Adaptive software process modelling with SOCCA and PARADIGM

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Abstract

One of the unsolved problems in the world of software process modelling is the question of formally incorporating change of a software process in the very model. To elucidate this problem and possibly solve it, the following approach has been chosen. In a standard case, the so-called ISPW-7 example, is change a part of the described problem situation. The purpose is that all, or many, existing software process modelling methodologies incorporate this change in their model for the ISPW-7 case. This hopefully leads to a better understanding of a general approach to model change.

In the ISPW-7 example has the process change been split up into two parts. One part addresses some form of permanent evolution of a process, this is called ‘process modification’. The other part addresses a temporary modification of the behaviour of the process, this is called ‘process exception’.

One of the existing software process modelling methodologies is SOCCA, which is currently still under development at the University of Leiden, department of Computer Science. This thesis concentrates on the topic of formally incorporating process change in the SOCCA methodology.

First, SOCCA has been extended with some new concepts to make it possible to model process change and secondly, this extended version of SOCCA has been applied to the ISPW-7 example. As it turns out, it is possible to model both the process modification part as the process exception part of the ISPW-7 example with aid of the new concepts introduced in this thesis.

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Chapter 1
Introduction

One of the unsolved problems in the world of software process modelling is the question of formally incorporating evolution of a software process in the very model. To this aim the standard software process modelling example as formulated in ISPW-6 [3], has been extended, among others, with change aspects. This has resulted in the ISPW-7 [4] example.

The extensions in the ISPW-7 example focusing on this so-called process change, have been split up into two parts. One part is intended to represent some form of permanent evolution of a process, this is called ‘process modification’ and it describes a permanent change in the behaviour of the process. The other part addresses a temporary modification of the behaviour of the process handling some exceptional circumstance, which has been called ‘process exception’; after the temporary modification, the process returns to its original form.

One way to model “normal” behaviour without any flavour of the above mentioned change, especially the behaviour of a software process model, is by means of dynamic descriptions. Dynamic descriptions which are used in this manner are in fact describing a specific form of change, as the current state of the object behaving according to the dynamic description, changes into another current state, which in turn changes into yet another current state, and so on. So a dynamic description of behaviour reflects some kind of change.

Within this thesis we have put this observation the other way round: it is possible to describe a change to something, like a software process model, with a dynamic description. Since a behaviour description is a dynamic description, the description of process change as mentioned in the paragraph above, which is a change in the behaviour of a software process model, can be considered as being a dynamic description (the change description) of another dynamic description (the behaviour description).

In PARADIGM, see [1], the concepts of processes, manager processes, employee processes, subprocesses, traps and state-action interpreters, have been used to describe a behaviour change as a consequence of the communication between the various processes: a manager process prescribes a subprocess to an employee process reflecting the behaviour of this employee before the communication; the employee may only behave according to the restrictions as imposed by this subprocess. After a while such an employee will enter a trap to another subprocess, which implies a communication to the manager, and from that moment on, the manager process may decide to grant permission to this employee to enter its new subprocess. This permission is the communication the employee is “waiting for” inside its trap. The effect of this communication then is the new behaviour of the employee after the communication as reflected by the new subprocess. So within PARADIGM communication has been used to describe a change of behaviour. By means of the communication between manager processes and their employee processes, this actually is a dynamic description of a dynamic description. Therefore it is useful to examine whether the PARADIGM approach can also describe evolution.

As PARADIGM is an integrated part of SOCCA and as SOCCA aims at modelling software processes, we will actually investigate whether the SOCCA approach can describe evolution too. This thesis gives the results of this investigation. In order to present these results, the thesis has been structured as follows: the following chapter consists of a short introduction into SOCCA and PARADIGM. In chapter 3 new concepts are introduced which are generalizations of the SOCCA concepts of external and internal processes. With aid of these new concepts, evolving software process models within SOCCA become something quite natural. In
Chapter 4 is shown how the new concepts introduced in chapter 3 can be used. Furthermore, chapter 4 shows some simplifications of the general approach, which problems can occur using these simplifications and some general solutions to solve those problems. Chapter 5 shows an example of the concepts developed in chapter 3 and in chapter 4. This example is based on a small part of the ISPW-6 example. In chapter 6 a larger part of the ISPW-6 example will be modelled using SOCCA and in chapter 7 this model used to show more of the aspects developed in chapter 3 and in chapter 4. This chapter follows the process change parts from the ISPW-7 example. In chapter 8 a brief comparison between SOCCA and some other modelling paradigms will be given with respect to process change and finally in chapter 9, some conclusions and topics for further research are given.
Chapter 2
A short introduction into SOCCA and PARADIGM

In [2] a complete introduction of SOCCA has been given. Those readers familiar with SOCCA may skip this chapter.

SOCCA is a software process modelling methodology, still under development at the University of Leiden, department of Computer Science. A SOCCA model describes the software process from three different perspectives; the data perspective, the process perspective and the behaviour perspective. To achieve this, SOCCA consist of (parts of) several formalisms combined together to describe the software process models.

The following formalisms have been used to cover the different perspectives:

- The data perspective is described by means of object-oriented class diagram models, based on Extended Entity-Relationship (EER) concepts. One of the features of the classes is that they can have export operations. Such an export operation of one class can call export operations of another class. To this aim in SOCCA an extra relationship exists between the various classes; the so-called uses relationship. Therefore, the class models have been extended with an extra diagram to display this uses relationship. Such a diagram is called an import/export diagram of the model.

- The process perspective will be described with so-called Object Flow Diagrams (OFD), being an extension of data flow diagrams with operations derived from the class diagram perspective. So in an OFD not only the dataflow is given as in data flow diagrams, but also the flow of the operations will be shown. The integration of OFD’s into a SOCCA model is still a topic of research. They will not be discussed further in this thesis.

- The behaviour perspective is covered with State Transition Diagrams (STD’s) with PARADIGM on top of them. The various classes have export operations which can be called in some order. To describe the order in which the export operations can be called, STD’s are used. So in fact, the behaviour of a class is described with an STD of which some transitions are labelled with the export operations of that class. Each such export operation has an internal behaviour; this internal behaviour actually achieves the task the corresponding export operation is supposed to perform. In SOCCA, STD’s have been used as well to describe these internal behaviours of the export operations. Since the cooperation between the external behaviour of a class and the internal behaviours of its export operations has to be coordinated, PARADIGM has been used in SOCCA to this aim. Moreover, the internal behaviour of an export operation can also call export operations from other classes. Therefore it is not only necessary to have communication between the external behaviour of a class and the internal behaviour of its export operations, but there should also be communication between the internal behaviour of the export operations from one class and the external behaviour of other classes. This communication is also modelled by means of PARADIGM. The STD’s describing the external behaviours are PARADIGM manager processes and the STD’s showing the internal behaviours of the export operations, are PARADIGM employee processes. In this way, the internal behaviour of an export operation can be controlled via the state-action interpreter of the external behaviour of a class. The italic terms will be described in the following section which gives a short introduction into PARADIGM.
2.1. A short introduction into PARADIGM

PARADIGM is a specification mechanism developed to model parallel processes. A PARADIGM model can be designed in the following manner:

- Describe the sequential behaviour of each process by means of a STD.
- Within each STD so-called subprocesses can be indicated. These subprocesses are subdia-
grams of the STD and are used for the coordination with other processes. The set of sub-
processes of one process is called a partition of that process.
- Within each subprocess certain sets of states, so-called traps, can be identified. By enter-
ing such a trap, an object indicates that it is ready to switch to another subprocess. The set
of traps of a process is called the trap structure of that process. One important property of
a trap is that, within a subprocess, there are no transitions leading from one of the states of
a trap to another state outside the trap. So when a process has entered a trap, it is no longer
possible for the process to leave this trap as long as the same subprocess restriction
remains valid.
- There is also an extra STD called the manager process. This process coordinates the
behaviour of the various objects. The objects of which the behaviour is controlled by a
manager process, are called the employee processes of that manager process. Depending
on the state it is in, the manager process prescribes a subprocess to each of its employees;
an employee may only behave according to the subprocess which is currently being pre-
scribed by its manager process. Next, the manager process monitors the behaviour of its
employees; when one of the employees enters a trap to another subprocess, the manager
process may follow a corresponding transition to another state where it can prescribe the
subprocess the employee wants to enter. Note that the manager can prescribe the new sub-
process to its employee but that it is not obligated to do this. The manager may postpone
prescribing the new subprocess to its employee as long as it wants to. The mapping of the
states of a manager process to the subprocesses it prescribes to its various employees and
the mapping of the transitions that a manager can make to the traps of its employees, is
called the state-action interpreter of the manager process with respect to the partition and
trap structure of its employee processes. So the state-action interpreter of the manager
process labels each state of that manager with the subprocesses it prescribes in such a state
to its employee processes and it labels the transitions with those traps that enable this tran-
sition to be selected.

One individual process may be the employee of more manager processes. When this is the
case, such a process will have a separate partition and trap structure with respect to each of its
managers. The behaviour of that process then will be controlled by all of its manager proc-
ceses together; at a given time instant, the process will be restricted to the intersection of the
various subprocesses prescribed by its various manager processes.

Note that this is only a very informal introduction into PARADIGM. The sequential behav-
iour of one process is in fact not fully determined by its STD. In addition to the STD a strategy
determines which transition in a state will be taken if several possibilities exist. Moreover, a
sojourn mechanism determines how long the process remains in each state. The strategy and
the sojourn mechanism can depend on the history of the process and on its current state. For-
malistically, the sequential behaviour of a process in PARADIGM is described by means of a
so-called decision process from the operations research field. However, the most important
features in SOCCA are formed by the STD which visualizes much of the behaviour of the
process and in addition to that a strategy, often informally described only, which tells what
transitions will be selected from a certain state when there are more possibilities.
Chapter 3
A way of viewing change

This chapter starts with the definition of some terms. As stated in the previous chapter, in SOCCA the various PARADIGM concepts have been used to manage the internal behaviour of the operations from a class via the state-action interpreters of the external behaviour of the classes. In the rest of this thesis, the internal behaviour of an operation is called an internal process and the corresponding STD is called the internal process description. Similarly the external behaviour of a class is called an external process and the STD describing this behaviour is called the external process description.

As also described in the previous chapter, the external process descriptions are PARADIGM manager processes and the internal process descriptions are the employees of these manager processes. During enactment of a software process model an internal process is restricted to one subprocess at a time (with respect to one partition of the internal process). Intuitively such a restriction to a subprocess is a behaviour restriction for this internal process; the internal process may only behave accordingly to those states and actions imposed by the subprocess. After remaining a while in the same subprocess an internal process will enter a trap towards another subprocess and at some time instant the permission to enter this new subprocess will be granted by the manager. As soon as the internal process receives this permission it will start behaving according to the new subprocess it has entered and it will remain behaving like this for a while. This type of behaviour change of an internal process is a direct consequence of the PARADIGM communication between the internal process and its manager process; the internal process changes from one behaviour restriction to another behaviour restriction as a consequence of this communication.

When analysing this total behaviour of an internal process it can be seen that the transition from one subprocess to another subprocess is the same kind of change as wanted for evolving software process models; when a software process model has to evolve, the behaviour of some part of the model has to be changed just like the behaviour of an internal process changes when it makes a transition from one subprocess to another subprocess. This evolution of the software process model can be considered as being a transition from one evolution stage (say evolution stage 1, EVS1) to another evolution stage (say evolution stage 2, EVS2). A conclusion drawn from this observation is that it might be possible to change a software process model by viewing its internal and external process descriptions as being subprocesses of some larger processes which have not explicitly been designed but which do exist. Furthermore it might be possible to view the total state space of the process descriptions from the SOCCA model up to now (which is in EVS1) as being a trap from the current process description to the newly designed process description (which forms the SOCCA model in EVS2).

For example, when one of the components has to be changed the new STD of the component, which does not yet exist, can be designed and after this design has been finished it can be activated by switching from the subprocess corresponding with the old STD to the subprocess corresponding with the new STD. This transition then corresponds with a transition from EVS1 to EVS2. Such a transition from one evolution stage to another evolution stage will be called an evolution step.

As the not explicitly designed external and internal processes combine the various behaviours of the software process model during all possible evolution stages, they will be called anachronistic external and internal processes in this thesis.

Note that viewing the process descriptions as being subprocesses means that we get a deeper
management hierarchy, in which a process can be both an employee process and a manager process at the same time. We get the situation that a subprocess (of an anachronistic external process) is managing the subprocesses of a subprocess (of an anachronistic internal process).

For example, let $E_1$ be an external process, $I_1$ an internal process and let $I_1S_1, ..., I_1S_n$ be the subprocesses of $I_1$ with respect to $E_1$. This means that in the original SOCCA approach, the process $E_1$ is a manager of the subprocesses $I_1S_1, ..., I_1S_n$ of process $I_1$. However, when $E_1$ and $I_1$ are considered being subprocesses of larger, not explicitly designed, anachronistic processes (say $E_A$ and $I_A$ respectively), then one can say that the subprocess $E_1$ is a manager of the subprocesses $I_1S_1, ..., I_1S_n$ of the subprocess $I_1$.

### 3.1. A condition for managing subprocesses of a subprocess

The notion of managing subprocesses of a subprocess is possible because a subprocess is a decision process by itself [1] and a decision process can have subprocesses [1]. Although it is possible to manage the subprocesses of a subprocess, a problem may arise; suppose that the above mentioned anachronistic internal process $I_A$ has another subprocess $I_2$ and suppose that $E_1$ is still managing the subprocesses $I_1S_1, ..., I_1S_n$ of $I_1$ (as in the previous section). Further suppose that for some reason the subprocess $I_2$ is prescribed in stead of $I_1$, for example when EVS2 has started in stead of EVS1. Then it can be no longer guaranteed that all states in the subprocesses $I_1S_1, ..., I_1S_n$ can be reached or do exist as some of the states and transitions of $I_1S_1, ..., I_1S_n$ may no longer exist in the subprocess $I_2$. Moreover, when the subprocess $I_1$ of which the processes $I_1S_1, ..., I_1S_n$ are subprocesses, is not prescribed, one could say that the subprocess $I_1$ and its subprocesses $I_1S_1, ..., I_1S_n$ temporarily do not exist. Therefore, it can not be allowed that a process $E_1$ is managing the subprocesses $I_1S_1, ..., I_1S_n$ of a subprocess $I_1$ which is currently not prescribed by its manager process $M_1$. Thus, to avoid these kind of problems, we need the following extra condition when viewing the external and internal processes as being subprocesses themselves:

When the subprocesses $I_1S_1, ..., I_1S_n$ of a process $I_1$, which in turn is the subprocess of a process $I_A$, are being managed by a process $E_1$, then the process $I_1$ must be prescribed by the manager process $M_1$ of the process $I_A$, with $M_1$ being the manager process of $I_A$ with respect to the partition of which $I_1$ is a subprocess of $I_A$.

### 3.2. Introducing the manager process WODAN

To formalize the change of a software process model during enaction, it is useful to introduce an extra manager process. This extra manager process will be called WODAN, which stands for What Ought to be Done As Necessary. The manager process WODAN is a manager of all (not explicitly designed) anachronistic external and internal processes and normally it stays in the same state, just prescribing the (explicitly designed) external and internal process descriptions. When a change has to be made, WODAN can go to a state which for example is called changing the model; when WODAN is in this state, the new external and internal process descriptions can be designed. Moreover, WODAN can also design new class descriptions when the static structure of the model has to be changed due to extra requirements. After the new model has been designed, WODAN can go to a next state prescribing the new process descriptions.
3.3. Three types of change

The changes made to a software process model to achieve evolution, can be split up into three different types of change; they range from a relatively simple change to more complicated forms of change. The following three types of change can be distinguished:

1) Do not change the state space, only change the strategies and the subprocesses and possibly add or remove transitions.
2) Do not add or remove processes, only change the strategies and subprocesses and add or remove states and transitions.
3) Add or remove processes and change the strategies, etc. of other processes.

3.4. The NULL process

Adding or removing processes within SOCCA, as in change type 3, is possible since the processes we are looking at, are only subprocesses of the anachronistic processes. When a process $E_1$ has to be added, one could say that the anachronistic process $E_A$ of which $E_1$ is a subprocess, already existed from the very beginning. However, WODAN was prescribing a nearly empty subprocess of it before the process $E_1$ was necessary. This nearly empty subprocess consists of one state together with one transition from this state to itself. In the same manner, a process $E_1$ can be removed during evolution by prescribing a similar nearly empty subprocess of the anachronistic process $E_A$ of which $E_1$ is a subprocess with respect to WODAN.

Such a nearly empty subprocess will be called the **NULL process**, or shorter NULL. This will also be used as a convention when designing WODAN to introduce new processes or remove old processes; in the states of WODAN where the process did not exist yet or has been removed already, the NULL process will be prescribed.
Chapter 4
Using the new concepts to describe an evolution step

In this chapter we will use the new concepts introduced in the previous chapter to describe the way in which an evolution step has to be performed. First we will give a very general method which will always work and then we will refine this method by making use of the notion that most times there will be many similarities between the processes before and after an evolution step. This however is a non-trivial notion which can lead to severe inconsistencies in the enactment state of the model when it is applied inaccurately. Thus we will also identify when such a refinement will fail and give some solutions to solve those inconsistencies in such a way that the refinements still can be used.

4.1. A general method to describe an evolution step

When an evolution step has to be made, the enacted SOCCA model has to make a transition from one evolution stage, for example EVS1, to another evolution stage, for example EVS2. During EVS1 a set of external and internal processes, reflecting the behaviour of some real life processes, will be prescribed by WODAN and during EVS2 another set of processes, reflecting the new behaviour of those real life processes, will be prescribed. Let for example P1 be an internal or external process reflecting the behaviour of a real life process during EVS1 and let P2 reflect the new behaviour of that same real life process during EVS2. Then, the processes P1 and P2 will both be subprocesses of the same anachronistic process Pa and during the evolution step, a transition from P1 to P2 has to be made.

The process Pa will be in one of the states of its subprocess P1 at the moment that the evolution step has to be made and it will be in one of the states of its subprocess P2 when the evolution step is finished. Thus the problem which has to be solved is that the process Pa must go from one of the states of its subprocess P1 to one of the states of its subprocess P2. As the subprocesses P1 and P2 may have no mutual states in Pa, this can be a real problem. This problem can be solved by using an intermediate, temporary, subprocess Pt of Pa which describes how the transition from P1 to P2 has to be made. This subprocess Pt has all states of P1, a non-empty subset of the states of P2 and possibly some extra states. Furthermore, it has for each state taken from P1 a path leading from that state to one, or more, of the states of P2. The trap from P1 to Pt can consist of all states of P1, making it possible to start the evolution step at any moment, regardless of the state of the subprocess P1 during EVS1. The trap from Pt to P2 can consist of those states of P1 which are taken from P2, thus the evolution step can be finished as soon as the temporary process is in one of the states which actually reflect some part of the behaviour of the modelled process during EVS2.

When using such a temporary process Pt, process evolution can be modelled as follows: during EVS1, WODAN prescribes the subprocess P1 of Pa. When process evolution is necessary, WODAN defines the new model, including the temporary phase and possibly a new EER model. WODAN will continue prescribing process P1 while the design phase is active. When the design phase has been finished, WODAN will prescribe Pt which reflects the behaviour during the evolution step, and as soon as Pt enters one of its traps, WODAN can prescribe P2, thereby actually starting EVS2. An example of this approach is shown in figure 1.
Chapter 4 Using the new concepts to describe an evolution step

It is very likely that during one evolution step, more processes will change and that also the communication between the various processes will change. The communication may change due to extra requirements. This can be modelled similar to the above sketched evolution step. However, in stead of using one temporary process $P_t$ for the change description of one anachronistic process $P_a$, one or more temporary processes have to be designed for each anachronistic process of which the behaviour changes from EVS1 to EVS2. In this case, more temporary subprocesses may be necessary per anachronistic process that changes because of the change in the communication structure. Such a communication structure change makes the evolution step more complicated; it may be necessary that the evolution step has to be executed in a phased manner to get the new communication between the various processes appropriate. Thus, in such a case, WODAN will first prescribe the first version of the temporary processes, wait until the appropriate temporary processes reach their traps, prescribe new temporary processes, and so on until the whole model is in a state which reflects some behaviour of EVS2 and from that moment on, the subprocesses $P_{2i}$ can be prescribed to the anachronistic processes $P_{ai}$.

Note that further categorisation of the various problems as a consequence of process change is a topic of future research.

4.2. Exploiting similarities between processes to refine the evolution step description

The general method described in the previous section makes no use of any information available about the specific problem of making one transition step. The temporary process $P_t$ has one separate state for each state of the process $P_1$ before the evolution step and some extra states taken from a non-empty subset of the states of the process $P_2$ which is prescribed after the evolution step. However, the processes $P_1$ and $P_2$ both represent the behaviour of the same real life process, which likely only changes slightly during the evolution step. Thus, there will be many similarities between the processes $P_1$ and $P_2$. For example, there can be a large overlap in the state space of $P_1$ and $P_2$, many transitions may be the same and there may be even many similarities between the trap and partition structure of $P_1$ and of $P_2$ when $P_1$ and $P_2$ are internal.
processes.

For example, when making a change of type 1 as described in section 3.3, the processes $P_1$ and $P_2$ will have exactly the same state space. In such a case, it might be possible to make the transition from EVS1 to EVS2 immediately, without using a temporary process $P_t$, as the process $P_a$ can stay in the same state when making the evolution step. Also, when a temporary process $P_t$ is necessary, this process $P_t$ can be designed much simpler; all states of $P_t$ can be taken from $P_1$ and the additional states which are normally taken from $P_2$ are now not necessary as they already exist in $P_1$. Thus, also the paths leading from the states taken from $P_1$ to the states taken from $P_2$ are in such a case not necessary.

In the following sections, we will examine whether it is generally possible to exploit these kind of similarities between the processes in the various evolution stages to simplify the evolution steps. We will also examine which kind of problems can arise with exploiting these similarities and sketch some ways to solve these problems in a formal manner with the aid of WODAN.

The study of the problems which may arise will be split up in two parts.

In the first part, an analysis at the level of the internal processes will be made; this discussion brings forward what inconsistencies may arise for the employee processes.

In the second part, the transition will be analysed at the more global level of the external processes. Since an external process in its role of manager process is responsible for the cooperation between the internal processes that form its employees, this part of the discussion underlines the possible inconsistencies in the cooperation control of the employees.

All inconsistencies will be related to the three types of change indicated in section 3.3. However, before starting with this survey, some terminology has to be introduced first:

- Let $P_A$ be an anachronistic internal or external process with two subprocesses $P_j$ and $P_k$, with $P_j$ the internal or external process prescribed during EVSj, $P_k$ the internal or external process prescribed during EVSk and $k=j+1$. So EVSk is the evolution phase next to and after EVSj. Then the process $P_k$ will be called corresponding with the process $P_j$.
- Let $P_A$, $P_j$ and $P_k$ denote the same processes as above. Furthermore, let $X_l$ be a state of $P_A$ which exists in both subprocesses $P_j$ and $P_k$ of $P_A$. Then the state $X_l$ in $P_k$ will be called corresponding with the state $X_l$ in $P_j$. So in fact, we will regard this same state as two different (but corresponding) states in the two corresponding subprocesses.

### 4.3. Possible inconsistencies as a consequence of process change

In this section, the consequences of switching from EVS1 to EVS2 will be examined to detect possible inconsistencies. This will be done in two steps; first we will examine the consequences of the process change for the individual internal processes and then we will examine the consequences of the process change for the cooperation between the internal and external processes.

#### 4.3.1. Consequences of process change for individual internal processes

In this subsection, the consequences of switching from EVS1 to EVS2 will be examined for the internal processes. We assume that only one process changes during the transition from EVS1 to EVS2. When more processes change, the cases below will hold for each individual process. The internal process under consideration will be called $I_1$ with subprocesses $I_1S_1$, ..., $I_1S_n$ during EVS1 and the corresponding internal process during EVS2 will be called $I_2$ with...
subprocesses $I_2S_1, \ldots, I_2S_m$. Furthermore we assume that the manager $E_1$ of $I_1$, and later of $I_2$, prescribes $I_1S_i$ during EVS1 and $I_2S_j$ during EVS2, and that $E_1$ remains in the same state during the transition from EVS1 to EVS2. So this means that the state-action interpreter $\phi$ also changes during the switching from EVS1 to EVS2, even if $E_1$ itself remains unchanged. Note that in this section we will not take the cooperation between the various processes into consideration. Thus, in this subsection it is not relevant whether the trap of $I_2S_j$ differs from the trap of $I_1S_i$. The consequences of changing traps will be analysed in subsection 4.3.2.

This situation is shown in figure 2.

![Figure 2. The general situation considered in this part](image)

As only one subprocess of an internal process is active at the same time, we will consider the possible differences between the subprocess $I_1S_i$ and the subprocess $I_2S_j$. There can be many differences between these two subprocesses. However, each difference will be a combination of one or more of the following four cases:

a1) $I_2S_j$ equals $I_1S_i$; this is the trivial case. As $I_2S_j = I_1S_i$ there is no change of process. Even $\phi(.)$ can remain unchanged.

a2) $I_2S_j$ does not have all states from $I_1S_i$; in this case the transition from EVS1 to EVS2 cannot be made as long as $I_1S_i$ is in a state that does not exist in $I_2S_j$. This is problem P1 and some solutions to it will be given in section 4.4. One of these solutions is very easy to apply, but cannot be used always. The other solutions are more complicated but they can be used always.

a3) $I_2S_j$ does not have all transitions from $I_1S_i$; if $I_2S_j$ is designed properly this does not cause any problem, the only consequence of missing transitions is that $I_2S_j$’s behaviour differs from $I_1S_i$’s behaviour.

a4) $I_2S_j$ has some states or transitions that do not exist in $I_1S_i$; this either does not cause any problem. The only consequence of this case is that $I_2S_j$ cannot be in one of these extra states at the moment that the moment that the evolution step starts.

Thus, we have found only one problem, called problem P1, which occurs in case a2.

Note that all four cases can occur which each type of change as mentioned in section 3.3. This is the case as we are looking at subprocesses of an internal process; even for the change of type 1, where no states are removed from or added to an internal process, a subprocess can have extra or less states since the subprocesses may always change.

### 4.3.2. Consequences of process change for the cooperation control

After the survey at the subprocess level in the previous subsection, we will examine the coop-
eration between the internal processes via an external process in this subsection. It is assumed that the external process can make the transition from $E_1$ to $E_2$ when the evolution step from EVS1 to EVS2 has to be made. When the change is of type 1, this assumption will always hold. However, when the change is of type 2 or type 3 it might be possible that the external process $E_2$ misses some states which exist in the external process $E_1$. This problem, which will be called problem P2, is similar to the problem P1 mentioned above. It can be solved with one of the solutions shown in section 4.4.2 when it occurs. Furthermore, it is assumed that only one external process changes. When more external processes change, the cases found below apply to each external process individually.

For the cooperation between the external process and the internal processes that form its employees, only the state-action interpreter of the external process and the partition and trap structure of its employees are relevant so it will be only examined how the transition from EVS1 to EVS2 influences these. The external process in EVS1 will be called $E_1$ and in EVS2 it will be called $E_2$. Furthermore, the state in which $E_1$ is before the transition, will be called $X_1$ and the corresponding state in $E_2$ will be called $X_2$ and the employees of $E_1$ will be called $I_I$ and $J_I$ and the corresponding employees of $E_2$ will be called $I_2$ and $J_2$ respectively. The following two cases can be distinguished:

b1) The state $X_I$ in which $E_I$ is at the moment that the evolution step from EVS1 to EVS2 starts, can only be reached via a path within $E_I$ which is equal to the path leading to the corresponding state $X_2$ within $E_2$. This means that $E_1$ and $E_2$ have an overlapping part from the start state up to the states $X_1$ and $X_2$ respectively, thus $E_1$ and $E_2$ have the same states, transitions, strategy and state-action interpreter from their respective start state up to and including the states $X_1$ and $X_2$ respectively. In this case, after the evolution step $E_2$ will be in a state in which it would have arrived at exactly the same manner as when $E_2$ had been active since the very beginning of the enactment of the model. Since $E_2$ would have arrived in this state in the same manner if it had been active from the beginning, there will be no difference between $E_2$’s history as it is after the evolution step and $E_2$’s history when $E_2$ would have been prescribed from the very beginning. Therefore, the evolution step from EVS1 to EVS2 can be made at once in this case. An example of this situation is shown in figure 3.

Note that in this case it is not relevant whether $I_2$ and $J_2$ have new or modified subprocesses during EVS2; the manager $E_1$, and later $E_2$, does not prescribe these new subprocesses in this part of the model so these subprocesses can not influence the behaviour here.

b2) This is the opposite of case b1, thus the state $X_I$ in which $E_I$ is at the moment that the evolution step from EVS1 to EVS2 has to start, can be reached via a path within $E_I$ which is different from the path to the corresponding state $X_2$ in $E_2$. In this case, the external process will have arrived in the state $X_2$ after the transition from EVS1 to EVS2 via a path it would not have followed when $E_2$ had been active since the start of the enactment of the model. As the path that $E_2$ would have followed to arrive in the state $X_2$ determines the global behaviour of its employees (via the subprocesses $E_2$ prescribes to its employees) and as it is also influenced by the behaviour of the employees (via the traps $E_2$ has to wait for before it can make the transition to a next state), it is possible that $E_2$’s state and history is not consistent with the state and history of $E_2$’s employees. One of the main problems that can occur, which will be called problem P3, is that $E_2$ should not have arrived in the state $X_2$ yet, because one of its employees has not yet reached a trap which $E_2$ was required to wait for in the past. Some solutions to problem P3 are shown in section 4.4.3.

An example of this problem is shown in figure 4. The manager $E_I$ is in state $X_I$, waiting for $I_I$ to enter trap $I_I$ when the transition to EVS2 is made. The manager, now called $E_2$, is still in the with $X_I$ corresponding state $X_2$ after this transition. However, according
Chapter 4 Using the new concepts to describe an evolution step

Figure 3. Situation b1: the first part of E1 and E2 is the same

First part of E1

External process E1 is the manager of I1 and J1

First part of E2

External process E2 is the manager of I2 and J2

Situation during EVS1

Situation during EVS2

Note that I1S1 in fact is the same subprocess as I2S1. Otherwise, the state-action interpreter of E2 would differ from the state-action interpreter of E1. The same applies for the combinations (I1S2, I2S2), (J1S1, J2S1) and (J1S2, J2S2).

Figure 4. The manager is different during EVS2

to the new model is I2S1, corresponding with I1S1, already in trap I2t1 when the manager is in state X2. Thus, the manager makes the assumption that it can make the transition to state Y2, were it will prescribe I2S2 to the employee I2. This, however, may not happen as the
trap I_{2\text{t1}} had not been entered when the transition from EVS1 to EVS2 was made. Section 7.3 shows an example which is very similar to this one. Note that both case b1 and b2 can occur with all three types of change.

### 4.4. Solving inconsistencies

In the previous section, three different problems have been mentioned that can arise at the moment that the evolution step from EVS1 to EVS2 has to be made. These three problems are:

- **P1** The subprocess I_{1}S_{i} of internal process I_{1} is within EVS1 in a state X_{1} without a corresponding state X_{2} in the subprocess I_{2}S_{j} which will be prescribed within EVS2 in stead of the subprocess I_{1}S_{i}. This problem can occur with all three types of change.

- **P2** The external process E_{1} is within EVS1 in a state X_{1} without a corresponding state X_{2} in the with E_{1} corresponding external process E_{2} within EVS2. This problem can only occur with change type 2 and change type 3.

- **P3** The process P is an external process and therefore a manager of some internal processes. It will arrive within EVS2 in a state X which it could not have reached yet within EVS2, since one of its employees has not reached a trap for which the manager should have waited in the past. This problem will mostly arise with change type 3, when a new process is added to the model.

In the following subsections, solutions to these problems will be suggested. Some of these solutions have also been used in the examples described in this thesis. The problem P1 arises in section 5.2, the problem P2 in section 7.6 and the problem P3 can be found in section 7.3.

#### 4.4.1. Solving problem P1: a subprocess of an internal process has less states

Let I_{1} be the internal process during EVS1, I_{1}S_{i} the subprocess prescribed by the manager, X_{1} the state in which I_{1}S_{i} is before the transition and let E_{1} be the manager of I_{1} with respect to the partition of which I_{1}S_{i} is a subprocess. Furthermore, let I_{2} be the corresponding internal process during EVS2, I_{2}S_{j} the corresponding subprocess prescribed by the manager, X_{2} a state corresponding with X_{1} and let E_{2} be the manager of I_{2} with respect to the partition of which I_{2}S_{j} is a subprocess. This situation is shown in figure 5.

Note that the state X_{2} is no part of I_{2}S_{j}. However, it can be a state of I_{2}. If there is no state X_{2} in I_{2} at all, a temporary version of the internal process can be defined which has a state corresponding to state X_{1} in I_{1}. This temporary version of the internal process will be called I_{t}, the state corresponding to state X_{1} will be called X_{t} and the subprocess corresponding with I_{2}S_{j} will be called I_{t}S_{j}. Furthermore, the manager of this process will be called E_{t}.

Note that X_{t}, I_{t} and E_{t} are not always necessary to solve the inconsistency. Whether they are needed or not, depends on the chosen solution. They will be used in the second solution down here. The processes named E_{t} in the solution S1 have nothing to do with the E_{t} as in the solution S2. The name E_{t} is only used to indicate that it is a temporary process.

The problem P1 can be solved in the following manners:

**S1** Let X_{ek} be the set of states of E_{1} in which the problem occurs. Thus, E_{1} prescribes in each state of X_{ek} a subprocesses I_{1}S_{i} while E_{2} prescribes from its corresponding state a subprocess I_{2}S_{j} which misses one or more states occurring in I_{1}S_{i}. It is possible to define a temporary external process E_{t} with the aid of the states X_{ek}. How this process will be designed is described below. When E_{t} has been designed, it is possible for WODAN to manage the transition from EVS1 to EVS2. To do this, it will consider all states of E_{1} together being a trap from E_{t} to the process that forms the successor of E_{1} during the evolution of the software process model. This successor will now be the external process E_{t}
The temporary external process \( E_t \) will be designed analogous to the external process \( E_1 \). However, there will be two differences between \( E_1 \) and \( E_t \). The first difference is that \( E_t \) has a smaller trap with respect to WODAN; the trap of \( E_1 \) consists of all states of \( E_1 \) while the trap from \( E_t \) to \( E_2 \) consists of all states of \( E_t \) except for the states of \( X_{ek} \), which lead to the problem. In this way, WODAN is forced to wait with completing the transition from EVS1 to EVS2 until \( E_t \) has left the states which form a problem. Secondly, all transitions leading out of the trap of \( E_t \) must be removed, so \( E_t \) can no longer enter a state of \( X_{ek} \) after it has entered its trap to \( E_2 \). This is required to make sure that \( E_t \) remains trapped in the states from where the transition to \( E_2 \) can be made safely. This solution has been used in the sections 5.3 and 7.6. An example of this solution can be found in figure 6.

Note that this solution can not be used when \( X_{ek} = X_{E_1} \), thus when \( X_{ek} \) consists of all states of \( E_1 \) as \( E_t \) will have an empty trap in this last case.

S2) In the second solution, a temporary version of the internal process \( I_2 \) will be used, it will be called \( I_t \). This temporary process \( I_t \) will be designed analogous to \( I_2 \). However, it will have some extra states and transitions: all states that are no part of \( I_2 \) but that are in \( I_1 \) will be part of \( I_t \) together with transitions leading from those extra states to the states that are also part of \( I_2 \). The extra states that exist in \( I_t-I_2 \) will be called \( X_{ik} \). In the same way, the subprocesses of \( I_1 \) must be designed analogous to the subprocesses of \( I_2 \) with eventually extra states from \( I_1 \). In the description of the rest of this solution, the example given in the introduction of this section will be considered. Thus we have a subprocess \( I_1S_i \) of \( I_1 \), a subprocess \( I_2S_j \) of \( I_2 \) and a state \( X_1 \) in \( I_1S_i \) with no corresponding state in \( I_2S_j \). Following the first part of this solution, we now also have a temporary process \( I_t \) that resembles \( I_2 \). As, in the example, \( I_2 \) has the same states as \( I_1 \), no extra state \( X_t \) will exist in \( I_t \). The process \( I_t \) now needs a subprocess \( I_tS_j \) which consists of \( I_2S_j \) together with an extra state corresponding with the state \( X_1 \) in \( I_1 \) and a transition from that state to one of the other states of \( I_2S_j \). As the state \( X_1 \) in \( I_1 \) has a corresponding state \( X_2 \) in \( I_2 \) (and in \( I_t \)), this state \( X_2 \) will be cho-
Generally spoken is it possible to design the subprocesses $I_1S_i$ for all combinations of subprocesses $I_1S_i$ and $I_2S_j$ that can lead to problems when switching from EVS1 to EVS2. After these subprocesses have been designed, a temporal manager $E_t$ can be made. This process $E_t$ will prescribe a subprocess $I_tS_j$. Just as in solution S1, the set of these special states of $E_t$ will be called $X_{et}$ and the trap from $E_t$ to $E_2$ will consist of all states of $E_t$ except for the states of $X_{et}$. When this all has been designed, the transition from EVS1 to EVS2 will elapse as follows: as soon as the transition has to be made, WODAN will prescribe $E_t$. Since $E_t$ resembles $E_2$, this means that in fact the new behaviour will start from the very beginning. However, as long as one of the subprocesses is still in a state that only exists during EVS1, this subprocess will keep behaving according to the EVS1 behaviour. After a while, such a state will be left and from that moment on the subprocess will have the EVS2 behaviour. As soon as the external behaviour enters a safe state (a state in which no problems can arise), WODAN can prescribe the external process $E_2$, thereby making the EVS2 behaviour definitive. An example of this solution is shown in figure 7. This solution is not used any further in the examples in chapter 5 or chapter 7. However, the following variant of it, called solution S3, is used in section 5.4.

**S3** As mentioned above, is this solution a small variant of solution S2. It follows solution S2 until the point where $E_t$ should be designed. In stead of designing a temporal process $E_t$, the process $E_2$ will be modified slightly: in all states where $E_2$ should prescribe a subprocess $I_2S_j$, $E_2$ can now choose between prescribing the subprocesses $I_1S_i$ and $I_2S_j$. The strategy from $E_2$ will be adapted to make this decision; there will be an extra statement like: when it is possible to prescribe both $I_2S_j$ and $I_1S_i$, the subprocess $I_1S_i$ should only be prescribed when the internal process under consideration is in a state that only exists in $I_1S_i$. In this way, the temporary subprocesses will only be used just after the transition from EVS1 to EVS2, as only immediately after this transition, the internal process under consideration can be in such a state. When using this variant of the solution, the subprocesses $I_1S_i$ are part of the same partition as the subprocesses $I_2S_j$; they are both subprocesses of the very internal process $I_1$ and the slightly modified manager $E_2$ is the manager of $I_1$ with respect to this partition.
4.4.2 Solving problem P2: the external process has less states

Let $E_1$ be the external process in EVS1, $E_2$ the corresponding external process in EVS2 and let $X_j$ be the states of the external process that do exist in $E_1$ but that have no corresponding states in $E_2$. Just as in the case of the internal processes, two possible solutions can be given:

**S4)** Make a temporary version $E_t$ of the external process. This $E_t$ is designed analogous to $E_1$. However, there are two differences: the first difference is that $E_t$ has a smaller trap than $E_1$; the trap of $E_t$ consists of all states except for the states $X_j$. The other difference is that all transitions which would lead out of the trap $E_t$ must be removed from the process $E_t$ to assure that $E_t$ will stay in its trap as soon as it has been entered. WODAN can now prescribe $E_t$ as soon as the transition from EVS1 to EVS2 has to be made and as soon as $E_t$ enters its trap, WODAN can prescribe $E_2$ to finish the transition from EVS1 to EVS2. A combination of this solution with solution S1 has been used in section 7.6.

**S5)** Also in this solution, a temporal version $E_t$ of the external process will be used. This temporal version however, is designed analogous to $E_2$: the STD of $E_t$ consists of the STD of $E_2$ together with the states $X_j$ and transitions leading from these states $X_j$ to the states that are taken from $X_2$. The trap of $E_t$ consists of all states taken from $E_2$. As in the previous solution, WODAN can prescribe $E_t$ as soon as the transition from EVS1 to EVS2 has to be made.
made and it can prescribe $E_2$ to finish the evolution step as soon as $E_1$ has entered its trap towards $E_2$.

The intuitively difference between solution $S_4$ and solution $S_5$, is that in solution $S_4$ the model will switch to the EVS2 behaviour only after a state that exists both in the EVS1 and EVS2 behaviour, has been entered. It will always follow its natural path (according to the EVS1 behaviour) to arrive in such a state. In solution $S_5$ however, the EVS1 behaviour can be aborted as soon as possible; as soon as the model wants to leave the state which only exists in the EVS1 case, it can travel via the extra transitions of $E_t$ to a state of the EVS2 behaviour. In this case, the model does not have to follow the complete path through the EVS1 behaviour as in the case of solution $S_4$.

4.4.3. Solving problem P3: the external process has reached a state to early

Since an external process manages the subprocesses of some internal process, an external process can only make the transition from a state $X_1$ to a state $X_2$ after the appropriate subprocess has reached the trap that corresponds with this transition. A consequence of this behaviour of the external process is, that its employees must have passed through various subprocesses and have reached various traps, before the external process can arrive in a state $X_j$.

For example, let the internal process $I_2$ with subprocesses $I_2S_1$ and $I_2S_2$ be an employee of the external process $E_2$. Furthermore, let state $X_{21}$ be a state of $E_2$ in which $E_2$ prescribes the subprocess $I_2S_1$ and in which $E_2$ has to wait until $I_2S_1$ has reached its trap $I_{2t_1}$ to the subprocess $I_2S_2$. As soon as $I_2S_1$ has entered this trap, $E_2$ may follow the transition towards state $X_{22}$, thereby prescribing $I_2S_2$ as soon as the state $X_{22}$ has been entered. When the external process $E_2$ with its employees is active from the start of the enactment of the model on, the model will be in a consistent state when the external process $E_2$ has entered the state $X_{22}$; the internal processes which are employees of $E_2$ have previously reached the traps to the subprocesses which they are currently restricted to by $E_2$. However, suppose that $E_2$ and its employees will be activated for the first time when EVS2 starts and that during EVS1, the external process $E_1$ will be used in stead of $E_2$. Let us consider the case in which the evolution step to EVS2 has to be made at the moment that $E_1$ is in the state $X_{12}$, which corresponds to the state $X_{22}$ of $E_2$. In this case $E_2$ will prescribe subprocess $I_2S_2$ to the internal process $I_2$ regardless of $I_2$ has reached its trap to $I_2S_2$ or not. When $I_2$ had not reached the trap to $I_2S_2$, the model will not be in a consistent state, since a subprocess of an internal process is prescribed at a moment that this is not yet allowed. Such a situation is shown in figure 8.

![Figure 8. Example of problem P3](image-url)
Note that this problem will only arise when the trap structure of I₂ is really different from that of I₁, with I₁ being the corresponding internal process during EVS1. This will mostly happen when the internal process I₂ is an entirely new process; since during EVS1 the NULL process will have been prescribed, the internal process will have had no history at all and therefore it will not likely be in the state where it should have been at the moment of entering EVS2. However, since this problem also can arise in other cases, the internal process during EVS1 still will be referred to as I₁ and not as NULL.

The above given problem can be solved in one of the following manners:

S6) Let X₂k be the set of states of E₂ in which the problem can arise. Furthermore, let X₁k be the set of corresponding states of E₁. Design a temporary external process Eₜ which is designed analogous to E₁. There will be two differences between E₁ and Eₜ. The first difference is that the trap of E₁ consists of all states of E₁ while Eₜ’s trap consists of all states of E₁ except for the states of the set of states X₁k corresponding with the set of states X₂k of E₂. The second difference is that all transitions leading out of the trap of Eₜ have to be removed. WODAN can then prescribe Eₜ as soon as the transition from EVS1 to EVS2 has to be made and it can finish the transition by prescribing E₂ as soon as E₂ has entered its trap.

Note that this solution can only be used when the states of X₁k of Eₜ don’t form a trap by themselves, otherwise the transition to EVS2 can never be finished when Eₜ has entered a state X₁k. This solution has been used in section 7.3.1. An example of this solution is shown in figure 9.

**Figure 9. Example of solution S6**

S7) First analyse the specification of the software process during EVS1 and during EVS2 and decide whether it is allowed to have an inconsistency during the first moment that EVS2 is active. In the following step, a temporary external process Eₜ can be made, which consists of some kind of mixture of the external processes E₁ and E₂; this Eₜ will partially have the behaviour of E₂ but it will wait for the trap of I₂ in another state then E₂ would have done. In which state it will wait depends on where the inconsistency may exist according to the analyses in the first step and where it is not allowed. In this way, when the external process Eₜ is in some states, it will permit the inconsistency to exist and when Eₜ is in some other states, it will prohibit the inconsistency to exists. The states in which the inconsistency is not allowed, can form the trap from Eₜ to E₂. Just as in the previous solutions, WODAN can first prescribe Eₜ to start the transition from EVS1 to EVS2 and it can prescribe E₂ to
finish the transition as soon as $E_t$ has entered its trap. An example of such a solution is shown in figure 10.

**Situation during EVS1**

\[ \begin{align*}
    &I_1S_1 \\ X_{11} \\
    &I_1S_1 \quad \text{in } I_{t1} \\ X_{12} \\
    &I_1S_2 \quad \text{in } I_{t1} \\ X_{13} \\
\end{align*} \]

External process $E_1$, manager of $I_1$.
The trap $T_{e1}$ is formed by the whole state space.

**Situation during temporary phase**

\[ \begin{align*}
    &I_1S_1 \\ X_{11} \\
    &I_2S_1 \quad \text{in } I_{t1} \\ X_{12} \\
    &I_1S_2 \quad \text{in } I_{t1} \\ X_{13} \\
\end{align*} \]

External process $E_t$.
The trap $T_{et}$ is formed by the states in the box.

**Figure 10. Example of solution S7**

S8) This is the most complex solution. In the previous two solutions, the transition was postponed until the external process was in a state were no inconsistencies can arise (solution 1) or the inconsistencies were allowed to exist for a while during the first moment of EVS2 (solution 2). In this solution however, the transition from EVS1 to EVS2 will be made immediately, with the restriction that, when the inconsistency arises on entering EVS2, the behaviour of $E_2$ and its employees will be “rolled back” to a state/subprocess which is normally reached earlier during the enactment of the model. To get this effect, again a temporary external process $E_t$ will be necessary. The internal process $I$ which causes the inconsistency will also need a temporary version $I_t$ with subprocesses $I_{tS_j}$. Since using this solution is a matter of high qualified engineering for each individual change of each individual model, the way to solve this problem will be sketched only roughly here. A more detailed example can be found in section 7.3.2, where a solution of the ISPW-7 example is given.

Let $E_1$, $X_{12}$, $E_2$, $X_{21}$, $X_{22}$, $I_2$, $I_2S_j$, $I_2S_1$ and $I_2S_2$ be as in the introduction of this section. Then $E_t$ can be designed analogous to $E_2$ but with the following differences: $E_t$ has some extra state $X_{ta}$ labelled ‘aborting process’, ‘turning back operations’ or whatever, with a transition from the state $X_{t2}$ (corresponding with the state $X_{22}$) leading to this state $X_{ta}$. This transition can be labelled ‘abort process’ or something alike. Furthermore, a second temporary process $E_u$ can be designed which consists at least of the state $X_{ta}$ corresponding with $X_{ta}$ of $E_t$ and a state $X_{u1}$ corresponding with state $X_{21}$ of $E_2$. The process $E_u$ can have two traps: one consisting of all states in which no inconsistencies can arise and the other one consists of the state $X_{ta}$. The first one is a trap towards the subprocess $E_2$ while the second one is a trap towards the subprocess $E_u$. The trap of $E_u$ can consists of the state $X_{u1}$. Furthermore, the temporary internal process $I_t$ and its subprocess $I_{tS_2}$ can have an extra transition in which it calls the export operation ‘abort process’ of the manager $E_t$ and after this transition it will arrive in a trap to the previous subprocess $I_{tS_1}$. WODAN can now first prescribe the process $E_t$; when $E_t$ is in a consistent state, it will arrive in the trap to $E_2$. In the other case, the internal process can be forced to follow the ‘call abort’ transition by prescribing an appropriate subprocess to it, and as soon as the internal behaviour has done this call, the manager process $E_u$ can be prescribed by WODAN. The manager $E_u$ can now manage the behaviour of the internal process until it arrives in a state that is com-
pletely consistent with the EVS2 behaviour and as soon as \( E_u \) has entered such a state, WODAN can prescribe \( E_2 \), thereby completing the transition to EVS2. An example of this scenario is shown in figure 11.

**Situation during EVS1**

\[
\begin{array}{c}
\text{null} \\
X_{11} \\
\end{array} \rightarrow 
\begin{array}{c}
\text{null} \\
X_{12} \\
\end{array}
\]

External process \( E_1 \).
The trap \( T_{e1} \) is formed by the whole state space.

**Situation during EVS2**

\[
\begin{array}{c}
I_2S_1 \\
X_{21} \\
\end{array} \rightarrow 
\begin{array}{c}
I_2S_2 \\
X_{22} \\
\end{array}
\]

External process \( E_2 \).
The trap \( T_{e2} \) is formed by the whole state space.

**Situation during temporary phase 1**

\[
\begin{array}{c}
I_1S_1 \\
X_{t1} \\
\end{array} \rightarrow 
\begin{array}{c}
I_1S_2 \\
X_{t2} \\
\end{array}
\]

External process \( E_t \).
It has two traps:
trap \( T_{e1} \) to \( E_2 \).
trap \( T_{eta} \) to \( E_u \).

**Situation during temporary phase 2**

\[
\begin{array}{c}
I_uS_1 \\
X_{u1} \\
\end{array} \rightarrow 
\begin{array}{c}
I_uS_2 \\
X_{ua} \\
\end{array}
\]

External process \( E_u \).
The trap \( T_{ua} \) is formed by the states in the box.

**WODAN**

\[
\begin{array}{c}
E_1 \text{ start change} \\
\text{neutral, EVS1 busy} \\
\end{array} \rightarrow 
\begin{array}{c}
E_3 \text{ change to EVS2} \\
\text{neutral, EVS2 busy} \\
\end{array} \rightarrow 
\begin{array}{c}
E_4 \text{ aborting} \\
\text{neutral, EVS2 busy} \\
\end{array}
\]

**Figure 11. Example of solution S8**

Note that this scenario is just a skeleton to sketch the process of rolling back the behaviour of a model during evolution to solve inconsistencies. In real life, many variants on this skeleton can exist. Even the example in section 7.3.2 differs a bit from this scenario.

**4.5. Concluding remarks**

In this chapter we have seen how the new concepts of WODAN and anachronistic external and internal processes can be used to describe process evolution. In the first section, a very general method to describe process evolution has been shown. This method can always be
used but it will lead to unnecessary complex evolution descriptions in many cases. In the following sections, we have made use of the fact that many similarities between the processes used before the evolution step and the processes used after the evolution step may exist. This notion leads to simpler process evolution descriptions. However, there can be many problems when using such simplifications. The rest of this chapter contained some general solutions to solve the most important problems which can arise. These solutions range from very simple ones to very complex ones. The last solution, solution S8 shown in section 4.4.3., is even that complicated that it is merely an example of using the general method shown in section 4.1. then an example of exploiting the similarities in the model before and after the evolution step.
Chapter 5
An example of changing an enacting process model

In this chapter, a concrete example of process evolution is shown which makes use of the concepts developed in the previous chapters. In this first example, a dynamic change of type 1 will be made. This means that only the strategy, the transitions and the subprocesses may change. There will be no change in the state space of the processes or in the number of processes the model consists of.

The reason to make an example of change type 1, is to examine whether such a strong restriction is useful. As it turns out, it is possible to change a model with the type 1 change but it makes the model unnecessarily complex. To avoid this complexity, the type 1 change will be redefined such that it will be a weaker restriction.

When making the wanted change to the model during enactment, the problem P1 - the subprocess of an internal process has less states - will arise and this problem will be solved with both solution S1 and solution S3.

The model that is going to be modified is an extension of the example in [2], which is an example of using SOCCA to model (a small part of) the ISPW-6 case. In that example the central class is the class Design, which is the model for the process of designing a document. In the extension, which is the start model for the example in this chapter, a monitor process int-monitor1 has been introduced that monitors the progress of Design. Design has also been modified to support this monitor process. The STD of int-monitor1 and of Design can be found in figure 12 and in figure 13 respectively.

W.r.t. to WODAN is this subprocess s-36a and the state space is trap t-36a

**Figure 12. Int-monitor1: STD of the internal behaviour**

Int-monitor1 has been designed to follow every phase of Design: Design must send a notify to the monitor when the modification has been opened and when it has been closed and it must also notify the monitor when review has been opened and finally Design must report the review result to the monitor to give the monitor the opportunity to update the statistics (one of the requirements of the ISPW-6 case, see [3], section 2.6.3).

As can be seen in figure 13 the STD of Design (which is an external process and therefore a manager process of some internal processes) is in fact just a subprocess with respect to WODAN. In the normal case, when the software process is being enacted and no change has to be made to it, this subprocess will continually be prescribed by WODAN so this notion of an external process being only a subprocess does not influence the behaviour in normal case.
When the behaviour of Design has to be changed for any reason, a new STD for Design can be made and at the appropriate time instant this new STD can be prescribed by WODAN in stead of the actual one.

To monitor the behaviour of Design, the monitor needs some subprocesses, which can be found in figure 14.

Subprocess s-31 is the start state of int-monitor1 for the first instance of Design; there is only one monitor per design document but there are many instances of Design for each design document: one instance for every separate version of the very same document (see \cite{2} for a justification of this). In the subprocess s-31, int-monitor1 will be waiting until Design will start the modifications. In subprocess s-32 it will be waiting until Design has closed the modification and in s-33 and s-34 it will be waiting until Design has started the review process and until it has reported the review result respectively. After this int-monitor1 will go back to subprocess s-31 (when the review result is not_ok) or to the neutral subprocess s-35 (when the review result is ok). Note that s-35 is also the starting state for the other instances of Design.

\textbf{Figure 13. Design: only viewed as manager of int\_monitor1}

W.r.t. to WODAN is this subprocess s-36 and the state space is trap t-36.
5.1. Designing a new model

Suppose that the monitor gets a short-cut from notify_mod_opened_asked to report_review_result because for small projects the exact intermediate result is not relevant, then the monitor and its subprocesses can be designed as in figure 15 and in figure 16 respectively.

When comparing int-monitor1 with int-monitor2, the following notions can be found:
- The subprocesses of int-monitor2 are numbered the same as the subprocesses of int-monitor1. This is done to show the correspondence between the subprocesses of int-monitor1 and int-monitor2; subprocesses with the same number in both models correspond with each other.
- In the new model, subprocess s-34 has an extra state 3 and a transition from state 3 to 6.
- In the new model, subprocess s-35 has an extra transition from state 3 to 6.
- Int-monitor 2 has an extra subprocess s-39. This subprocess will be used in section 5.5, until there it can be ignored.
As long as the current version of Design is being kept as a manager of monitor, it is possible to switch from int-monitor1 to int-monitor2 when enacting without introducing inconsistencies. Thus in this special case, we are not obliged to use a new version of Design when switching to the new evolution stage. However, as long as we keep using the old version of Design, Int-monitor2 will show the same behaviour as Int-monitor1. This follows from the notions below:

- As, with respect to Design, trap t-31 is only a trap from subprocess s-31 to s-32 the newly introduced transition from state 3 (t-31) to state 6 (in s-34) will not be used, so the behaviour remains the same.
- With respect to Design s-34 can only be reached from s-33 so the newly introduced state 3 in s-34 can not be reached and because of this it will not affect the behaviour.
- Subprocess s-35 (the neutral subprocess) means that all states from the monitor can be reached so introducing an extra transition here does not effectively influence the behaviour.

As mentioned above, the design process also has to be changed to achieve the new result. This new design process will be called Design2. Its STD is shown in figure 17. Design2 can prescribe different subprocesses in some states. Which subprocess will be chosen depends on the strategy:

**Str-1** Determine in state 11 whether it is a small project or a big project. When it is a small project follow the path 12, (13), 15, 17 prescribing subprocess s-34 in all states. Otherwise follow the path 12, (13), 14, 15, 16, 17 prescribing subprocess s-32, (s-32), s-32, s-33, s-33 and s-34 respectively.

Another strategy which can be used is the following one:

**Str-2** Determine in every state in which two different subprocesses can be prescribed whether it is a small project or a large project. When it is a small project subprocess s-34 has to be prescribed and the transition to the following state has to be taken following the path 12, (13), 15, 17. Otherwise subprocess s-32 or s-33 has to be prescribed (depending on the state) and the transition to the following state has to be taken following the path 12, (13), 14, 15, 16, 17.

When using strategy str-2, one of the consistency problems as mentioned in the previous chapter will arise. As it is one of the purposes of this example to clarify these problems with their solutions, the strategy str-2 will be worked out in the following sections.

Note that in this special case, the consistency problem could have been avoided by using strategy str-1 in stead of strategy str-2.

Note also that in fact the new process descriptions of Design and of int_monitor are only new subprocesses of some anachronistic processes. The transition from the old subprocess int_monitor1 to the new subprocess int_monitor2 and from the old subprocess Design to the new subprocess Design2 is made when WODAN prescribes the subprocesses corresponding
Despite the remark above that we are not obliged to use a new version of Design when switching to the new evolution stage, it is still necessary to design WODAN in such a way that the transition from int-monitor1 to int-monitor2 is made simultaneously with the transition from Design to Design2, just as has been pointed out in section 3.1. This is the case since Design2 can prescribe certain subprocesses of Int-monitor2 which are no subprocess of Int-monitor1.

Thus in this case, it is possible to prescribe Design together with Int-monitor2 (in accord-
5.2. Starting the new model during the enactment of a software process

In the previous section, we have designed new models to model the changed behaviour of the monitor operation and the class Design. In this section, we will model the behaviour of the evolution step to switch from the old behaviour of the total model to the new behaviour of the total model. As only the behaviour of Design and of Int-monitor changes, we will only take these two behaviours into consideration.

In comparing the original model with the new model the following observations can be made:
A) When the actual instance of Design models designing a huge project the behaviour remains the same so the new processes can be started immediately.
B) When the monitor is in s-31 or s-34 no inconsistencies will be introduced.

W.r.t. to WODAN is this subprocess s-38 and the state space is trap t-38

Figure 17. Design2: only viewed as manager of int_monitor2
C) When it is a small project and the monitor is in s-32 or s-33 a problem can arise: when switching to the new model, Design2 will prescribe s-34 because of it is strategy str-2 (determine in every state which project type it is and prescribe the right subprocess according to the project type). When at this moment the monitor is in state 4 (which is possible in both subprocesses) it can not leave this state any more since state 4 and the transitions out of state 4 are no part of s-34. This is an example of problem P1 as mentioned in chapter 4.

The problem introduced in observation C can be solved in 3 manners:

• Introduce the new method only when the monitor is not in state 4, so when it is not in subprocess s-32 or s-33. This means that the new behaviour must be introduced in some phases: say to design that the new behaviour has started but that it has to wait with the new strategy until it is in a safe state. This solution, which in fact is solution S1 of the previous chapter, can be found in section 5.3.

• Make an extra subprocess s-39 which consists of the states from the subprocesses that would introduce inconsistencies and change the strategy of Design2 to be the following one (str-3): when switching to the new process description while prescribing s-32 or s-33 and according to the new strategy s-34 would be necessary, then prescribe s-39 in stead of s-34. This method can be found in section 5.4. and it is an example of solution S3.

• Use another strategy in which the problem does not arise (like strategy str-1). This solution has not been mentioned in chapter 4 since it is not a solution to the general problem that the subprocess which will be prescribed during EVS2, misses one of the states of the corresponding subprocess during EVS1. However, it will always be a good advise to examine the model carefully to find out whether it is possible to avoid the inconsistencies by using a differently designed model which exploits specific properties of the real life process which has to be modelled and of the models which have been used in the original evolution stage. This approach is similar to the one used in the special solutions shown in chapter 4. The special solutions shown there exploited a specific property of the models before and after the evolution step; they all made use of the fact that many similarities exist between the STD’s before and the STD’s after the evolution step. The special solution shown here makes use of another specific property; it makes use of the fact that the total behaviour of the model is not only determined by the STD’s but also by a strategy.

5.3. Designing WODAN to manage the change

When choosing for solution S1, WODAN must consist of 4 states:

• There is no change made, the whole process can be enacted at a normal way.
• The new processes are being designed. The process still has to be enacted at the old way.
• The new processes have been designed. The intermediate phase of the design process can be started.
• Design has reached a safe state, the final subprocess of design can be prescribed and everything can enact at the new way.

The intermediate subprocess of design, which will be called TempDesign, and WODAN are shown in figure 19 and in figure 18 respectively.

TempDesign is a manager of int-monitor1. As has been mentioned in solution S1, it is designed analogous to Design with the trap of TempDesign consisting of the states in which no problem will arise and with the transitions which would lead out of this trap, removed from the STD of TempDesign.
5.4. Using an extra subprocess for int-monitor to avoid intermediate states

When choosing for solution S3, WODAN only has to consist of 3 states since there is no intermediate phase for the design process. The design process, called Design3, has to manage everything at the right manner with the aid of the extra subprocess s-39 and strategy str-3.

Design3 and WODAN to control the change are as displayed in figure 21 and in figure 20 respectively.
Chapter 5 An example of changing an enacting process model

5.5. Losing some restrictions

As can be seen from this example, restriction 1 (only change strategies, transitions and subprocesses) is too strong to make it possible to design models for the external processes which are easy to interpret:

When there are no extra states (in accordance with restriction 1) the manager must examine its strategy to determine which subprocess should be prescribed in some states. This makes the model very complicated to interpret since one can no longer determine from the state of the manager process in which subprocess the employee process is. To find this out one should know all about the followed strategy and eventually the followed history up to now. Thus, it would be useful when the manager has some extra states to prescribe the new subprocesses introduced for the new behaviour restrictions.

W.r.t. to WODAN is this subprocess s-40 and the state space is trap t-40

Figure 20. WODAN: switch to monitor2 and Design3.

Figure 21. Design3: only viewed as manager of int_monitor2
Therefore, the first restriction will be redefined to the following one:

restriction 1') Do not change the state space of the internal processes, only change the strategies, transitions and subprocesses. When necessary, do introduce extra states for the external processes to prescribe the new subprocesses in a clear manner.

When applying this new restriction 1' to the example one only has to change the manager process (Design) and the introduction of this manager (via WODAN). In the new design process description there will be enough states to prescribe only one subprocess per state. This will also simplify the strategy:

Str-4 Determine in state 11 whether the current is project small or large. When it is a small project the path 23, (24), 25, 17 has to be followed, prescribing the right subprocesses. Otherwise the (old) path 12, (13), 14, 15, 16, 17 has to be followed, prescribing the right subprocesses.

In fact this strategy is analogously to strategy str-1 in section 5.1., the only difference is that following the right path and prescribing the right subprocesses is now explicitly forced by the states of the STD of Design, while in the other case it was implicitly forced by the strategy.

As this new version of Design has been extended with some extra states and transitions, it will be called ExtendedDesign. When switching to ExtendedDesign, no inconsistencies will be introduced since ExtendedDesign can not prescribe s-34 when it was prescribing s-32 or s-33 according to the old behaviour. It now first has to follow the path corresponding to the old path in subprocess s-36, since it can only decide in state 11 to follow the new path according to the new strategy.

Therefore, introducing this change of the software process model only requires 3 states for WODAN. WODAN and ExtendedDesign are shown in figure 22 and in figure 23 respectively.

5.6. Concluding remarks

- Although it is possible to change the behaviour of an enacting process with the restriction that the state space is not to be changed at all, this introduces some problems:
  - There is a high probability that problem P1 arises as in some states a new subprocess will be prescribed which contains other states and transitions then the subprocess that was prescribed according to the old strategy.
  - It is hard to interpret the exact state of the process as in one state more subprocesses can be prescribed. To interpret the exact state one should be aware of the followed strategy and the history up to then.

The first problem can be solved with the solutions mentioned in chapter 4. The second problem however, can not be solved in such a manner. To avoid this problem, the first restriction has been made less stronger to allow extra states for the managers.

- The problems mentioned in the previous chapter can sometimes be avoided by carefully extending the model. In my personal opinion, such a carefully designed extension should be used whenever possible as it seems to be better to avoid inconsistencies then to solve them afterwards.

- In practice, it may be possible to exploit special properties of the real life processes and the
models which have been used before and after the evolution, to simplify the evolution step. Thus, one can not only make use of the similarities between the STD’s before and after the evolution steps as has been shown in chapter 4 but one can also exploit other properties like the strategy which is being used.

W.r.t. to WODAN is this subprocess s-41 and the state space is trap t-41

Figure 23. ExtendedDesign: only viewed as manager of int_monitor2
Chapter 6
Extending the model to cover more of the ISPW-6 example

In the next chapter, the process change part of the ISPW-7 example will be worked out in SOCCA. However, before we can start with this, the SOCCA example, which is based on the ISPW-6 case, must be extended somewhat because of the following reason. The change that has been proposed in the ISPW-7 example concerns the cooperation between *DesignDocument* and (modify) *Code*. As *Code* has not yet been included in the current model, this has to be done first.

We will continue with the last version of the model as presented in the previous chapter; for designing a document, the model of *ExtendedDesign* (figure 23) will be used and *int-monitor2* (figure 15) will be used to model the process of monitoring the progress of *ExtendedDesign*.

Since *ExtendedDesign* is a model for designing a document, it will be called *Design* again in the sequel of this thesis and likewise, *int-monitor2* will be referred to as *int-monitor* from now on. Furthermore, the SOCCA model as it is at this moment, will be called ‘the original SOCCA model’ or the ‘original SOCCA example’ and the model introduced in this chapter will be called ‘the current model’ or ‘the current SOCCA example’.

In this chapter, the SOCCA approach will be followed as far as possible; not only the behavioural aspects of the processes will be modelled with the PARADIGM part of SOCCA, but also the data aspects will be modelled by means of the EER based class diagrams and the SOCCA extensions to these. However, the process perspective will be ignored as the use of object flow diagrams and the integration of these into SOCCA has currently not been worked out completely.

6.1. Redesigning the class diagrams

First a new class diagram has to be defined, as in addition to the human agents also automated tools are necessary. For example a compiler to compile a code source document into a code object document. This class diagram is given in figure 24.

Together with this class hierarchy specification the attributes and operations of the various classes have to be defined. They are presented in figure 25.

In this class diagram two extra classes have been defined compared with the original SOCCA example:

- **Compiler**: this is an automated tool for compiling source code into object code. It will be discussed in detail further down.
- **ProjectManager**: this is the project manager with several tasks, like scheduling and assigning tasks and monitoring the progress of the design and review process. The behavioural aspects of the monitor process have been worked out in chapter 5. However, as chapter 5 was only meant to show the basic aspects of dynamic process change within SOCCA, the other SOCCA aspects of the monitor were not discussed there. Therefore, these other SOCCA aspects of the monitor will be discussed here.

The project manager’s task ‘scheduling and assigning tasks’ is called *assign_and_schedule_tasks* and its behaviour will also be discussed here.

Furthermore, some operations are moved from the superclass *DesignDocument* to the subclass
Chapter 6 Extending the model to cover more of the ISPW-6 example

Design, as these operations are only necessary in DesignDocument's subclass Design and not in DesignDocument's subclass Code. A last change in the class diagram is that the part-of relationship between ProjectDocs and the various documents has been moved from the subclasses Design, Code, TestPlan and TestPack to their ancestor class Document. This has been
done to show more explicitly that ProjectDocs is constituted of (many) Documents.

In the following step the general relationships between the classes have to be defined. For the sake of completeness not only the relationships between the new classes are shown but also the other relationships from the current SOCCA example. The general relationships are shown in figure 26.

![Class diagram: classes and general relationships](image)

**Figure 26. Class diagram: classes and general relationships**

Note that in the SOCCA example the superclass DesignDocument has been defined. Both the classes Code and Design inherit operations and attributes of this superclass. The class Code represents a code document and likewise, the class Design represents a design document. In the discussion in this theses, terminology is used to address both code documents and design documents. The term ‘design document’ means an actual instance of the class Design and not an instance of the superclass DesignDocument.

As a last step in the EER part of the SOCCA specification, the uses relationship is given (figure 27) together with the import list (figure 28). Note that in the import list some export operations are parametrized with the parameter doc_name. Each such parametrized operation in fact stands for \( n \) separate export operations where \( n \) is the number of different document names.

One of the requirements of the ISPW-6 case is that Code has to wait with releasing the object code for the test phase until the design document has been approved. The behaviour of Code therefore depends on the behaviour of Design, this dependency is modelled via the internal behaviour of release_object_code. As can be seen in figure 56 on page 55, which shows the traps and subprocesses of int-release_object_code with respect to Design, int-release_object_code waits in its starting state until Design has been approved. Since it is waiting in its starting state, there is no transition to this state which could be associated with an export operation of Design. This means that the dependency of the behaviour of Code on the behaviour of Design is not modelled via an explicit export operation of Design but via an implicit dependency. Therefore this uses relationship (uses11) is shown with a dashed arrow in stead of a solid one in the import/export diagram. Note that this is a deviation of the original
SOCCA approach. We will come back to this further on in the thesis were we discuss the communication between Codes export operation release_object_code and the external behaviour of the class Design.

6.2. Designing the external behaviours of the classes

The next step consists of modelling the external behaviours of the classes. From then on, the order in which the export operations can be called will be known.

Modifying the code has to be carried out by a design engineer. The export operation code of DesignEngineer can be parametrized, just like the export operations design and review in the original SOCCA example. The operations can be called in any order, so adding the code operation to the external behaviour of DesignEngineer is straightforward. The new STD will be as in figure 29. Entering the state starting code can be viewed as starting the modify code activity.

The behaviour of the class ProjectDocs is also extended because now not only new versions
of design documents have to be created but also new versions of code documents. The new
behaviour of ProjectDocs is shown in figure 30. This model has two transitions with the same
label create_version. This is necessary because of the trap structure of its employees int-design and int-code. One transition will be followed when int-code enters the appropriate trap and the other transition will be followed when int-design enters the appropriate trap. See section 6.4 for the details.

The third class, Design, remains unmodified as the extensions to the original SOCCA model
do not influence the behaviour of this class.

Modifying the code document has been modelled by means of a separate class. This class is
called Code and it is the fourth class in the current SOCCA example. Just like in the case of
Design there will be one instance of Code, representing exactly one version of a code docu-
ment (a source code and eventually the associated object code). The STD for Code will be
displayed in figure 31. Some of its operations are inherited from its superclasses DesignDocument and Document. Other operations are specific for the class Code itself. The
STD of Code is designed analogously to the STD of Design; the first part models creating
the new version of the document and modifying it and the last part models the process of reading
and copying it. The only real difference is in the middle part; for a design document the model
has to reflect the behaviour of reviewing the design, while for the code document the behav-
ior of compiling and testing the code document has to be modelled. The part of testing the
document will not be worked out further in this example.

Note that compile automatically creates an object code document when the compile result is
compile_ok. Note also that the ISPW-6 requirement that it must be possible to have multiple
object codes with one version of a source code, is not supported by this model. To support this
requirement, a separate class for the object code document should have been defined, whose
behaviour depends on the behaviour of the source code document. At this moment Code is one
class, representing both the behaviour of a source code document and the only one object code
document associated with it.

The fifth class is the class ProjectManager. In this example the export operations monitor
and schedule_and_assign_tasks will be used. The export operation monitor is parametrized
with the document name of the document which has to be monitored and it is called from the
internal behaviour of the export operation schedule_and_assign_tasks. This means that the
export operation monitor is an example of an export operation which is imported in another

Figure 29. DesignEngineer: STD of the external behaviour

Figure 30. ProjectDocs: STD of the external behaviour
Chapter 6 Extending the model to cover more of the ISPW-6 example

The sixth and last class to be modelled is the newly introduced Compiler class with export operation `compile`. This export operation can be parameterized with a document name, just like the operations `design`, `review` and `code` of DesignEngineer, `create_version` of ProjectDocs and `monitor` of ProjectManager. The STD of Compiler is given in figure 33.

6.3. Designing the internal behaviours of the export operations

After specifying the external behaviours of the classes, the internal behaviours of the operations can be specified. In this example only the various internal behaviours of `code` (from the class DesignEngineer), `compile`, `release_object_code` and `test_ok` (from the class Compiler) and `schedule_and_assign_task` (from the class ProjectManager) will be given. The other internal behaviours are not really interesting within this example as they are highly internal...
operations which do not communicate with other parts of the model. For the internal behaviour of \textit{schedule\_and\_assign\_task}, only a very rudimentary scheme will be given, as it is not relevant for this example to model the complete behaviour of this complex task. It is only intended to show the process of starting the monitor process (so it is an example of starting one internal behaviour from within another internal behaviour of the same instance of the very same manager). The STD’s of the internal behaviours are shown in the figures 34, 35, 36, 37 and 38 respectively.

W.r.t. to WODAN is this subprocess s-99 and the state space is trap t-99

\textbf{Figure 34. Int-code: STD of its internal behaviour}

W.r.t. to WODAN is this subprocess s-82 and the state space is trap t-82

\textbf{Figure 35. Int-release\_object\_code: STD of its internal behaviour}

\textbf{Figure 36. Int-compile: STD of its internal behaviour}

\textbf{Figure 37. Int-test\_ok: STD of its internal behaviour}

Note that these STD’s not only show what export operations are imported but also in which uses relationship these export operations occur.
6.4. Adding PARADIGM to model the communication

After the specification of the external and internal behaviours of the classes and operations, the communication between these behaviours has to be specified. This communication specification is shown in several parts.

The first part of the communication specification shows the communication between the manager process DesignEngineer (figure 29 and 41) and its employee processes int-code (figure 34 and 40), int-design, int-review and int-schedule_and_assign_tasks (figure 38 and 39).

Note that the subprocesses and traps of int-design and int-review are not given here, because they remain the same as in the original SOCCA example.

The manager DesignEngineer waits in its neutral state until int-schedule_and_assign_tasks
calls either design, review or code, parametrized with a name name1, by entering the appropriate trap. Assume that a call_code transition has been made and that int-code, likewise parametrized with name1, is in its trap t-42. At that moment DesignEngineer can go to its state starting_code, prescribing subprocess s-43 of int-code and subprocess s-72 of int-schedule_and_assign_tasks. As int-code was in trap t-42, it will immediately enter subprocess s-43, thereby starting the process of coding a document, and entering trap t-43. Likewise, int-schedule_and_assign_tasks will enter subprocess s-72 and therefore it will be allowed to go back to its ‘neutral’ state schedule_started from where it can start other tasks again. As soon as it enters this state it will be in trap t-72, so DesignEngineer can go back to its neutral state prescribing s-42 of int-code and s-69 of int-schedule_and_assign_tasks again, waiting for other tasks to be assigned by the internal behaviour int-schedule_and_assign_tasks of the Project-
Manager. *Int-design* and *int-review* can be started analogous.

The second part of the communication specification shows the communication between the manager *ProjectDocs* (figure 30 and 42) and its employees *int-code* (figure 34 and 43), *int-design* and *int-create_version*. Since the last two have not been modified, their traps and sub-

![Diagram of communication between ProjectDocs, int-design, int-code, and int-create-version](image)

**Figure 42. ProjectDocs, manager of int-design, int-code and int-create-version**

This new version of *ProjectDocs* not only allows *int-design* to make a call to *create_version* by prescribing s-5 to it, but it also allows *int-code* to make such a call by prescribing s-44 to it. As soon as *int-code* or *int-design* performs a *call_create_version* by entering the appropriate trap, *ProjectDocs* will allow its employee to continue by prescribing the new subprocess to it and it will start up the internal behaviour of *create_version*. Since now two employees can perform a *call_create_version*, *ProjectDocs* has two different states which can be reached in one step from the neutral state: one state for the call done by *int-code* and the other state for the call done by *int-design*.

Note that another approach to model *ProjectDocs* is by making use of the concept of roles and views. In stead of having two different transitions modelling the same operation *create_version* and likewise having two states modelling starting a creation, one can also...
make a model of *ProjectDocs* with one *neutral* state, one *starting_creation* state and one transition labelled *create_version* to model both creating a new version of a code document and of a design document. Whether the transition *create_version* models creating a new version of *code* or a new version of *design* depends on the view one has of the class *ProjectDocs*; at the moment that one views *ProjectDocs* as a manager of *int-code*, following the transition *create_version* yields the creation of a new code document. Likewise, a new design document will be created when *ProjectDocs* is viewed being a manager of *int-design*. This concept of incorporating views and roles into SOCCA can be a topic of future research.

The third part of the communication specification shows the communication between the manager *Code* (figure 31 and 48) and the employees *int-code* (figure 34 and 44), *int-create_version*, *int-create_next* (copy call from the next instance of *Code*), *int-create_next* (the managers own internal behaviour), *int-compile* (figure 36 and 45), *int-release_object_code* (figure 35 and 46), *int-test_ok* (other instance, figure 37 and 47) and *int-test_ok* (same instance, figure 37 and 49).

![Diagram](image-url)
Figure 44. Int-code’s subprocesses and traps with respect to Code

Since both creating a new version of a code document and modifying it, are modelled exactly like Design in the original example, this part of Code will not be discussed here. After the process of modifying the code document has been finished, Code will be in the state pre-compile, waiting for int-compile to enter trap t-52 (which means that a possibly existing previous compilation process has been finished). When this trap has been entered, Code will prescribe s-53 to int-compile, thereby releasing it to start compiling a document, and Code will keep int-code in s-50 until compiling the document has been finished. When int-compile enters its trap t-54 (compile_not_ok), Code will restart the modify code activity. However, when it enters trap t-53 (compile_ok), Code will remain prescribing s-50 to int-code to permit
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Figure 45. Int-compile's subprocesses and traps with respect to Code

it to leave the state compile_asked and enter the state compile_done. The manager will now be waiting until int-compile has reached its trap t-50, which means that the code has been compiled, and int-release_object_code has reached trap t-56, which means that the object code may be released. After prescribing s-57 to int-release_object_code, Code will wait until inter-release_object_code has reached trap t-57, which means that the object code has been released. Note that int-release_object_code will wait in its first state as long as the design document has not been approved by Design (see the discussion of the communication between Design and its employees). After releasing the object code, the test round will be started until the internal behaviour of test either performs a call_test_ok or a call_test_not_ok. Since the behaviour of testing the code document has not been worked out here, no traps for these events are indicated in the figure. However, when such a call has been made, the manager has to continue in the appropriate way; when the test result is not ok, a new modify, compile, test
round has to be started. Otherwise possible copy requests have to be handled. The copy request are modelled in the same way as in the model of Design in the original example.

The fourth part of the communication specification shows the communication between the manager Compiler (figure 33 and 50) and its employees int-compile (figure 36 and 51) and int-code (figure 34 and 52).

Compiler is waiting in its neutral state until int-code performs a call_compile, parametrized with a document name name1, by entering its trap t-63. As soon as int-code is in trap t-63 and int-compile is in trap t-61, Compiler will start compiling the document by entering its next state and therefore prescribing the subprocesses s-62 and s-64 to int-compile and int-code respectively. After int-compile has started, Compiler will wait until int-code has left trap t-63 and entered trap t-64. As can be seen in the previous paragraph about the communication

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**Figure 48. Code: manager of 8 employees.**
between Code and int-code, this means that Compiler has to wait until the compilation has been finished, before it can return to its neutral state.

The fifth part of the communication specification shows the communication between the manager ProjectManager (figure 32 and 54) and its employees int-monitor (figure 15 and 55) and int-schedule_and_assign_tasks (figure 38 and 53).

The manager process ProjectManager starts in its neutral state, waiting until the Configuration Control Board (CCB) performs a call to schedule_and_assign_tasks. The CCB is the authority which, according to the ISPW-6 example, prompts for the required design and code modification. Its behaviour is outside the scope of this example.
Chapter 6 Extending the model to cover more of the ISPW-6 example

At the moment that the CCB performs the call to `schedule_and_assign_tasks`, the manager process `ProjectManager` will go to its state `starting schedule` thereby prescribing subprocess `s-75` to `int-schedule_and_assign_tasks`. After a short while, `int-schedule_and_assign_tasks` will enter its trap `t-75`, thereby allowing `ProjectManager` to return to the neutral state. At some
given time instant, the internal behaviour of \textit{schedule\_and\_assign\_tasks} will perform a \textit{call\_monitor}, parametrized with a document name \textit{name1}. When at that moment the monitor process which is parametrized with \textit{name1} is in its trap t-65, \textit{ProjectManager} can enter the state labelled \textit{starting monitor}, starting the monitor by prescribing subprocess s-66 to \textit{int-monitor} and allowing \textit{int-schedule\_and\_assign\_tasks} to return to its ‘neutral’ state \textit{schedule\_started}. Note that this is an example of one internal behaviour of an operation from an external process controlling the internal behaviour of another operation of that very same external process. This is in accordance with the original SOCCA approach. The advantage of showing the internal behaviour of an export operation which is only called from another internal behaviour of that same external process is that the internal behaviour of that operation becomes visible in the behaviour of the external process.

The sixth and last part of the communication specification shows the communication between the manager \textit{Design} (figure 23 and 57) and its employees \textit{int-design}, \textit{int-review}, \textit{int-create\_version}, \textit{int-create\_next} (other instance), \textit{int-create\_next} (same instance), \textit{int-review\_ok} (other instance), \textit{int-review\_ok} (same instance), \textit{int-monitor} (figure 15 and 16) and \textit{int-release\_object\_code} (figure 35 and 56).

The behaviour of \textit{Design} is being modified for the second time since the first model of it has been designed in [2]. The first modification was required for managing \textit{int-monitor} (chapter 5) and the second time is the current modification, where \textit{Design} has to notify \textit{Code} that the design document has been approved. Because of these two modifications, a new informal comment on the behaviour of \textit{Design} is necessary.
Just as before, every instance of Design, except for the first one which starts in the state labelled *, starts in the state labelled **, waiting for the previous instance of Design to enter trap t-26 of int-review_ok. After this, it will wait until int-create_version enters either trap t-18 or trap t-19 and it will continue with the old behaviour until int-design enters trap t-9 and int-create_version enters trap t-20. Now Design enters the state where it has to decide which route has to be taken: the route with a full notification of the monitor or the route with a partial notification of the monitor. As already has been mentioned in the previous chapter, the outcome of this choice depends on the size of the project. Let us assume that the size is large, so the longer route will be taken. In this case Design will wait until int-monitor enters trap t-31. After this it will prescribe subprocess s-32 to int-monitor, thereby forcing it to be notified of all events that will happen. It will now wait for int-design to enter trap t-10 to start modifying the document or to enter trap t-11 to close the modification. After trap t-11 has been entered, Design will wait again for int-monitor, but now for trap t-32 and after this it will wait until int-review wants to start a review round by entering trap t-13. When this has happened, int-monitor has to be notified again and the review round can really start. If the review of the document turns out to be not ok, a new modify and review round will start. Otherwise the final part of Design can be started to manage copying the document and to release a new version to be modified. However, before this end part starts, Design will check whether int-release_object_code is in trap t-67. Since this is the starting state of int-release_object_code, Design does not have not to wait at all, but it can prescribe subprocess s-68 to int-release_object_code immediately, thereby allowing Code to continue after releasing the object code document.

Note that Design has no explicit export operation for this notification that the design document has been approved to Code. This is because of the fact that the trap in which int-release_object_code is waiting, is the first state of it and therefore no transition that can perform a call_export_operation does exist. This way to start the behaviour of int-release_object_code can be compared with the starting of an internal operation by an external process in the normal way. From this point of view one could say that int-release_object_code is merely an internal operation of Design and not of Code. The fact that Design does not have such an explicit export operation is a deviation from the original SOCCA approach. When the original SOCCA approach had been followed, the communication between Code and Design should have been modelled by means of an explicit export operation of Design which would have been called from within the internal behaviour of one of the export operations of Code.

6.5. Concluding remarks

In [2], the SOCCA approach has been defined. This SOCCA approach can be split up into two parts:
Adaptive software process modelling with SOCCA and PARADIGM

- The SOCCA rules: these rules state that the external behaviours of the classes and the internal behaviours of the export operations of these classes are modelled with STD’s and that the communication between the various processes is modelled with PARADIGM on

Figure 57. Design: manager of 9 employees
top of them. In the PARADIGM part are the manager processes formed by the external behaviours and the employee processes are formed by the internal behaviours.

• The SOCCA conventions: these conventions are implied by the techniques which have been used in the example in that paper. The following conventions can be identified:
  C1: Let all internal behaviours, denoted with “int-behave”, start with a transition labelled “act-behave” leading from the first state of the STD to the second state of the STD. The external behaviour of the class which exports the operation “behave” keeps the internal behaviour “int-behave” trapped in the first state until the operation has to be started. As soon as the external behaviour arrives in the state after the transition corresponding with starting that internal behaviour, it will prescribe a new subprocess to the internal behaviour, forcing it to leave its first state according to the transition “act-behave”.
  C2: Export operations of a class are called from the internal behaviours of operations from other classes or at least from the internal behaviour of an operation from another instance of the same class. Thus, export operations of one particular object are imported into the internal behaviours of operations from a really different object.

In this chapter, two deviations from these SOCCA conventions have been made. These deviations are not breaking with the formal SOCCA modelling rules as defined in [2], they are only breaking with the conventions as implied by the original SOCCA example in that paper.

The first deviation is a deviation from convention C1: the first state of \texttt{int-release\_object\_code}, which is an export operation of \texttt{Code}, is not only a trap in the trap-structure with respect to \texttt{Code}, but it is also a trap in the trap-structure with respect to \texttt{Design}. Thus, \texttt{int-release\_object\_code} has two managers which keep \texttt{int-release\_object\_code} trapped in its first state in stead of only one manager. This has been done because \texttt{Code} has to wait at that moment until the design document has been approved.

This deviation could have been avoided by changing the behaviour of \texttt{Design}; give \texttt{Design} an export operation called something like \texttt{design\_doc\_approved} and give \texttt{Code} a state in which it waits until \texttt{design\_doc\_approved} arrives in a state notifying that the design document has been approved.

The main difference between both methods is that the first method models a direct coordination between \texttt{Design} and \texttt{Code} via a PARADIGM communication between the behaviour of \texttt{int-release\_object\_code} and the behaviour of \texttt{Design} which is not made visible with an explicit export operation in the class diagrams. This in contrast to the second method where the object oriented approach is used to make the PARADIGM communication between \texttt{Design} and \texttt{Code} visible in the class diagrams.

The second deviation is a deviation from convention C2: in this example, the export operation \texttt{monitor} of \texttt{ProjectManager} is imported in the internal behaviour of \texttt{assign\_and\_schedule\_tasks} of the very same instance of the external process \texttt{ProjectManager}. This means that the export operation \texttt{monitor} is no real export operation of \texttt{ProjectManager}; it is not imported into any other class or instance. From the EER point of view, one could say that \texttt{monitor} is an internal operation of \texttt{ProjectManager} which should not be visible from outside. However, by making \texttt{monitor} an export operation of \texttt{ProjectManager}, it is made visible from the external behaviour of \texttt{ProjectManager} whenever a new instance of \texttt{int-monitor} is started by \texttt{ProjectManager}.
Chapter 7
Example 2: changing the model according to the ISPW-7 specification

The ISPW-7 extensions address two issues: teamwork and process change. As within the context of this thesis we are particularly interested in dynamic process modification, we will only concentrate on the process change part of these extensions. The process change extensions have been split up into two parts. One concerns process modification; this is a permanent change to the model. The other part concerns process exception which is a temporary change of the process to handle exceptional circumstances. After such a temporary change, the model has to return to its original behaviour. These two parts will be discussed in the following sections.

7.1. Process modification: problem description

The proposed change in the ISPW-7 example is as follows; in the original ISPW-6 example, coding could start before the design document was approved. From now on this restriction is tightened: coding may only start after the design document has been approved. This change of the model has to be applied to some process which is being enacted and thereby three cases should be considered (quoted from ISPW-7 example, section 4.2.1):

• ‘The executing process has not yet reached the step affected by the change, so the change will have no immediate impact on the process state’.
• ‘The executing process has reached or passed the steps affected by the change, but for whatever reason, the change is consistent with the existing process state’.
• ‘The executing process has reached or passed the steps affected by the change, and the change is inconsistent with the existing process state’.

In the following section first a new model for the external behaviour of Code will be given and the internal behaviours of the operations will be modified as far as needed. This new model will be referred to as the ISPW-7 model or the ISPW-7 case. Likewise, the current SOCCA model will be referred to as the ISPW-6 model or the ISPW-6 case. The ISPW-6 model and parts of it will also be referred to as the old model and the ISPW-7 model will sometimes be called the new model.

Section 7.3 concentrates on making the transition from the ISPW-6 model to the ISPW-7 model. In that section, the three cases mentioned above will also be taken in consideration and they will be related with the problems as mentioned in section 4.3. The solution to the third problem will be derived from the solutions suggested in section 4.4. When necessary, new (temporary) processes will be designed and the cooperation between Code and other parts of the model will possibly also be changed.

7.2. Designing the new model

In the ISPW-6 model, Code waits with releasing the object code to the test phase by means of the internal behaviour of int-release_object_code; as long as the design document has not been approved by Design, int-release_object_code can not enter trap t-57 and Code will have to
wait in the state labelled \textit{releasing}.

According to the ISPW-7 specifications, \textit{Code} may only start after the design document has been approved. This can be managed by designing a new model. In this new model, \textit{Code} will get an extra export operation called \textit{wait\_for\_approval} to model waiting for the design document to be approved. In the STD of the external behaviour, the transition corresponding to this operation will be placed before the state labelled \textit{creatable}. The new model of \textit{Code} is displayed in figure 58.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig58}
\caption{\textit{Code}: new STD of the external behaviour}
\end{figure}

Note that in this case not only the dynamic description changes but also the static description; the class \textit{Code} gets the new export operation \textit{wait\_for\_approval}. This new class description will also be defined by WODAN, in exactly the same manner as WODAN defines the new behaviour description. The internal behaviour of \textit{wait\_for\_approval} is shown in figure 59.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig59}
\caption{Int-wait\_for\_approval: STD of its internal behaviour}
\end{figure}

Note also that the state labelled with \textit{creatable} in the old STD of \textit{Code} corresponds to the state labelled with \textit{pre-creatable} in the new STD of \textit{Code}. This means that when the transition of the old STD of \textit{Code} to the new STD of \textit{Code} is made and the process is in the state \textit{creatable} in the STD of \textit{Code} before switching to the new STD, that the process after this transition will be in the state \textit{pre-creatable} in the new STD.

After these modifications of the external and internal behaviours, the new communication has
to be specified. In the figures specifying the communication, only the communication between the relevant managers and \textit{int-release_object_code} and \textit{int-wait_for_approval} will be given. The other parts remain the same as in the figures modelling the ISPW-6 case.

First the communication between the manager \textit{Code} (figure 58 and 61) and its employee \textit{int-wait_for_approval} (figure 59 and 60) will be given.

**Figure 60. Int-wait_for_approval’s subprocesses and traps w.r.t. Code**

All instances of \textit{Code}, except for the first one which starts in the state labelled \\(*\), will be waiting in the stated labelled \\(**\) until the previous version of \textit{Code} performs a call\_prepare. At that moment however, the creation of the new version of a code document will not be started immediately. In stead of this, \textit{Code} will wait in the state \textit{pre-creatable2} until \textit{int-wait_for_approval} has entered trap \textit{t-77}, which means that the design document has been approved. From that moment on the behaviour will remain almost the same as described in the

**Figure 61. Code: viewed as manager of int-release_obj_c and int-wait_for_approval**
Chapter 7 Example 2: changing the model according to the ISPW-7 specification

explanation of the ISPW-6 case; the only other difference is that with this new version of Code it is no longer necessary to wait until the design document has been approved before releasing the object code document (since the design document has already been approved).

However, this difference is not visible in the model of int-release_object_code or in the communication between Code and int-release_object_code. It is only visible in the new communication between Design and int-release_object_code; int-release_object_code is no longer an employee of Design, thus Design can no longer keep int-release_object_code trapped in its first state. Instead, Design is now a manager of int-wait_for_approval. This new communication structure is shown in figure 62 and in figure 63.

![Figure 62. Int-wait_for_approval’s subprocesses and traps w.r.t. Design](image)

Except for the fact that Design is no longer a manager of int-release_object_code but of int-wait_for_approval instead, no part of the behaviour of Design has been changed. Since from the viewpoint of Design, the function of this new employee is the same as the function of the replaced employee, the global behaviour of Design does not change at all; it still keeps this employee trapped in the first state until the design document has been approved and after this event, Design still allows this employee to move freely through its state space.

7.3. Introducing the ISPW-7 model.

When this model is introduced during the enactment of a software process model, a problem may arise; since in the ISPW-6 case Code could start before the design document was approved, int-release_object_code was an employee of Design to make it possible to wait for the approval of the design document. In the ISPW-7 case however, int-release_object_code no longer waits for the design document to be approved, as Code waits with the aid of int-wait_for_approval for the design document to be approved. However, when switching from the ISPW-6 case to the ISPW-7 case, Code may have past the transition labelled wait_for_approval while the design document has not yet been approved. This is problem P3 as defined in section 4.3. This problem corresponds with the inconsistency mentioned as the third case in section 7.1.

In the ISPW-7 specification two options to solve this inconsistency have been suggested: ‘(1) you may allow the inconsistency to remain, or (2) you may attempt to change the state (by rollback, or whatever) to achieve consistency’. In the following sections, these two solutions will be followed. As it turns out, these solutions are equivalent with some of the solutions mentioned in section 4.4.3

7.3.1. Option 1: do not solve the inconsistency

In this section option 1 will be worked out. For this purpose an intermediate phase of Code will be given, which still has the structure of the ISPW-6 model. By choosing the traps from this STD to the STD of the ISPW-7 model in the right manner, it is possible to switch only from the ISPW-6 case to the ISPW-7 case before modify code has started (this situation is
equivalent with the first case mentioned in section 7.1) or after modify code has waited until the design document has been approved (this situation is equivalent with the second case mentioned in section 7.1). It is straightforward to incorporate these two cases into the SOCCA model.

As Code remains behaving like in the ISPW-6 case in the middle part of this intermediate phase, the inconsistency as mentioned in the third case in section 7.1, will remain in this middle part. As soon as the intermediate phase of Code has left the middle part, it will have waited for the design document to be approved and the inconsistency does not arise at all.

This solution to the problem is equivalent with solution S6 from section 4.4.3.

The intermediate phase of Code is given in figure 64. Note that this intermediate phase has the same state-action interpreter as the original phase of Code. Therefore, the state-action interpreter has not been shown in figure 64.

W.r.t. to WODAN is this subprocess s-86 and the state space is trap t-86

Figure 63. Design: viewed as manager of int-wait_for_approval
The last step to finish the transition from the ISPW-6 case to the ISPW-7 case is designing WODAN to manage this change. As stated in solution S6 in section 4.4.3, WODAN first has to prescribe the intermediate phase of Code and as soon as this intermediate phase has entered its trap, WODAN can prescribe the ISPW-7 model. Note that in the state-action interpreter of WODAN, only the employees of which the STD changes during the transition from the ISPW-6 case to the ISPW-7 case, have been mentioned. WODAN is shown in figure 65.

In this example three important notions can be found:

- The only part of Design that changes when switching from the ISPW-6 case to the ISPW-7 case, is the state-action interpreter. The states, transitions, strategy and all other parts defining a process remain the same. Since Design is a subprocess of an anachronistic process, this means that a subprocess restriction not only defines a restriction on the states, transitions, etc., as defined in [1] but that it also defines a restriction on the state-action interpreter; the anachronistic process of which Design is a subprocess, has a not explicitly designed state-action interpreter which minimal consists of the union of the state-action interpreters from the subprocesses s-41 and s-86.
- The subprocess int-wait_for_approval is introduced for the first time in the ISPW-7 case.
Before that time it did not exist. Introducing this new process has been done by prescribing the NULL process, defined in section 3.4, in those state where int-wait_for_approval did not yet exist and by prescribing int-wait_for_approval as soon as the ISPW-7 case becomes active.

- WODAN is not only able to change the dynamic model description part but it can also change the static model description part; in this example the class description of Code has been extended with a new export operation called wait_for_approval.

### 7.3.2. Option 2: solve the inconsistency

In this section a solution to the inconsistency mentioned in the third case in section 7.1 will be given. When Code already has started before the design document is approved, Code will go back to its starting state, thereby discarding all changes made to the code.

Since some employees of Code have side effects, these side effects also have to be rolled back. Therefore the behaviour of all employees has to be studied to find out how the side effects of their behaviour can be discarded. Some employees may need extra states and/or transitions to rollback the side effects. If so, subprocesses representing this temporal behaviour will be defined.

Code needs an intermediate STD for managing the process of rolling back all side effects. This intermediate STD of Code, which is displayed in figure 67, will be called TempCode, since it is valid only temporary.

This solution will follow the procedure as sketched in solution S8 of section 4.4.3.

Code has the following employees: int-create_version, int-create_next, int-code, int-compile, int-release_object_code and int-test_ok. We will study each employee to determine whether the behaviour of that employee has to be rolled back or not.

As creating the new version of a code document does not really change the code document - it only changes the version number-, the behaviour of the employees int-create_version and int-create_next does not have to be rolled back.

The employee int-code really modifies the code document. Thus, this employee needs an intermediate phase to rollback its side effects when the inconsistency arises. This intermediate phase, which is shown in figure 66, calls TempCode’s export operation abort, which aborts the

![Figure 66. Intermediate phase of int-code](image)

W.r.t. to WODAN is this subprocess s-88 and the state space is trap t-88

modify code activity and discards all modifications made to the code document. This means that after execution of the abort operation it seems as if no modification to the code document has been made.
Chapter 7 Example 2: changing the model according to the ISPW-7 specification

Note that the temporary export operation *abort* also has to be placed in the class description of *TempCode*.

Note also that *int-code* has been designed in such a manner that, when the code document has been opened for modifications, modify code has to be closed before calling abort. This is necessary to assure that only one version of the code document is opened at the same time.

*Int-compile* reflects the behaviour of an automated tool which can not be modified and thus the behaviour of *Int-compile* can not be modified or rolled back.

WODAN (see figure 71) is designed in such a manner that *TempCode* will only be prescribed when the design document has not yet been approved. If the design document already has been approved before the ISPW-7 case has to be started, the process will be in case 2 of section 7.1 and no inconsistency will arise. Thus, the code document may not be release when *TempCode* is prescribed. Therefore is the transition labelled *release_object_code* removed from *TempCode*. So it is not necessary to rollback the behaviour of *int-release_object_code*.

Note that, as *int-release_object_code* is removed from the behaviour of *TempCode*, WODAN prescribes the NULL process for *int-release_object_code* during the intermediate phase.

The operation *int-test_ok* can only be called when the design document has already been approved, thus no rollback of this operation is necessary.

The communication structure to solve the inconsistency is shown in figure 68 (*int-code* as employee of *TempCode*), figure 67 (two temporary phases of *TempCode* as manager of *int-code* and as employee of WODAN), figure 69 and 70 (two temporary phases of *Design* as employee of WODAN) and figure 71 (WODAN as manager of *Design, Code, int-code, int-release_object_code, int-wait_for_approval*).

After designing the new model, WODAN prescribes the intermediate phase to *Design* to determine what action has to be taken; when *Design* is in trap t-90, the design document will have been approved, which means that no inconsistency arises. Thus the transition to the ISPW-7 case can be finished in that case. Otherwise, the design document has not been approved and therefore it is necessary to abort the modify code process when it has already been started. Thus, WODAN then starts the intermediate phase of the employees *Code* and *int-code* and WODAN prescribes the NULL process to *int-release_object_code*. To determine whether the modify code activity has started or not, WODAN examines the trap of *TempCode*. When *TempCode* is in trap t-96, the modify code activity has not been started, thus the transition to the ISPW-7 model can be finished in that case. Otherwise, WODAN has to wait until

![Figure 71. WODAN: viewed as manager of 5 employees](image)
the modify code operation is aborted. This operation is aborted only after TempCode has entered trap t-97; TempCode enters this trap after int-code has reached trap t-92, which is entered by int-code after calling the abort operation.

Note that int-code first closes the modify code document when it already has been opened, this is modelled by means of int-codes trap t-93 and TempCode’s transition from the state modifiable to the state pre-compile.

Further note that TempCode has all states and transitions which are necessary for the communication with int-compile. These states and transitions are needed as the communication between (Temp)Code and int-compile does not change during the intermediate phase.
Chapter 7 Example 2: changing the model according to the ISPW-7 specification

When TempCode has finally entered trap t-97, WODAN will prescribe s-98 to TempCode and s-91 to Design and then WODAN will wait until the design document has been approved (trap t-91), the abort operation has been finished (trap t-98) and, via the cooperation between TempCode and int-code, until int-code has re-entered the state labelled creation_asked; TempCode can only enter trap t-98 after int-code has entered trap t-94. When this all finally happens, WODAN finishes the transition to the ISPW-7 case.
7.4. Process exception: problem description

The second part of the ISPW-7 example concentrates on process exception; this is a temporary change to the model due to an exceptional circumstance.

In SOCCA such a temporary change can be handled as follows:

- Design a model for the process as it should be during the process exception.
- Switch with aid of WODAN to this model at the right time instant.
- As soon as the exceptional circumstance has passed, WODAN can be used to switch back to the standard situation.

As stated above, it is necessary to switch two times to another model; first to the model of the process exception and later back to the model of the standard situation. This switching to the right model can be handled in the same manner as switching to another model during process

Figure 69. First intermediate phase of Design
Chapter 7 Example 2: changing the model according to the ISPW-7 specification

Evolution. Also in this case, special care should be taken to avoid inconsistencies and if it is not possible to avoid inconsistencies, they should be solved as indicated in chapter 4.

The proposed process exception in the ISPW-7 example is as follows: ‘Suppose that due to unavailability of assigned personnel, it is decided to bypass a follow-up (say second) design review. This decision is made dynamically at the time that this review was scheduled to occur. The rest of the process continues normally in this instance.’ (quoted from section 4.2.2 of [4]).

In the following sections it will be examined how this exceptional circumstance can be incorporated into the current SOCCA model and how WODAN must be designed to switch to the exceptional circumstance and return back to the standard situation as soon as possible.

W.r.t. to WODAN is this subprocess s-91

Figure 70. Second intermediate phase of Design
7.5. Designing the exceptional model

In this section, the model to handle the exceptional situation will be designed. According to the ISPW-7 example, there is not enough personnel to review the design and therefore, reviewing the design should be skipped. This can be modelled in two manners:

- Change the external behaviour of Design in such a manner that all parts that handle reviewing the design document will be skipped; make one transition from state 15 (see figure 23 on page 37 for the state numbering) and one from state 25 (both labelled pre_review) to the state 20 (review_closed) and label these transitions with the export operation skip_review. This however has a huge disadvantage; since the various instances of Design depend on each other through the behaviour of int-review_ok and int-prepare, this dependence will be disturbed:
  
  The behaviour of the next instance of Design is initiated by a call to its prepare operation performed from the internal behaviour of int-close_and_review_ok of the current instance of Design. However, as the close_and_review_ok operation of the current instance will be skipped when the review process is skipped, the current instance of Design will not call the prepare operation of the next instance of Design, thus the next instance of Design will not be initiated. This problem can be solved by changing the next instance of Design in such a manner that it does not wait for int-close_and_review_ok of the current instance of Design to call the prepare operation but that it does wait for skip_review of the current instance of Design to call the prepare operation. Thus, when the current instance of Design is changed in such a way that the review process will be skipped, the next instance of Design will also have to be changed, despite of the fact that such a next instance should behave in the normal manner without being aware of any exceptional circumstances.

- Change the behaviour of int-review in such a manner that reviewing the document will be skipped but that the communication with other instances of Design will not be disturbed. Fortunately this is very easy; as starting the process of reviewing the design document is modelled by means of entering trap t-14 of subprocess s-14 (a subprocess of int-review), it is only necessary to remove trap t-14 and the transition to it, labelled call_review, from subprocess s-14. This can be done without introducing inconsistencies as Design is the only manager that can react to the call_review transition; Design will be waiting in its state reviewable until int-review either performs a call_review, a call_review_not_ok or a call_review_ok and on such a call, Design will make the appropriate transition. When int-review does not perform a call_review because that transition has been removed, it will not influence the behaviour of Design.

As the second way to handle the exception gives the least problems, this solution will be used. Of course it is not possible to remove a transition and a state from a subprocess. However, it is possible to make a new subprocess that resembles subprocess s-14 without that state and transition and to adapt the state-action interpreter of Design to prescribe this temporary subprocess and react to the traps of it, instead of prescribing subprocess s-14 and reacting to the traps of that one. The subprocess of int-review to handle the process exception is given in figure 72.

![Figure 72. Int-review’s subprocess to handle the ISPW-7 process exception](image-url)
Chapter 7 Example 2: changing the model according to the ISPW-7 specification

Note that not only the `call_review` transition has been removed but also the `call_close_review_not_ok` transition. This is because, in accordance with the ISPW-7 example, the behaviour of `int-review` during the process exception has to reflect the behaviour of bypassing a follow-up design review step; it is assumed that the design document has been (re)designed in the right manner and thus that such a follow-up design review step is not necessary.

*Design* as manager of `int-review` has to be changed too in the exceptional circumstance because *Design* has to prescribe subprocess s-100 in stead of s-14. As s-100 has no trap t-14 nor a trap t-15, the transitions of *Design* that are followed on entering these traps, have to be removed from *Design* to assure that *Design* will only follow the transition corresponding with trap t-100. The state of *Design* that corresponds with starting the review process, can also be removed in the exceptional case, as this state will not be entered.

The STD for *Design* as manager of `int-review` during the exceptional case can be found in figure 73.

![Diagram](image)

W.r.t. to WODAN is this subprocess s-101

**Figure 73. Design: viewed as manager of int-review during process exception**
7.6. Starting the exceptional case

The last step consists of checking for the problems mentioned in chapter 4 and solving these following the suggested solutions.

As the subprocess for Design during the exceptional case has less states than the subprocess for Design during the normal case, WODAN can not always switch to the exceptional case immediately. This is problem P2 and the easiest way to solve this problem is applying solution S4; make an intermediate phase of Design with a trap consisting of those states that form no problem and design WODAN in such a manner that first the intermediate phase of Design will be prescribed and afterwards, the exceptional phase of Design.

However, also another problem exists; subprocess s-100 of int-review (see figure 72) has less states then subprocess s-14 (see [2]), which is prescribed from the same state of Design. This is problem P1 and the easiest way to solve it in this case, is using solution S1; make an intermediate phase of Design with a trap consisting of those states in which no problem arises and design WODAN to prescribe first the intermediate phase of Design and the standard phase of int-review and afterwards the exceptional phase of Design and of int-review.

The solutions S1 and S4 can be combined to form the intermediate phase of Design and to design WODAN.

Note that the STD of int-review remains the same during the exceptional phase. The different behaviour of int-review is modelled only by means of its new subprocess s-100.

When switching back from the exceptional phase to the normal phase, no problems will arise, so this can be done without further special actions.

WODAN is displayed in figure 75, the ‘normal’ phase of Design in figure 63, the exceptional phase of Design in figure 73 and its intermediate phase is displayed in figure 74.

7.7. Concluding remarks

Modelling the change parts of the ISPW-7 example is completely possible within SOCCA. The problems that have been mentioned in the ISPW-7 example correspond with the general problems with process change in SOCCA as mentioned in chapter 4 and the intuitive solutions like allowing the inconsistencies to remain or rolling the process back, correspond with the SOCCA solutions introduced in chapter 4.

The definition of a subprocess has been slightly extended, compared with the original papers defining PARADIGM; in these papers, a subprocess is defined being a restriction to a decision process [1]. However, this definition does not take into account that a process may be the subprocess of a manager process, like an external process which is the subprocess of an anachronistic external process. When this is the case, the process is not only a decision process but it is a decision process with a state-action interpreter. Likewise, the subprocess does not only impose a restriction on the decision process but it also imposes a restriction on the state-action interpreter. Thus, a subprocess is a restriction to a decision process, together with its state-
W.O.D.A.N. is responsible for all possible changes of the model. It does not only change the dynamic perspective by defining new external and internal processes, new subprocesses of the internal processes and new state-action interpreters to model the changed communication but W.O.D.A.N. can also change the static perspective by adapting the class structure; W.O.D.A.N. can add and remove export operations from a class description whenever necessary and W.O.D.A.N. can even define or remove complete classes. W.O.D.A.N. will probably also be able to change the process perspective of a SOCCA model, which is described by means of object flow diagrams.

Figure 74. Design: viewed as manager of int-review during start of exceptional case

W.r.t. to W.O.D.A.N. is this subprocess s-102

Chapter 7 Example 2: changing the model according to the ISP-W-7 specification
Chapter 8
A very brief comparison of SOCCA with other paradigms

In this chapter the properties of SOCCA with respect to the ability of dynamic process modification will be compared with some other paradigms mentioned in [5]. In [5] there is also a paper considering some requirements for enactment mechanisms [6]. In that paper the notion of so called process variables has been introduced as a fundamental mechanism for process change. In the following section this notion of process variables will be applied to SOCCA and in the sections afterwards SOCCA will be compared with some other existing paradigms.

8.1. The notion of process variables applied to SOCCA

In [6] the notion of process variables to control process change, has been introduced. According to that paper, process variables are not intended as a concrete feature of a process definition formalism but they represent a set of features needed by any effective process definition formalism. Process variables should have the following features:

- They are introduced in the “text” of a process definition and can be associated there with type specifications, constraints and default values.
- They need to represent a wide variety of different aspects of a process, like products produced by a performance of the process, tools to be used in performing the process, project specific goals or subgoals or various process definition fragments.
- Process variable binding needs to be incremental and multi-faceted. For example, a process variable might be first bound to a type specification, constraining the actual values to which it can be bound, and have actual values conforming to that specification bound later during enactment.

Process variables are mainly intended to represent yet undefined aspects of the process that is being defined by the process definition formalism.

In chapter 3 the concept of anachronistic external and internal processes has been introduced. The external and internal process descriptions that define the SOCCA process specification are just subprocesses of these anachronistic processes. When applying the concept of process variables to these notions found in SOCCA, the anachronistic processes can be regarded as being process variables with the explicitly designed internal and external process descriptions being the values that can be bound to these process variables. For example the STD of the internal behaviour of \textit{int\_monitor1} can be regarded as the value that is initially bound to the process variable representing the monitor process. When some time later, the STD of \textit{int\_monitor1} gets replaced by the STD of \textit{int\_monitor2}, it can be said that from that moment on the STD of \textit{int\_monitor2} is the value bound to the process variable representing the monitor process.

The binding mechanism, to bind the process variable value to the process variable, is modelled explicitly by WODAN and its state-action interpreter. So within SOCCA, this binding mechanism itself is a part of the model instead of a property of the enactment mechanism. This property makes SOCCA a reflective specification mechanism.

The notion of process variables can also be applied to the class perspective of the SOCCA model; the static structure of the model can change when the model evolves, an example of
such a change can be found in chapter 7. To achieve such a change of the static structure, one can say that a process variable exists which value is the current static structure. When WODAN has to change the static structure, WODAN only has to bind a new value to this special process variable.

The notion of process variables can also be applied to WODAN itself; WODAN is in fact an infinitely large decision process which can follow any arbitrary path through its state space. Which path will be followed, and therefore how the model evolves, depends on the input - specifying the process which has to be modelled, the wanted process change, etc.- WODAN receives from somewhere outside the model. However, despite the fact that WODAN is infinitely large, only a finite part of WODAN is relevant, and therefore visible, at any time instant. Thus, the currently visible part of WODAN can be considered being a value bound to a process variable representing WODAN.

When considering this from the viewpoint of the SOCCA approach, one could also say that a not explicitly designed version of WODAN exists of which only one subprocess is visible each time; the currently visible part of WODAN is only another subprocess of the not explicitly designed version of WODAN and starting the design of a new model and the transition to the new evolution stage in which the new model is prescribed, is triggered by prescribing a new subprocess of WODAN from somewhere outside of the model.

8.2. Comparing SOCCA with Document Flow Model (DFM)

In [7] three primary objectives have been mentioned which guided to the development of DFM. These objectives are process mobility, framework for change and simplicity. According to [7] these objectives can be reached when the enactment system has two basic properties:

- Independent processes
- Asynchronous communication

By independent processes it is meant that all processes are first class citizens within the model: there is no master process and new processes can join the evolving network. At a first glance SOCCA does not have this property, since the external processes are managers of the internal processes and furthermore, WODAN is a manager of both the external and internal processes. However, when comparing SOCCA and DFM in more detail it can be seen that somehow the external processes in SOCCA correspond with the actons in DFM and the internal processes in SOCCA correspond with the internal behaviours of the actons in DFM. Since the external processes in SOCCA are first class citizens in relation to each other - no external process is the master of another external process and new external processes may join the model-, this property of independent processes is fulfilled. As WODAN is mainly used to guide the process evolution, one can neglect the fact that WODAN is a manager of everything in the normal case when the process is just enacting and no evolution has to happen.

As the communication in SOCCA between the various processes is PARADIGM communication, which is a form of asynchronous communication, all communication in SOCCA is asynchronous so also the second property is fulfilled in SOCCA.

Thus, the two basic properties of DFM are fulfilled in SOCCA, which makes SOCCA powerful enough to satisfy the three primary objectives that guided to the development of DFM.

8.3. Comparing SOCCA with SPADE

Another process centred environment is SPADE which is centred on a language, SLANG,
based on high level petri nets [8]. In SPADE the ability to process change is established via modularization of the SLANG model: to change a part of the process during enactment, enactment of the module to be modified can temporarily be stopped and after modification, enactment of the module can continue. This has the disadvantage that the enactment partially has to be stopped for a while, which is not necessary in SOCCA when changing a process.

One of the main features of SLANG is the possibility to model time constraints. For example to automatically abort some function after a timeout period. Such time constraints can also be used in SOCCA; an STD which is used to model the behaviour of a process in fact is a decision process with i.a. a sojourn mechanism that determines the time instant when the next transition is going to be followed. One can make use of this fact by making an abort transition leading from a state which possibly has to be aborted to some other state. This transition can then automatically be followed when the STD is still in the state where the abort transition starts at the moment that the timeout period elapses.
Chapter 9
Conclusions and further research

This thesis shows that incorporating the concept of anachronistic processes together with WODAN and its state-action interpreter into SOCCA, gives SOCCA the reflectivity necessary for process evolution [9]. This reflectivity property is in fact a direct consequence of the existence of WODAN’s state-action interpreter, which is a part of the model, describing another part of the model. Thus, within SOCCA, the reflectivity is a natural feature of one of the constituting formalisms, namely of PARADIGM.

Process evolution can lead to inconsistencies in the model after switching from one evolution stage to another evolution stage. These inconsistencies have to be detected by a careful analysis of the effects of the intended change. This possibly can be supported by tools which check for the occurrence of the problems P1, P2 and P3 mentioned in chapter 4 by comparing the old SOCCA processes and the new SOCCA processes with each other. After detecting the inconsistencies, they can be solved or even avoided by following the guidelines mentioned in chapter 4.

Further categorisation of problems as a consequence of process change is a topic for further research.

A SOCCA model can become very large. However, through the modular approach such a large model can still be understood very well. This modular approach also makes it easier to analyse the consequences of an intended change at a local level, without taking any part of the model into account which is not directly related with the changed part.

An interesting approach to make SOCCA models smaller and less complex is by incorporating the concepts of roles and views into SOCCA. This approach has only slightly been mentioned in section 6.4. It can be a topic of further research to incorporate it fully into SOCCA.

In this thesis, the newly introduced concept of anachronistic processes in combination with WODAN to incorporate change in SOCCA has only been used to model process evolution and emergency handling, both mentioned in the ISPW-7 case. An interesting topic of future research is to analyse the application of this change incorporation for model growth and incremental modelling, prototyping in modelling and customizing. Another application of the change incorporation may be reusability by viewing reuse as a certain evolution of a model component and even interoperability might be incorporated with the above mentioned change concepts.
Chapter 10

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