



Possibilities for Action

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1.0 INTRODUCTION

The aim of this paper is to develop concepts that are important for the formalisation of means-end analysis. The work is of preliminary nature and may therefore contain material that should later be revised. The particular problem addressed is to define the conditions under which an action or a sequence of actions are possible and therefore can be executed. This problem is obviously relevant in the planning of action sequences but it is also equally relevant in the analysis of observed activity. The context of the work is the identification of control tasks from empirical data in maritime operations. The paper does not refer specifically to this domain but it is believed that the work reported here is relevant to analysis of control tasks in this domain (Lind, 2000a). Some of the concepts developed have been used by Petersen and Nielsen(2001) in the maritime domain.

The paper is divided into three parts. The first part provides an analysis of the concept of action but is not, at the moment, absolutely necessary for reading the other parts. In the second part we analyse the modal concepts of capability and opportunity and show how they in two interpretations can be used to formalise the analysis of conditions for interaction between agents and objects. In the last part of the paper we explore different ways to combine actions into sequences. This part is inconclusive and require more work.

1.1 Problems of Analysing Action Sequences

Observing the performance of an activity does not reveal the underlying fabric of conditions and circumstances that must be satisfied for realization of each individual action and to enable the binding of the actions smoothly together into a sequence. The fabric is embedded in the setting of the activity but symptoms of its existence are only revealed when an action fails or when the fabric changes due to changes in the setting. The fabric of conditions and circumstances can be identified by analysing the intentions that are behind the activity i.e. ask what are the aims or why is the activity performed? In this way we can recognize consequences of the activity in the setting that mark the completion of the individual actions that are part of the activity. We can also see the activity as being the one actualized among a set of possible activities and ask: what are the feasible set of activities and what criteria were used by the agent to select the activity that has been actualized?

There is a simple reason why these questions unwrap the fabric of conditions and circumstances and that is that an action cannot be actualized if it is not possible in the first place. So, if an action has been identified (e.g. through its completion) we can analyse the setting and identify the conditions or circumstances that enabled and initiated the action.

2.0 ASPECTS OF ACTION

A complete specification of an action include the following five aspects (adapted from Rescher(1966)).

- *Agent* (WHO did it?)
- *Act-type* (WHAT was done?)

- *Modality of Action* (HOW was it done?)
 - a. Modality of manner (IN WHAT MANNER?)
 - b. Modality of means (BY WHAT MEANS?)
- *Setting of Action* (IN WHAT CONTEXT?)
 - a. Temporal aspect (WHEN?)
 - b. Spatial aspect (WHERE?)
 - c. Circumstantial aspect (UNDER WHAT CIRCUMSTANCES?)
- *Rationale of Action* (WHY?)
 - a. Causality (WHAT CAUSED?)
 - b. Finality (WITH WHAT AIM?)
 - c. Intentionality (IN WHAT STATE OF MIND?)

The aspects relate to the three steps involved in the realisation of an action - forming the intention, determining the feasible actions and the actualisation of the action. This will be explained below in more detail.

2.1 The Agent

The agent of an action may be an individual or a group but may also refer to physical non animate objects that have causal powers i.e. are capable of changing the state of other objects (Harré et.al., 1975).

2.2 The Act-type

The act type describes what the agent is doing. This aspect can be given on varying levels of abstraction. The act-type can be generic (“the opening of *a* valve”, “the turning of *a* rudder”) by only mentioning the type of object involved in the action. It can also be a specific act-type by involving concrete particulars (e.g. *this* valve or *this* rudder). A detailed specification of the act-type may accordingly include the specification of the types of objects or the particular concrete objects involved in the action but could also be a further qualification of the result of the action e.g. “turning the rudder *by 5 degrees*”.

2.3 The Modality of Action

This aspect describes the way an action is accomplished and includes both the means (the operator closed the valve by means of the *motor*) and the manner (the operator closed the valve by *starting* the motor and *letting it run for five minutes*). The aspect of manner describes accordingly the procedure for using the means and refer therefore to other action descriptions (*starting the motor* and *letting the motor run for five minutes* in the example).

2.4 The Action Setting

The setting of the action fixes the action in time and space. Thus the “opening of the valve” may e.g. be specified to take place every hour. The location of the action is not defined in this case, but in other cases the location should be specified in order to characterize the action properly (e.g. the closing of a robot hand when picking up a block or the turning of a rudder on a ship when at a certain location). The setting of the action includes also the circumstances that are required for the action to be possible and actualized. These circumstances may involve the condition of the agent and of objects and other agents interacting with the agent in the setting.

2.5 The Rationale of the Action

The performance of an action can be explained in three ways as a response to the question “Why did the agent do it”. It can be given a *causal* explanation as when the pumping of the pump is explained by the mechanical forces turning the impeller. However, the performance of the action can also be explained by referring to its *finality* i.e its aim or purpose Thus we can explain the pumping by referring to the purposes or the aims of the designer or the user of the pump. In the case of objects that are ascribed aims or purposes (as in the example) we are talking about indirect agency. These purposes could also refer to other actions e.g. in the case of the pump, the purpose of its pumping (in a circulation system) could refer to the transportation of energy which is a state of doing. The performance of an action can also be explained by accounting for the considerations that led to the doing of the action i.e. to intentionality including beliefs and expectations that provide the basis for a decision to intervene or to omit to act. In the case where actions are ascribed to objects this aspect would refer to the reasons why the object was selected by the user for a particular purpose or to the designers goals.

3.0 POSSIBILITIES FOR ACTION

In order to understand the conditions for intentional actions and forbearance it must be realised that the agent must have the ability to act. An agent that has an intention but is unable to act is impotent. Furthermore, an agent cannot forbear an act that he is unable to implement. The ability to act comprise actually a twofold condition: 1) the agent should have the *capability* to perform the action and 2) the setting should offer an *opportunity* to act. Note that concepts of ability, capability and opportunity are modal notions referring to the possibility for action not to the actualization or performance of the action.

A preliminary explanation of the concepts of capability and opportunity can be given by means of the figure below. Here the *opportunities* O are the state of affairs that can be obtained by *any agent in a specific setting* and the *capabilities* C are the states *that a specific agent is able to obtain in a range of settings*. The opportunities O and the capabilities C are (hopefully) often partially overlapping as shown below. The intersection R of O and C define the state of affairs that can be obtained i.e. are potentially within the reach of the agent in a given setting. R is therefore called the *reachability set*. The set R represents in this way several alternatives for action that each may be realized.

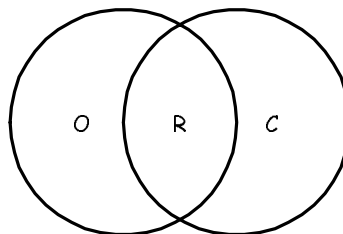


FIGURE 1. Opportunity, reachability and capability.

Note that the capabilities C represent the state of affairs that can be obtained by the agent in all possible settings each offering a set of opportunities. If there were states that could not be obtained by the agent in any setting it would not be meaningful to include them in C. The ability of obtaining those states would presuppose the existence

of at least one setting offering the opportunity for their realization. In this way the capabilities C of the agent is defined relative to a set of possible settings.

3.0.1 Extrinsic and intrinsic capacity and opportunity

It is necessary to distinguish between extrinsic and intrinsic capacity and opportunity. Take as examples a pump and a coin. The capability of the pump to produce pressure in a pipe is an intrinsic property (independent of its particular environment) whereas the capability of a coin to serve as money is an extrinsic property depending on the conventions of the agents handling the object. Similar distinctions can be made with respect to opportunities. Thus, the presence of water in a pipe provides an opportunity for flow because the water is movable. This property is intrinsic to the water and can be exploited if we have a pump which is capable of providing the required pressure for moving the water. The presence of a loaner provides an opportunity for the coin to serve as money. These distinctions will be elaborated later.

3.0.2 Non reachability as failure

The distinction between O and C is important for analysing failures of action in a dynamic environment (Lind, 2000b). Changes in the opportunities O could change states from being reachable to being not reachable even if the capabilities of the agent were unchanged i.e. the agent could bring about the states if the setting was different. Conversely, states reachable before a change can become not reachable if the capabilities C of the agent change. Here the failure to obtain a state can be resolved if the capabilities of the agent could be changed. It is seen that the two situations distinguished by the two conditions call for different remedial actions.

3.1 Two Perspectives

The distinction between capability and opportunity reveal accordingly two types of condition under which an agent is able to perform an action. It is realized that the two concepts have been defined above with a focus on the agent. In the following we will show that it also makes sense to define capabilities and opportunities in relation to the object. The modal concepts of capability and opportunity have therefore two interpretations depending on the perspective imposed by an observer describing the interaction (Fig 2). Note that the concept of possibility imply a cognitive agent (Rescher, 1979), the existence of an observer is therefore necessary.

The two interpretations correspond to two distinct observational situations. In the first situation the observer have an agent in the foreground and the objects in the setting in the background. In the second situation an object is in the foreground and the agents in the setting is in the background.

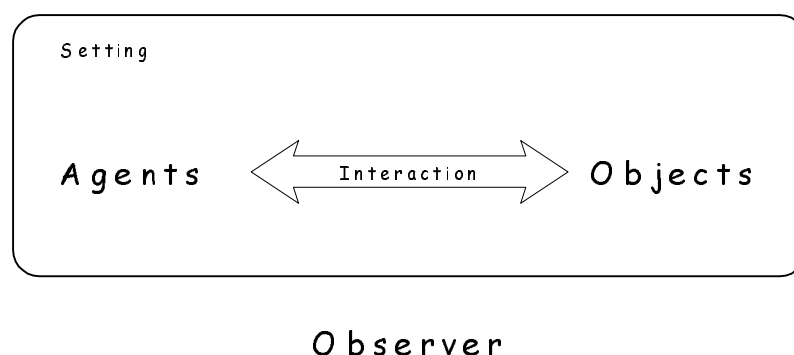


FIGURE 2. The description situation

Making a distinction between capabilities and opportunities does not imply that the agent or object is seen in isolation from the context. Describing capabilities and opportunities is merely to describe the same setting with two different emphases or perspectives. We shall return to this point below when we have described the two observational situations in more detail. For this purpose we must first introduce the concept of a *disposition*.

3.1.1 Dispositions

The concept of disposition is used to refer to the liability of objects to be in a particular state, or to undergo a particular change, when a particular condition is realized (Ryle, 1959). An example could be an object that has the disposition to be “moveable” i.e. when the proper conditions are satisfied it can be moved. The problem of disposition statements has also been discussed by Bunge(1972) and Mumford(1998). Mumford make connections between dispositions and functions as we do (see later). Bunge make the important observation that dispositions always come in pairs (Bunge, 1972). Thus in the example above, there should be a mover i.e. an agent that has the disposition to move blocks i.e. the agent can move a block under certain conditions.

3.1.2 An Agent in the Foreground

In this perspective the observer has the agent in the foreground i.e. the entity attended to and the objects and the other agents are part of the background.

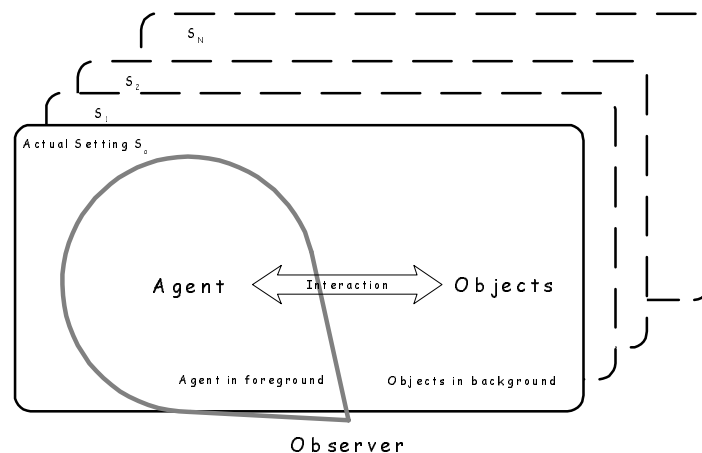


FIGURE 3. An agent in the foreground.

In this case we can define the *capabilities* of the agent as the doings the agent can realize in a range of possible settings $S_a, S_1, S_2, \dots, S_N$. The *opportunities* are the *functions or roles* the objects afford the agent in the actual setting S_a . The functions can also be defined as the subsets of an objects dispositions that are serviceable in a given setting (here S_a). Functions are here defined relative to the *particular* agent in view having an intention. In comparison, the dispositions of an object are independent of the particular agent (but not of the existence of *some* agent - remember that dispositions come in pairs). Note that the terms and syntax used for description of functions and dispositions are the same. The difference in their meaning relate to two different observation situations.

3.1.3 An Object in the Foreground

In the second case the object is in the foreground and the agents and the other objects are part of the background.

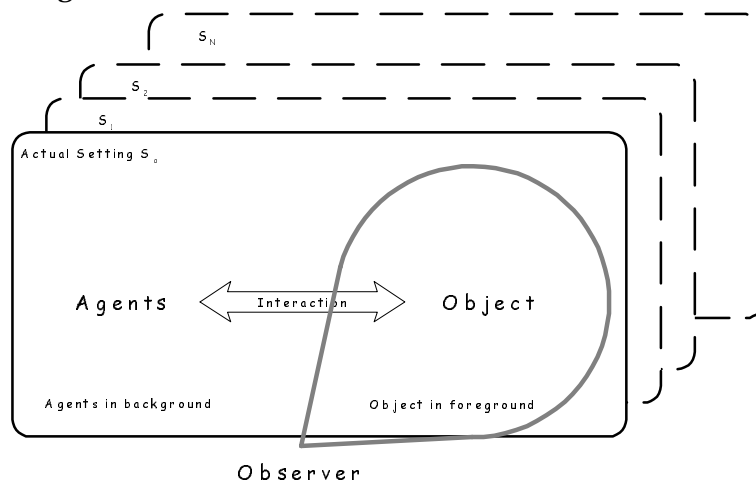


FIGURE 4. An object in the foreground.

Here are the *capabilities* what can be done to the object by any agent i.e. the *dispositions* of the object in a range of possible settings $S_a, S_1, S_2, \dots, S_N$. The *opportunities* are the *functions or roles* the agents in the actual setting S_a offers the object. Note that the roles are independent of the particular agent and depend only on the type of action in question. The object may occupy several roles at the same time.

3.1.4 Relations between the perspectives

It is clear that the two observational perspectives (Figs. 3 and 4) provide dual descriptions of the same setting and the descriptions are therefore related. They are related because functions or roles, as mentioned above, are the subsets of an objects dispositions that are serviceable in the given setting. They are also related because *roles are predication of doings*. The roles in an object perspective include only the roles that are relevant for the object in view i.e. in the context of a particular agent and not all the roles that are implied by the possible doings of the agent or the roles that were possible in the setting. Due to these relations we cannot distinguish between roles, functions and dispositions on the basis of their logical form or syntax. They are made of the same stuff so to speak.

The number of roles an object can seem to be infinite since there in principle are no limits to the number of distinctions that can be made between action types. However, the number of roles may be constrained in specialized sub-domains of action. An object offer therefore in principle unlimited opportunities for action. Of the same reasons, the dispositions of an object seems also to be unlimited in principle, since an object can be serviceable i.e. be used in action in an unlimited number of ways. An object has therefore in principle an unlimited capability. Note however, that dispositions can be conditioned so that e.g. a disposition is only available under certain circumstances or two dispositions may not be available at the same time.

3.2 Enabling Conditions

Capabilities and opportunities in both the interpretations discussed above can be conditional on some state of affairs. Thus, focusing on the agent, it can be the case that an object cannot participate in an action as intended unless some conditions for providing a

function or role (opportunity) are satisfied. In addition, an agent cannot act unless conditions for providing the capabilities for action are satisfied. Similarly (focusing on an object) an agent is only able to interact with an object if conditions for are satisfied. These conditions, comprising both capability and opportunity conditions, are together called enabling conditions.

3.3 Constraints

The concepts of capability and opportunity introduced above refer to state of affairs that can be obtained i.e. are possible to bring about. However, often it is also of interest to analyse the interaction between agents and objects in terms of the *impossible* by describing the mutual constraints between agents and objects in a setting that prevent the execution of actions.

The interaction between agents and objects is constrained in two ways. The doings (capabilities) of the agents restrict the functions or roles an object can have in the setting i.e. some dispositions of the objects (its capabilities) cannot be utilized because they do not match with the roles offered by the agents. Conversely, the dispositions of the objects in the setting will also restrict the doings i.e. make some doings impossible to realize for the agents because there are no objects to fill the role.

4.0 SEQUENCES OF ACTION

Above we have analysed the conditions that enable an interaction between agents and objects in a setting i.e. make it possible. In the following we will use this analysis to discuss how individual actions compose into action sequences. The questions of enabling conditions and sequencing of actions are related because an action may change the state of affairs in the setting so that the enabling conditions of another action are satisfied. This means that the two actions can be composed. In this way actions can be integrated into sequences of state transformations. A particular expression of this principle is described by the so-called 'praxis triangle shown below (Larsen, 1975).

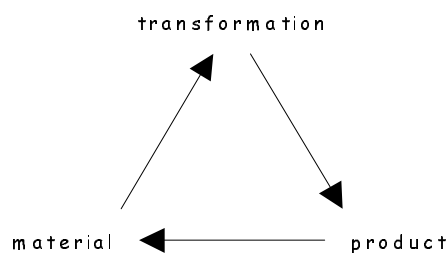


FIGURE 5. The Praxis triangle

The triangle describes how materials are transformed (through some action) into a product, and that the product can be the material (condition) for a subsequent transformation.

4.1 Activity Flows

Sequences of action can relate to the same object being acted upon in a sequence of steps (examples of such sequences are flow-structures in an MFM model). Here each level

describes the actions done on energy or mass. The sequence of actions of a robot in the blocks world represents an activity flow. The robot actions required to grasp a block A from the table, pick it up, move it, put it on top of another block B and ungrasp it is an example of an activity flow. Note that in an activity flow the *object* is in focus and the opportunities offered by the object determines the actions that can be realized i.e. the actions that have a role that fits with what is afforded by the object (e.g. grasp able and graspable-object (role)). Different dispositions of the object may be exploited through an action sequence (e.g. grasp-able, pick-up-able, move-able, put-able and ungrasp able).

4.2 Object Flows

Action sequences can also be repetitions of the same type of action that is applied on different objects. Examples can here be found in manufacturing systems where the same operation is done in sequence on a set of objects. Another related example is the use of reaction schemes in chemical engineering. Reaction schemes describe the transformation of chemical component molecules in a reaction product. The action is the chemical reaction. The robot example above can also be extended in this direction if we include several blocks that e.g. can be grasped at the same step. For example, if several blocks are put on top of each other, the same action 'put-on-top' is repeated on each block in the set. Since each 'put-on-top' action can be decomposed in to a sequence of action on each block it is realized that the action in focus in the object flow can be decomposed into an activity flow where the object is in focus (a means-end decomposition?). Note that in an object flow the *action* is in focus and that the opportunities (roles) offered by the agent determine the objects that can be subject of action i.e. the objects that have the dispositions to fill the role.

4.3 Rescher's Process Types

Above we have characterized two types of action sequences who were distinguished by the particular action done or object involved. Sequences can obviously be characterized in other ways. Below we will discuss a typification of action sequences or processes proposed by Rescher(1996). Rescher define a process as – "a coordinated group of changes in the complexion of reality, an organised family of occurrences that are systematically linked to one another either causally or functionally".

Rescher propose the following two distinction between productive and transformative processes:

- *product-productive* processes that produce actual products that can themselves be characterized as things or substances (for example, manufacturing processes that produce pencils or automobiles, seed germanization that produce plants).
- *state-transformative* processes that merely transform states of affairs in general, paving the way for further processes without issuing particular things or states thereof (for example, windstorms or earthquakes).

Following this line of categorizing we could also propose a third type of process:

- *product-transformation* process that produce changes in the states of a thing or substance (e.g. changes in shape, phase and form), but maintain its identity.

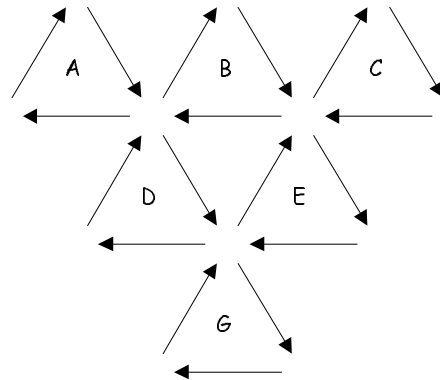


FIGURE 6. Embedded action sequences

4.4 Embedded action sequences

Above we have described how actions can be combined in sequences by a principle of composition. However actions can also be combined through an embedding principle which can be derived from the praxis triangle (Larsen, 1975). Sequences can be embed-

ed in three ways as shown in table 1. Complex activity patterns as shown above in Fig.6

TABLE 1. Three embedding principles

Explanation	Illustration
<p><i>Transcription</i></p> <p>The product of an activity is material for another activity.</p> <p>Example: connection relation in MFM</p>	
<p><i>Inscription</i></p> <p>The product of an activity is the means of transformation (e.g. action) in another activity.</p> <p>Example: A means end relation such as the mediation relation in MFM. A design-use relation. The control interventions in a process.</p>	
<p><i>Description</i></p> <p>A transformation (action) is material for another activity.</p> <p>Example: The flame problem – heat of reaction in the combustion of fuel and air. The heat is the material used for heating the boiler. Fuel and air are transformed into combustion products - carbon dioxide etc.</p>	

can be created by following these embedding principles.

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