answer, and an order generates a need for an acceptance or rejection. One turn

generates the next and in this way enrolls the participants in a temporary social system (Luhmann 1984, 1990).

2.3 A unified model

My suggestion is therefore the one illustrated in Fig. 2.6. Its point of departure is the fact that it is the Interpretation, not the Representation, that plays the role of mediator in Peirce's semiotics. The Interpretation mediates between Representation and Object in the sense that it indicates the aspect under which the former stands for the latter, or the rule according to which this takes place. My suggestion is therefore that, typically, Mediator = Representation and the two Objects are the same.

This configuration seems in fact very useful in analyzing instruments. As an example, consider Fig. 2.5. On the one hand, the wheel is a physical Mediator (Tool) between the driver and the front wheels. On the other hand, any Peugeot driver that looks at Fig. 2.5 will understand that the front wheels have been turned and the car will move to the right, provided that he knows the right rule (Interpretation) that relates steering wheel to front wheels. Thus, the wheel is both a Mediator between driver and the wheels *and* a Representation that denotes the direction of the car.



Fig. 2.5. Steering wheel in a Peugeot 306.

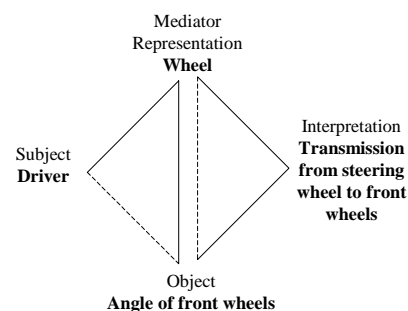


Fig. 2.6. The combined triangles.

Fig. 2.6 will be the basic figure of thought explored in this paper. However, since nearly everything can be used as a sign, we will also meet other configurations in reality. The instrumental Object, for example, can easily be used as a Representation of Tool or Subject: if I encounter a stump of a tree in the woods, I can take it as a sign of the workings of a chainsaw or an axe by inspecting its surface, or, if I know who has the right to collect firewood there, I may infer the identify of the Subject of the activity (I owe this to Susanne Bødker).

Fig. 2.6 claims that all activities are double: in addition to tools mediating the relation between subject and object, there is a second-order reflection going on that uses the tool as a sign for the object. Or, to put it differently, all activities are interpreted:

But in many situations, when observing other people's behavior we understand what they are doing. Their behavior is meaningful to us...Actions directed to other persons need to be comprehensible, otherwise the addressee might respond in an inadequate way. *Goldkuhl 2001: 9.*

After having arrived at a common representation of instrumental and semiotic activities, we need to distinguish them in some way. According to Posner 1993, the purpose of communication is for the speaker to make the listener aware of the fact that the speaker intends the speaker to believe something (assertions), to assume an obligation to do something (direc-

tives), or to trust that the speaker has assumed an obligation (commissives). One can say that semiotic activities aim at making the listener *or* the speaker himself change his Interpretation (the latter happens in soliloquies where the speaker is a listener to his own communication).

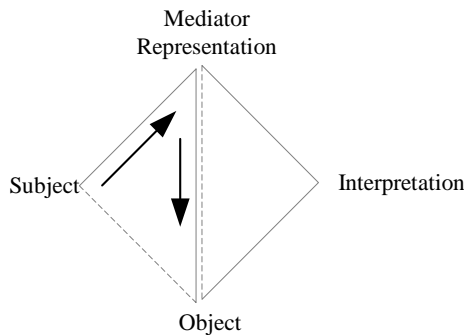


Fig. 2.7. Instrumental mediation

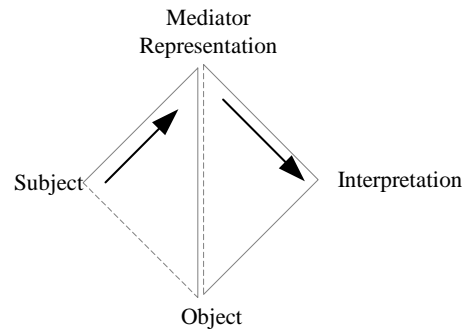


Fig. 2.8. Semiotic mediation

We can symbolize the difference between instrumental and semiotic mediation by introducing a main direction in the basic diagram from Fig. 2.6. If the main direction is from Subject, via Mediator to Object, the activity is instrumental, even if the Interpretation changes as a side-effect. On the other hand, if the main direction is Subject \rightarrow Mediator \rightarrow Interpretation, then the activity is semiotic, even if the Object should also happen to change.

A communicative action aims primarily at establishing some change in knowledge; i.e. that some other person gets to know something. A material action aims primarily at establishing some change of material conditions with importance to somebody. This other person must usually understand the change of material conditions, otherwise this material action will not lead to intended effects.

Goldkuhl 2001: 10.

In instrumental mediation, the Interpretation is the meaning attributed to the activity by the Subject or an Observer. In the former case it guides the activity, in the latter case it is the meaning attributed by the Observer. Consider for example a car moving back and forth near the pavement. The driver is not just moving the car, he is trying to park it, and, although the Observer can only see a car moving, he will make sense of the event by seeing a driver parking his car. In semiotic mediation, the Interpretation is a particular way of relating Representation to Object.

Although there seems to be a connection between the two Interpretations, they may not coincide. Interpretations of instrumental activities represent the distinctions we need to act, whereas those of the semiotic activity reflect those we need to talk about activities.

In some cases, one action interpretation corresponds to several semiotic interpretations. For example, cases are used to define a variety of perspectives on actions (Fillmore 1977) and therefore allow variation in the way activities are viewed. Does the different grammatical roles of the medium of communication in *We communicate by walkie-talkie* (instrument) and *We listen in on walkie-talkie* (location, literal translation from the Danish original) indicate that the action structure is different, or is the same action structure just staged in two different ways?

In other cases, we need two action concepts where language has only one. Petersen (2000) describes a furnace plan where ore is transported into the furnace by a conveyor belt and molten ore lead out by means of a pipe. If too much ore is lead out, the error cannot be in the pipe since it is “passive” whereas the fault may be in the conveyor belt because of its “active” na-

ture. The belt runs too fast. In this case, we need to distinguish between two variants of agents, active and passive ones, in order to arrive at the correct error diagnosis. But language treats the two cases identically. We say *the conveyor belt transports ore into the furnace* but also *the pipe transports ore out of the furnace*.

In spite of these differences, the distinction between instrumental and semiotic activities has now become a matter of degree. In verbal communication, the semiotic aspect dominates, since material objects of communication do not change just because we talk about it; this is only true of social objects that can be changed by performative speech acts like *wedding*, *sentencing*, *appointing*, *firing*, etc.

In instrumental mediation, the instrumental path dominates. Even if there will always be an associated Interpretation, the purpose is to change the material object. For example, cutting firewood has the primary purpose of cutting the wood into pieces, but the way I am doing may also serve to impress my wife.

Instruments in process control, like the maritime ones we shall look at later, lies in between: the main purpose of the machine telegraph is to change the speed of the ship, but it is designed in such a way that the speed intended by the captain is clearly interpretable by all crew members just by looking at it (Fig. 2.9). The machine telegraph is also a good example of how activities can move historically on the instrumental/semiotic scale. In the old days, the machine telegraph was in fact a communication device which the captain used to signal to the engine chief who did the actual manipulation of the controls (Fig. 2.10). This kind of self-service represents a move from semiotic to instrumental mediation, and is very characteristic of our times.



Fig. 2.9. The machine telegraph represents the desired state of the Object, the speed of the ship.



Fig. 2.10. Old machine telegraph. The orders to the chief are communicated by pressing buttons

We have now proposed a solution to the first requirement, that semiotic and instrumental actions should not differ in kind, but are rather end-points on a continuous scale. Let us try to tackle the second one: we want to describe how semiotic and instrumental actions influence one another.

3 Process types

Before we do this, we must give a slightly more detailed account of instrumental and semiotic activities.

3.1 Counterfactuals states

Consider a situation where pilot and captain stand amidships on the bridge, with the helmsman placed at the helm. The pilot issues course commands, like (1), to the helmsman (Fig. 3.1).



Fig. 3.1. Helmsman, pilot and captain.

(1) Pilot: Steady as she goes, please.

The command aims at making the helmsman maintain the present course, and three factors are involved (Lind 1994): the actual present course, the desired future course, and the counterfactual course that would result, had the helmsman not done anything (called *the passive projection* by Ryan 1991). In this case, the actual and the desired course are identical, and the passive projection is different, since the ship may be set off course by wind and current.

The pilot is maintaining a certain situation whose stability is threatened by external forces. Other activities involve the same three concepts, but combined differently, as in (2):

(2) Pilot: Stop engine, Captain.

The actual state is that the engine is running and will continue to do so if nothing is done; the intention is to suspend the present state.

In summary, when we specify an instrumental activity we need at least three elements: the state of departure, the intended future state, and the counterfactual state that would obtain, had we not done anything. A possible notation is shown below where the counterfactual state is italicized.

Maintaining:

Course is 200 → Course is 200
Course is not 200

Suspending:

Engine is running → Engine is not running
Engine is running

In some cases the three states are negations of one another, but in most cases it is not sufficient to describe states negatively. For example, in most course commands, one definite course is replaced by another. When the pilot says

Pilot: Zero eight seven

...

Pilot: Zero eight five

he wants the helmsman to go from 087 to 085, knowing that if he does not say anything it will stay on 087.

Producing:

Course is 087 → Course is 085
 Course is 087

Apart from *Maintaining*, *Suspending*, and *Producing*, we also have *Preventing* where a negative state would result, had we not intervened. A signpost warning against smoking in bed is an example:

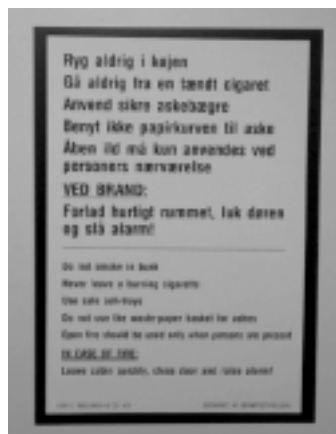


Fig. 3.2. Preventing fire.

Preventing:

No fire → No fire
 Fire

Thus, the general form of object transformations is the following:

Material → Active Result
 Passive Result

It says that activities aim at changing a material into a result by an active intervention, but always with a thought of what would happen if we did not intervene. The benefit of this analysis is that we can not only describe normal productive actions, but also preventive and supervisory work, yes even smart exploitation of natural forces can be analyzed. For example, if the wind is in the right direction, the captain can let the wind blow the ship to quay. In this activity type, the passive projection and the intended state coincide.

Letting:

Ship not at quay → Ship at quay
Ship at quay

We can recognize these types in semiotic activities too. Introducing a new topic of conversation is *Producing*, reminding people of a point they may have forgotten is *Maintaining*, *Suppressing* occurs when polite people try to avoid disagreeable topics, and *Letting* is the strategy of the smart debater: let them talk, they will eventually end up sharing my opinion.

3.2 Semiosis

A main difference between instrumental and semiotic activities concerns *who* effects the transformation. In recent years, the tendency has been to assign a much more active role to the listener. It is the listener that decides whether to listen at all, which interpretation he gives to the sign, and which possible actions should follow his interpretation.

Compare two ways to get people out of your office; one is the polite semiotic way where you look at your watch and say “I am sorry I have to throw you out, but I have a meeting in five minutes”. Your visitor understands immediately and says “Well, we are also finished now I think, so I’ll say goodbye”. You only try to make the visitor understand that you want him to leave, and he does the rest all by himself. The instrumental way is to use physical force and push him out of the door. The former method maintains your social relations intact; the latter method is a violation of the integrity of the chocked visitor who will probably terminate all contacts with you.

What basic rules should we assume to govern semiotic activities? Below is one suggestion that is based on two recursive processes (processes that use their own output as input)

- (1) *Understanding*: $\text{Interpretation}_t \rightarrow \text{Interpretation}_{t+1}$ / in the context of Representation_t
- (2) *Speaking*: $\text{Representation}_t \rightarrow \text{Representation}_{t+1}$ / in the context of Interpretation_t

When I hear my conversation partner’s next utterance – a new Representation – my previous Interpretation is changed (1); and subsequently my newly created Interpretation can make me transform *his* old Representation into a new one which I can utter myself (2). My partner changes his old Interpretation into a new one in the light of the Representation produced by me (1), and, in the context of his new Interpretation, transforms my old Representation into his new contribution to the conversation, and so on and so forth.

In the example below, our ship is leaving Felixstowe, there is some traffic, and the captain and pilot are interpreting what they see on the radar and through the front pane. The representations they use are the radar, their pointing gestures and gaze directions, their verbal conversation, and what they see through the front pane. Their interpretations are determined by their task of maneuvering the ship through a heavily trafficked canal, so they view all ships as potential causes of future trouble.



Fig. 3.3. “Okay...ferry coming in there”

- P Okay ... ferry coming in there
 C Yeah he is right here
 P Small ship there
 C Yeah
 P and the dredger
 C No that is the dredger..
 P That is the dredger, and there is a small ship
 (...) coming in or .. I'm not quite sure what
 course he is gonna take, but we will see in a
 minute

Text 3.1. Comparing radar and reality. P = pilot, C = captain

It is easy to see that they use the other's previous representation to build their own new one. For example, the ferry is referred to as “he” since it has been mentioned in the previous utterance, and part of the previous utterance is repeated in the next: *and the dredger* → *No that is the dredger..* → *That is the dredger....*

In this way we can explain why texts have *cohesion* and *coherence*. *Cohesion* means that the text refers to the same recurrent set of objects by means of nouns and pronouns (Halliday & Hasan 1977).

Cohesion occurs where the interpretation of some element in the discourse is dependent on that of another. The one presupposes the other, in the sense that it cannot be effectively decoded except by recourse to it. When this happens, a relation of cohesion is set up, and the two elements, the presupposing and the presupposed, are thereby at least potentially integrated into a text.

Halliday & Hasan 1977: 4

Typically, a new object is introduced in one sentence, and commented upon in the next. Texts without cohesion seem not to be about the same world from sentence to sentence.

Coherence is a different concept. Coherence occurs when the meaning of the text can be arranged in simple symmetrical structures within a limited set of dimensions. The set of dimensions is normally called the *isotopy* of the text, because they are meanings that recur as a part of many sentences and words.

The recursive rules predicts these phenomena: because new Representations are built out of old ones, the new ones will contain traces of the old one (repetitions, anaphors); and because new Interpretations are built out of old ones, the new ones will retain the conceptual structure of the old one. In our case, the distinction between dangerous and harmless ships is maintained throughout the conversation, so that when the captain later asks about a ferry *Is he coming in without a pilot....* the question is interpreted in terms of this distinction: ships without pilots sometimes behave unpredictably and even illegally.

Note also the *maintenance* action done by the captain: the Pilot makes a wrong identification of the dredger, and if the captain had not intervened by saying “No, that is the dredger” the wrong identification would have lived on.

Finally note that verbal representations are not used alone, but together with other representations, like the radar. This is the typical case.

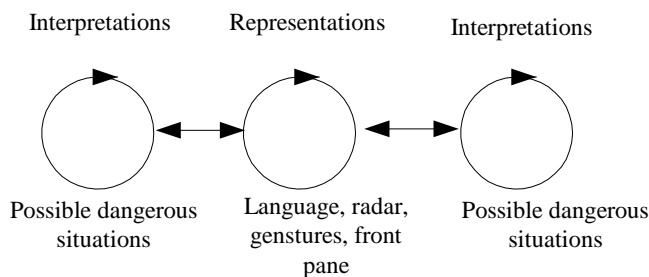


Fig. 3.4. Recursive systems mutually perturbing one another

The model suggested above makes a number of empirical predictions: because there are three recursive processes – their shared conversation and their individual reproduction of interpretations – that are perturbed by one another but always use their own output as input, the prediction is that only people that interact regularly are able to form converging interpretations, whereas their Interpretations will spontaneously drift apart otherwise. Shared interpretations are the exception rather than the rule!

Another prediction is that soliloquy (egocentric speech) can be a rewarding activity where new insights can be gained. In the conveyor tube model, it makes no sense for me to send a message to myself; after all, I know it already since I sent it. In the model above, an individual engaged in a monolog – e.g. writing a paper – is interacting with a foreign system, the language system that he only partly understands and which has amassed experiences and points of view that are not his, but were produced by his forefathers during many hundreds of years. There is something to be learned by interacting with such a system, and learning is possible since the speaker is also a listener.

Finally, because the rules are recursive, the systems have opportunities for building up complexity by self-organizing processes. This seems at least to be the case in the chemical domain according to Prigogine & Stenger (1984). They find recursive reactions interesting because they are the only ones that can produce chemical instability:

in a chain of chemical reactions occurring in the system, the only reaction stages that, under certain conditions and circumstances, may jeopardise the stability of the stationary state are precisely the “catalytic loops” — stages in which the product of a chemical reaction is involved in its own synthesis. (Prigogine & Stenger 1984: 145)

In Prigogine’s theory, instability in its turn is a necessary prerequisite for self-organizing processes in systems far from equilibrium. Under the far-from-equilibrium condition, small fluctuations can create a new and more complex order in an unstable system.

In semiotics, we also have to stipulate self-organizing processes in order to account for the complex syntactic and phonetic structures discovered by linguistics. (see Andersen 2002 for further arguments)

4 Interaction between instrumental and semiotic activities

There are essentially two ways in which semiotic and instrumental activities can influence one another: either instrumental actions depend upon communication, or it is the other way around. The former is the case with commands; the action will not be done, had the communication not taken place. A typical example is given in text 4.1.

Pilot: Starboard twenty
 Helmsm: Starboard twenty
 Helmsm: (turning rudder and watching the rudder angle display)
 Helmsm: Starboard twenty
 Text 4.1. Rudder commands

The helmsman is not supposed to turn the wheel except when hearing a rudder command, so his action on the wheel depends upon the command. A command *produces* the action. On the other hand, he will not report “starboard twenty” before the rudder angle pointer has reached twenty, marking his action as finished. Thus, his report depends upon the termination of his action. The action *produces* the report.

However, there is more to it than that. Notice that the full command is not given: the pilot neither bothers with the Agent (the helmsman does it), the Time (it is now), the Verb (turn), or the Object (the wheel). The choices are reduced to the Manner slot with a few degrees of freedom (the wheel can be moved 30 degrees to each side) as shown in Table 4.1.

Agent	Modality	Verb	Object	Manner	Time, place
Helmsman	should	turn	wheel	starboard or port , 1-30	Now, at the helm stand

Table 4.1. The Interpretation of the Helmsman’s activity. All cases except the Manner slot are filled out beforehand.

The reason for this presupposed knowledge is found in Section 3, rule 1 – 2: the Interpretation of a Representation is predominantly a transformation of an already existing Interpretation. This existing interpretation has filled all roles except the Manner role, and therefore the new Interpretation can be built of the old one just by updating the Manner case, i.e. the rudder angle. Andersen, Carstensen & Nielsen (2002) presents a classification of communicative functions based on the distinction between *backgrounded* slots that are already filled out and *focus* slots open for discussion.

Thus, the dependency between the semiotic and the instrumental action consists in the former filling out a missing parameter in the latter.

When we talk about instrumental actions here, we mean *anticipated actions*. Anticipated actions are specified in most respects but contain a few empty slots, in Table 4.1 the Manner slot. The skill to anticipate actions is important in navigation, as we saw in Text 3.1. In our data, most activities are talked about before they are executed, and because of the many contingencies at sea, plans can be reviewed and changed many times before they are executed. In our fieldwork we recorded a 9 hours conversation whose subject was procedures for entering Rotterdam harbor. The procedures were revised, refined, and rescheduled continually during this period of time (Andersen 2000, Section 3).

Thus, semiotic actions are used to modify and fill out the Interpretation of anticipated instrumental activities; but the same mechanism of slot-filling can also be used to describe dependencies between purely instrumental activities. Consider the simple action of mowing the lawn:

Agent	Verb	Object	Instrument
I	Mow	The lawn	Lawn mower

Table 4.2. I mow the lawn by means of the lawn mower.

In order for this activity to take place, all fillers must be qualified to fill their respective roles, but unfortunately Instrument, Agent, as well as Object may be substandard.

Instrument: I pull the cord, but nothing happens. Therefore I get hold of a wrench and start to repair it. The lawn mower ceases to be an Instrument and turns into an Object of an auxiliary activity, namely repairing the mower, a process called *focus-shift* in Bødker 1996.

Agent	Verb	Object	Instrument
I	Repair	Lawn mower	Wrench

Table 4.3. I repair the lawn mower by means of a wrench

The main activity of mowing the lawn (the *end*) thus comes to depend upon the success of the auxiliary activity of repairing it (the *means*). We will say that the repair activity changes the mower’s material *ability* to enter into the role of Instrument in lawn mowing. This can be diagrammed as shown in Fig. 4.1 where the repair activity changes the relation between the lawn mower and the role of Instrument in the mowing activity in the positive direction.

Agent: In a similar way, the semiotic activity of studying the manual will change the relation between me and the Agent role in the activity: I become better suited for playing that role. However, apart from ability, human agents must often also be morally qualified, i.e. they must both be *obliged* and *entitled* (deontic logic) to assume the role, or they must *desire* it (axiological logic). In the lawn mower example, the obligation could be created by my wife, or as a silent pressure from the neighbors. On a ship, obligations are created by means of the watch schedule, and rights are generated by appointments. Captains are entitled to be Agents in more activities than 2nd officers.

Object: Finally, the reason for failure in the mowing project could also reside in the Object itself: the lawn could for example be too uneven and bumpy to be mowable. This would generate a third auxiliary activity, namely redoing the lawn.

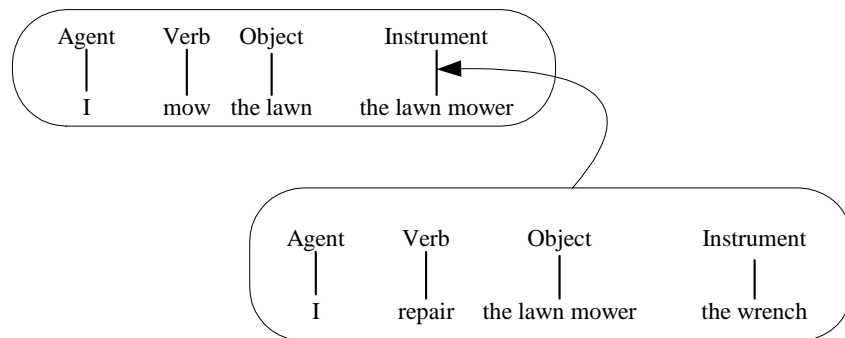


Fig. 4.1. Means and ends. Instrumental actions influencing instrumental actions.

The diagram for rudder commands, where semiotic activities influence instrumental ones, are given in Fig. 4.2.

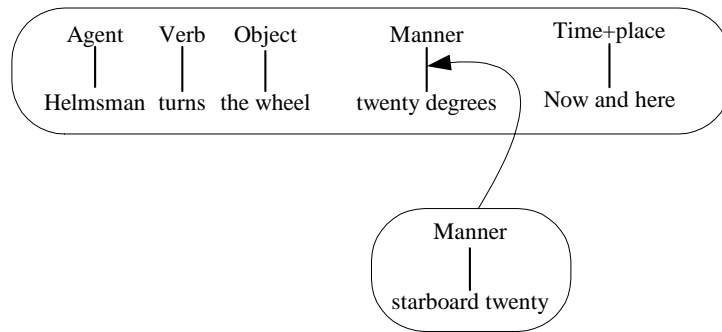


Fig. 4.2. Rudder command. Semiotic action influencing instrumental action.

In both Fig. 4.1 and 4.2, a slot-filler is provided or enhanced. The difference between the two cases is that the filler (the mower) in Fig. 4.1 is changed materially to function better as an instrument, whereas in Fig. 4.2, an anticipated activity becomes further specified.

A possible metaphor for describing these processes is a lump of *glue*. The glue specifies the probability, ability, desire, obligation, or right of a filler to fill a specified role in some activity. When two activities influence one another, one of them changes the glue between a role and a filler in the other one. Only when all glue in an activity is above a certain threshold can the activity be executed. Many activities live most of their life as anticipated activities whose glue is too weak to warrant execution. Aesthetic products in fact functions by means of a conscious manipulation of glue, because, as Hitchcock knew, “There is no terror in the bang, only in the anticipation of it”.

Plans are a good example of activities that live most of their life as anticipated activities whose fillers are too weakly glued to their fillers to be executed. We saw an example above where the plan for entering Rotterdam harbor took 9 hours to finish. The goal of the voyage is to land Sally in a designated berth in Rotterdam harbor. In order to do this all fillers must be qualified and specified to a degree that enables execution. This is true of the Force, Sally, that must sail to Rotterdam in order to be able to berth; and it is true of the Destination, the berth, that must be empty. The method of emptying the berth is that Gudrun, that occupies it, finishes loading. And, finally, it is true of the Time for landing that must be specified. The tour to Rotterdam is well under way, so Sally will soon be able to land, but although the captain knows that Gudrun will sail, he does not know the exact time. Gudrun is supposed to inform over the VHF band, but it turns out that it is the VTS that finally gives the information. Fig. 4.3 shows this setup.

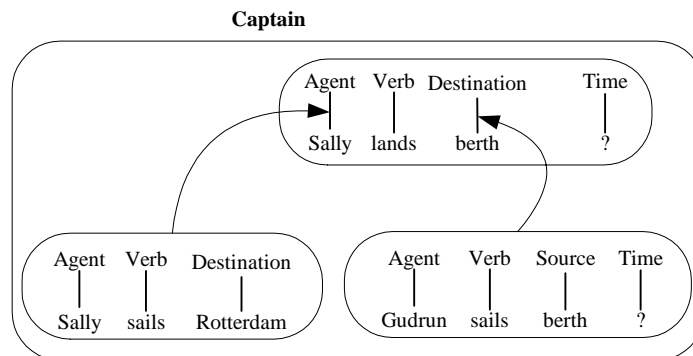


Fig. 4.3. Incomplete plans.

The captain's plan exists with a question mark in the Time slot during the whole voyage, and this gives rise to 24 discussions and revised scenarios for entering Rotterdam harbor. The problem is that if we just sail ahead, we will reach the harbor too early and will have to anchor inside the harbor, which the Captain does not want, because of possible current, wind and traffic. In order to avoid this, we can try to kill speed by going slow; and if this is not enough, we can anchor in the roadstead outside the harbor. The contingencies are not only a problem for the officers; it also affects the crew, since they do not know when to stand by.

Apart from a "positive influence" which describes actions of producing and maintaining, we must also have "negative influence" in order to account for actions of suspending and preventing. For example, in Fig. 3.2 the ship owner tries to weaken the desire of the crew to become the Agent of "smoking in bed".

In narratives that live of the conflict between hero and antagonist the two characters will typically be engaged in activities that aim at preventing the other party from accomplishing his plan. If the villain is trying to shoot the hero with a gun, the hero can try to disqualify the gun from playing the role of Instrument by removing ammunition or hiding it; or he can disqualify himself from playing the role of Object in the murder activity by hiding; or the villain can be disqualified from the Agent role by tying him up or even killing him.

In the maritime domain, we also encounter positive and negative forces of this kind. In fact, maritime work can be said to be the art of balancing these forces against each other:

The movement of a ship is determined by the forces working at it. Some of these forces are controllable, others are not. In order to achieve a desired movement of the ship the captain must exercise controllable forces against the uncontrollable forces in such a way that the desired movement results.

DMI: Ship handling, Course Manual, 1995: 1

This battle between forces is exemplified in the text below where the 2nd officer and captain discuss a problem with maneuvering at low speed. We are still heading for Rotterdam but since our berth is occupied, we try to kill time so that we will only arrive when the berth is free. The problem is that when we reduce speed, the water flow along the rudder decreases, and this in turn decreases the effect of the rudder. We are having heavy side-wind, and therefore use supporting rudder, so when speed decreases, we need to increase the rudder angle to achieve the same effect.

- C Now look here, now you have to take care, now we are reducing speed, right, then the wind gets more power over the ship and...
- A Yes
- C ...and start to...There may be current too, so try and give it five degrees leeway to port.
- A We are already high up, we are steering seventy so...
- C Yes
- A ...and the course in the map says seventy eight...but it did take hold when I came over Noordhinder.
- C Yes, but it changes all the time here, right, but particularly when you reduce speed, then of course you become more sensitive to ...
- A Yes
- C ...both wind and current.

Text 4.2.

The goal of the 2nd officer is to maintain a course of 78 degrees. As shown in Fig. 4.4, the rudder plays a positive role in the activity, whereas the role of the wind is that of the villain's: the wind will change the course (the passive projection) if we do not counteract it by means of the rudder. The speed of the ship has a positive influence on the rudder: the more speed, the more power will the rudder have. But, on the other hand, if we decrease speed the rudder

will become weaker. In the diagram below, $A \longrightarrow B$ means that increasing the power of A will increase the power or magnitude of B. $A \longrightarrow \bullet B$ means that increasing the power of A will decrease the power or magnitude of B.

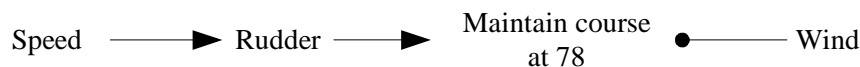


Fig. 4.4. Negative and positive forces

For this reason, the two activities, *maintaining the course by means of the rudder*, and *decreasing speed in order to save fuel*, become antagonistic, even if we are the Agents of both. Even if the Object of the fuel-saving activity, the speed, does not enter directly in the steering activity, it has a causal influence on the rudder that does enter into steering as an Instrument. Nature is so to speak staging a conspiracy behind our backs (Fig. 4.5. Another example of the same is when we set the rudder in reverse to brake the ship; the reverse rotation will produce a turning moment that will collide with the goal of maintaining the course).

Thus, dependencies between activities can be caused by physical dependencies between the fillers of role in the activities.

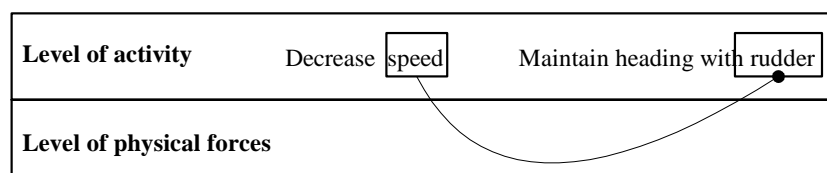


Fig. 4.5. Activity dependencies is caused by physical dependencies

The genesis of cooperative work may also be explainable by means of shared fillers of activities, or, more indirectly, by physical dependencies between the fillers, as suggested in the following definition:

Cooperative work is constituted by the interdependence of multiple actors who, in their individual activities, in changing the state of their individual field of work, also change the state of the field of work of others and who thus interact through changing the state of a common field of work

(Schmidt and Simone 1996: 158).

Maritime cooperation seems to be caused by three main factors: excessive demands on skills and knowledge, the inability of being in two different places at the same time, and the impossibility for two physical objects to occupy the same volume of space.

An example the former is the cooperation between pilot and captain. The captain knows the ship, but not the harbor, while the pilot knows the harbor but not the ship. Both possess parts of the necessary qualifications for being the Agent of the activity of steering the ship safely into the harbor. They share their work object, the ship, but only jointly qualify as an able Agent.

The second cause, not being able to fill two Location roles at the same time, earlier motivated cooperation between the officer of the watch and look-out, or between bridge and engine crew, since it is impossible for the same person to be on the bridge and in the engine room simultaneously. However, these cooperative forms are made obsolete by introducing remote control. The machine telegraph is a good example: as mentioned in Section 2.3, before it was a communication means between bridge and engine room, now it offers the cap-

tain direct access to the engine. In fact, much engine information has been made accessible to the bridge by means of computer technology (Fig. 4.6). In some cases, the engine room is even physically moved to the bridge (Fig. 4.7).

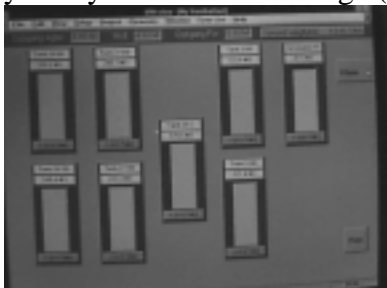


Fig. 4.6. Engine display from the Trekroner ferry



Fig. 4.7. Engine room is moved up on the bridge.
From the fast ferry Carisma

The third cause is the reason for cooperation between vessels: they cannot occupy the same volume of water at the same time, and therefore has to cooperate in order to avoid collisions.

Thus, it seems possible to specify the causes for cooperation in terms of simple restrictions on fillers of roles in work activities.

5 Levels of automation

Let us return to Section 2 where we tried to combine instrumental and semiotic mediation. The combined model is repeated for convenience in Fig. 5.1.

Fig. 5.1 seems to work well if we restrict ourselves to simple pre-industrial examples, or interfaces we have separated from the internal structure of the system, but the previous sections gave a hint that reality is more complicated than that.

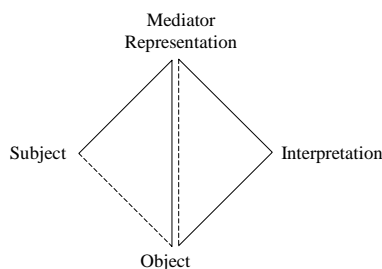


Fig. 5.1. Instrumental and semiotic mediation revisited.

In stead of having a nice set of *Subject – Mediator – Object* schemas, we are in fact faced with a hierarchy of physical levels, where activities take place on each level and between the levels. What is the Instrument in one moment becomes the Object in the next. Operators of complex machinery move their focus of attention up and down the levels of automation.

This is very clear in Text 5.1, where the captain is commenting upon his current activity, which is about increasing the speed of the ship. He discusses how fast the increase should be in order to get “worth for the money” and has figured out himself that five revolutions at a time may be a good idea. This is a rule relating acceleration of the propeller to the acceleration of the ship. His main activity is to maneuver the ship, so the ship and its speed is his ultimate work Object. And since he uses the engine to increase speed, the engine is the Instrument. But as he has direct access to the engine, he has also taken over the responsibility for

economizing fuel and protecting the engine, “when you think of the thermal influences of the engine”. Therefore his focus of attention shifts to the engine which also becomes his work object (*I could give it twenty at a time*), and, interestingly enough, to *the relation* between engine and ship.

Capt It is just something I do — like, um, it...I don't have any evidence, but you know, ... if (...). I could give it twenty at a time and (...) but, but, yeah, but um, as long as it is out of the load program, right, then it goes up immediately, and gives you a lot of revolutions, and, and, and, you don't get any worth for your money, it... it turns into foam, the whole lot, right, and, and, um, the engineers, they prefer this slow increase of...when you think of the thermal influence of, of the engine, it, it is a large Bertha lying down there.

Text 5.1. Representing the relation between acceleration of ship speed and engine revolutions.

This composite activity can be diagrammed as shown in Fig. 5.2. To the left, the captain uses an engine *display* (The “Maihak” display) and the machine telegraph *control* to manipulate the propeller's RPM under the Interpretation: possible damage to the engine. To the right he uses the speed indicator display to observe the effect on speed. There is a causal chain from propeller to speed. His speech constitutes a third Representation whose Object is the whole of Fig. 5.2, and whose Interpretation is “value for money”.

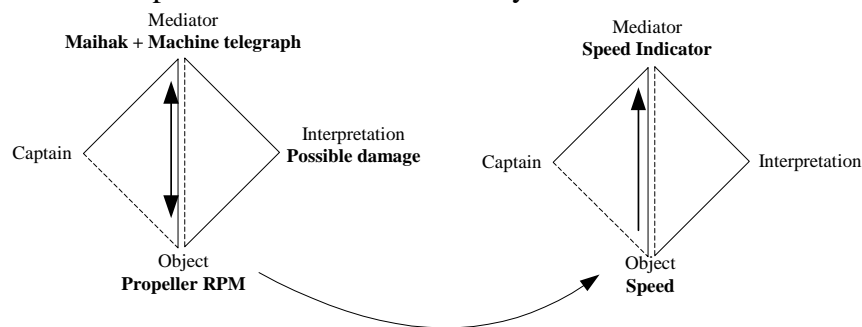


Fig. 5.2. Working simultaneously at two different levels. Controls are mediators that influence the Object, whereas displays are influenced by it.

How many levels should one assume? Petersen 2002 describes five levels of control available for ship navigation, and we could in fact find all five levels mentioned in bridge conversation, as exemplified in the table below. The captain above discusses the relation between level 4, force production, and level 2, vessel movement.

1. Spatio-temporal norms related to vessel position and heading.	P (leaving a harbour): he is coming <i>without a pilot</i> . Yeah, he is gonna pick up a Pilot ... in here, to go to Ipswich, which is sometimes a bit of a <i>problem</i> cause they don't always... realise exactly where they <i>should be in the channel</i>
2. Vessel movements	P (about speed): So we need about seven <i>knots</i> C: Yeah so we better start coming down... Yeah C. Yeah we will kill some <i>speed</i> when ... while <i>turning</i> here P: ... <i>turning</i> yes
3. Vessel momentum balance	C (about the diminished effect of the rudder due to low speed): Now look, you have to take care, now we <i>reduce speed</i> , right, so the wind <i>gets more power</i> over the ship, and...and starts so...there is possibly <i>some current</i> too, so give it five degrees drift to port.
4. Force production	P (worried about the functioning of the thruster): is she always <i>working</i> ? C: The thruster? P: The thrusters, yeah.

	C: Yeah.
5. Appearance and location of control devices.	C (about the size of the thruster propeller): what is the <i>propeller diameter</i> , it is something like, it is around <i>a meter</i> , not more, or <i>a meter and twenty</i> , I can't remember .

Table 5.1. Conversations at different levels

In the last sections we shall offer some ideas of how complex machinery is interpreted by its users, i.e. how Fig. 5.1 can be adapted to complex systems. Firstly we look at the object as described from a technical point of view

5.1 The system as described from a technical point of view

Technically, the levels can be reflected by *control loops* consisting of controllers. A *controller* (Fig. 5.3) is a piece of equipment that can receive two inputs, a *process variable* and a *set-point*. It finds the difference between the two and computes a *control signal* that is sent to another system part that influences the process variable. The signal is designed in such a way that the process variable will approach the set-point.

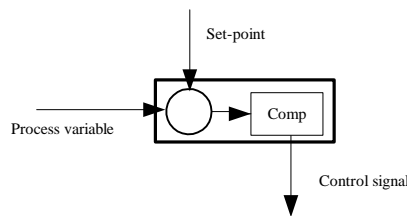


Fig. 5.3. Controller

In Fig. 5.4 we have illustrated two loops: the upper one, the autopilot, measures the course of the ship, displays it on the course display, and inputs it as a process variable, *the course made good*, to a controller. The controller calculates a control signal that will move the course towards the set-point, *the steered course*, that is input through the course knob of the autopilot. The control signal from the autopilot, *the rudder angle command*, is used as the set-point of the controller at the level below, *the rudder servo system*; however, if steering is manual, the rudder angle command is taken from the wheel.

The process variable of the rudder servo system, *the rudder angle*, is measured, the angle error is found, and a control signal, *the rudder position signal*, is calculated and used as a set-point to the rudder servo machine.

A real system contains many more control loops, both lower and higher ones: the Voyage Management System (a VMS system allows the captain to enter the voyage plan of the ship into a map in the form of a set of waypoints and keeps the ship on the track by sending course commands to the Autopilot) can be added on top of the autopilot and produce a control signal, *the steered course*, that is used as the set-point to the autopilot; and the valves and engines controlling the rudder are themselves controllers at a lower level.

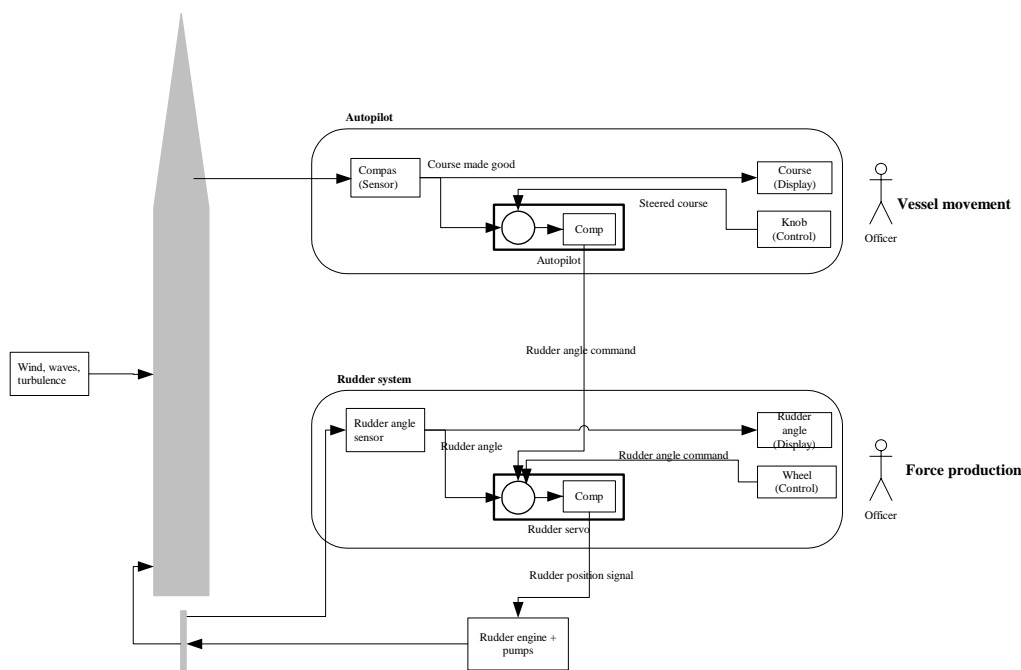


Fig. 5.4. Autopilot and wheel.

5.2 The system as described from the users' point of view

How does the crew interpret their work activities with this kind of machinery?

1. There is one pattern with *Subject = crew* and *Object = machinery*, as when the pilot says to the captain *Okay, stop the engine* or *and the stern thruster to starboard, Captain*. In both cases, the Instrument is implied: only the machine telegraph can stop the engine, and only the thruster controls can influence the thrusters. The pattern is: *the crew influences the machinery (by means of controls)*.

2. On the other hand, there are other examples where the grammatical subject is the vessel, the machinery or a natural force. For example, ships sail by themselves: *As she goes full speed at shallow water, then she creates a water wave* (Pilot about fast ferry: *she* refers to the ship, not the captain of the ship). Also the VMS system is seen as “sailing”: *then you can just put it in “Nav” Mode, then it sails by itself* (Officer about the automatic VMS system) or *You will always end by sailing against the current, because it will try to keep to the exact line* (Officer about the same system). Finally, natural forces can act as grammatical subjects as well: *Yeah, the wind in there try to pushing us this way ... so we go higher up into the wind and then turn*. The pattern may be: *natural forces or machinery influence the ship*.

3. There is a third pattern where the subject is the crew as in the first pattern, but the Object is the vessel as a whole. When the captain moves the telegraph he says *Dead slow ahead* and the pilot comments *Yeah we can give her a kick ahead Captain*. The Subjects are captain and pilot (*we*), but the Object is not a piece of machinery but the ship as a whole (*give her a kick ahead*). Later the captain says: *So we get her down to two knots then*, where the Object is speed, a property of the vessel. The pattern seems to be: *the crew influences the ship (by means of machinery)*.

5.3 Signs of automation

The technical perspective and the users' point of view seem to be related in the following way, corresponding to what Petersen 2002 calls *doing* and *bringing about*:

In a specific control situation the *ability to do* is determined by the ability to manipulate a specific system component (part of the means-system). This includes the controls provided by the interface of the human-machine system, the ability of the operator to manipulate these controls and the possibility of the control system (*control means*) to manipulate some system component. The ability to *bring about* is given by the capability of the means-system being manipulated to produce the desired consequences in the controlled system. *Petersen 2002, p. xx.*

Doing: the operators that provide the set-points become *Agents*, the controls and displays they use become their *Instruments*, and the Controllers become their *Object*. This corresponds to pattern 1 in the previous section: *the crew influences the machinery (by means of controls)*.

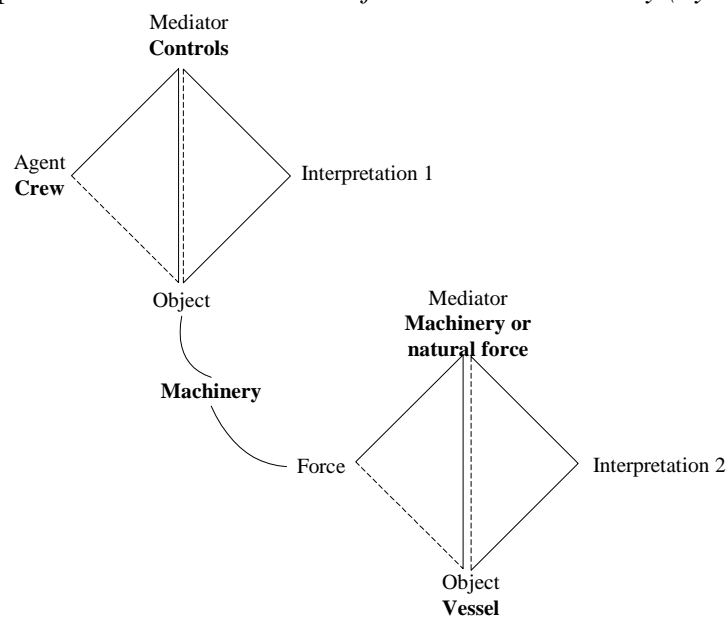


Fig. 5.5. The two layers of automatic machinery.

Bringing about: The Controllers providing set-points are *Forces*, the Controllers receiving the set-points are *Instruments*, and the Process Variable is the *Object*. This corresponds approximately to pattern 2 in the previous section: *natural forces or machinery influence the ship*.

We can diagram this as a two-layered figure in which the upper part corresponds to the do-activity, the lower part to the bring-about activity. The two layers hang together by sharing a filler, namely the machinery, that plays the role of *Object* in the upper part, but the role of *Force* in the lower one.

If we make a shortcut and disregard the intervening machinery, we get a third pattern where the *Agent* is the crew, the controls or the machinery is the *Instrument*, and the *Object* is the vessel as a whole. This corresponds to pattern 3 in the previous section, and is shown in Fig. 5.6. *The crew influences the ship (by means of machinery or controls)*.

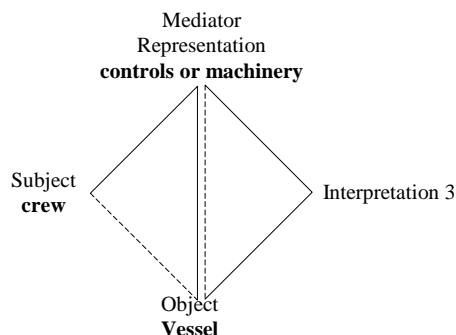


Fig. 5.6. A short-cut.

5.4 The Force category

Finally a word about the notion of Force that is used to represent the special role of automatic machinery. On the one hand, it is able to perform processes without continuous human intervention – it is in fact the reason for using it in the first place. If my dishwasher could not do the dishes itself, why spend money on it? In this respect it is like a human being, and some types of machinery could be viewed as reified versions of operations that were originally manual. On the other hand, it is not an intentional but a mechanical phenomenon, and in this respect is like other tools. It seems as if the grammatical behavior of the Force role reflects its position between humans and tools.

In some respects, a Force is grammatically similar to the Agent role: it is the part of speech to which causality is attributed, only it is inanimate, and no intention is implied as in Agents. But although both can occur in subject position, Forces and Agents behave differently in other respects. For example, artefacts in a Force role can often be converted into Instruments which Agents cannot. Whereas we can change *The bus drove me home* into *I drove home by bus* we cannot turn *My aunt drove me home* into **I drove home by my aunt*.

Similarly, although we can reformulate *The dishwasher cleaned the dishes* into *The dishes were cleaned by means of a dishwasher*, we cannot do the same to *I cleaned the dishes*: **The dishes were cleaned by means of me* sounds strange.

Finally, Forces are different from Instruments. Although we can convert *A hammer broke the window* into *The window was broken by means of a hammer*, we cannot turn *The storm destroyed the village* into *The village was destroyed by means of a storm*. The correct wording is *The village was destroyed by a storm*, analogous to *The village was destroyed by the Huns*.

Thus, our grammar is sensitive to the Agent/Force distinction, and the Force role seems to lie somewhere between Agents and Instruments.

6 Summary

The main points of this paper can be summarized in seven points.

1. Activities consist of Subject (Agent or Force), Mediator (Representation), Interpretation and Object.

2. In semiotic activities, Representations and Interpretations are recursively transformed in the context of each other.
3. In instrumental activities, Objects are materially transformed by means of a Mediator.
4. Anticipated activities can be analyzed into a limited set of roles. Linguistic cases and action roles are related but do not coincide. Fillers are bound to roles by means of “glue” that describes the propensity of the filler to act in the role.
5. An activity influences one another by changing its glue.
6. Activities come to depend upon one another because they share fillers.
7. Automatic machinery is layered. Users conduct activities at many different layers, and need to understand the relations between them.

7 Acknowledgements

I thank Morten Lind, Susanne Bødker, Johannes Petersen, and Morten Nielsen for inspiring discussions.

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