

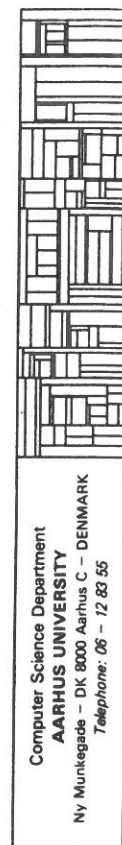
**A Conceptual Framework for  
the Characterization of  
Petri Net Description Techniques**

Kim Halskov Madsen

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Madsen: The Characterization of Petri Net Description Techniques



# A CONCEPTUAL FRAMEWORK FOR THE CHARACTERIZATION OF PETRI NET DESCRIPTION TECHNIQUES

## Abstract

In this paper we present a conceptual framework for the characterization of Petri net description techniques, and we apply this framework to characterize some wellknown techniques. The important point however, is that we feel that a conceptual framework (though perhaps not the one presented here) is essential for identifying and propagating description techniques. And surely for making progress in applications of nets, it is essential that we develop and communicate net description techniques that can deal with large systems.

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## 1 Introduction

A lot of the literature on Petri nets is on the theory of nets. But the only way nets can really prove their value is through their application. From Petri net descriptions made by ourselves and by others we see that even small descriptions very often get messy and difficult to understand. In this paper we wish to study one way this problem can be reduced. The work presented here is a summary of chapter 3 and 4 of a Masters thesis [Hansen and Madsen 83].

Parts of our work is inspired by [Oberquelle 81]. Oberquelle presents mainly what we call techniques for structuring the layout of a net. Similar ideas are discussed in [Reisig 82]. In [Reisig 83] various techniques for refining the net-structure are presented. What we are advocating is that we do not only need techniques but also concepts for the characterization and communication of techniques.

In this paper we present a conceptual framework for the characterization of Petri net description techniques, and we apply this framework to characterize some of the techniques in the above mentioned papers as well as other techniques. The conceptual framework enriches our language and enables us to give a more precise specification of description techniques, and thereby supports the communication of techniques. But even more important, the concepts may directly influence our search for new techniques.

Our conceptual framework is composed of two categories of concepts introduced in section 2 and 3, respectively. The first category is used to denote the various components of a net (net-structure, inscriptions, net-text, associated-text and layout). The second category consists of some general concepts for the characterization of description techniques (to structure, to refine and to formalize).

In section 4 the concepts are used for the characterization of techniques based on net morphisms, and in section 5 we characterize "abstract storage structures" introduced in [Oberquelle 82]. In section 6 we characterize the techniques used in the

description of a realistic system.

The meaning of the concepts is formed through their use. This is reflected by the fact that the meaning of our concepts is not only formed by the definitions in sections 2 and 3 but also by their use in sections 4, 5 and 6.

The description of techniques is much easier when we as starting point take the effect of their use. Therefore we often describe the techniques implicitly through an example showing the effect of their use. We use High Level nets but the concepts and techniques we use are suitable for any net model in the range between High Level nets and Place Transition nets.

## 2 Net concepts

We introduce five concepts in order to denote the components of a net. The concepts are chosen so as to fit any net model ranging between High Level nets and Place Transition nets, hence not all aspects of each concept may be relevant for a particular net model, e.g. the set of colours are not relevant for Place Transition nets. The 5 concepts are:

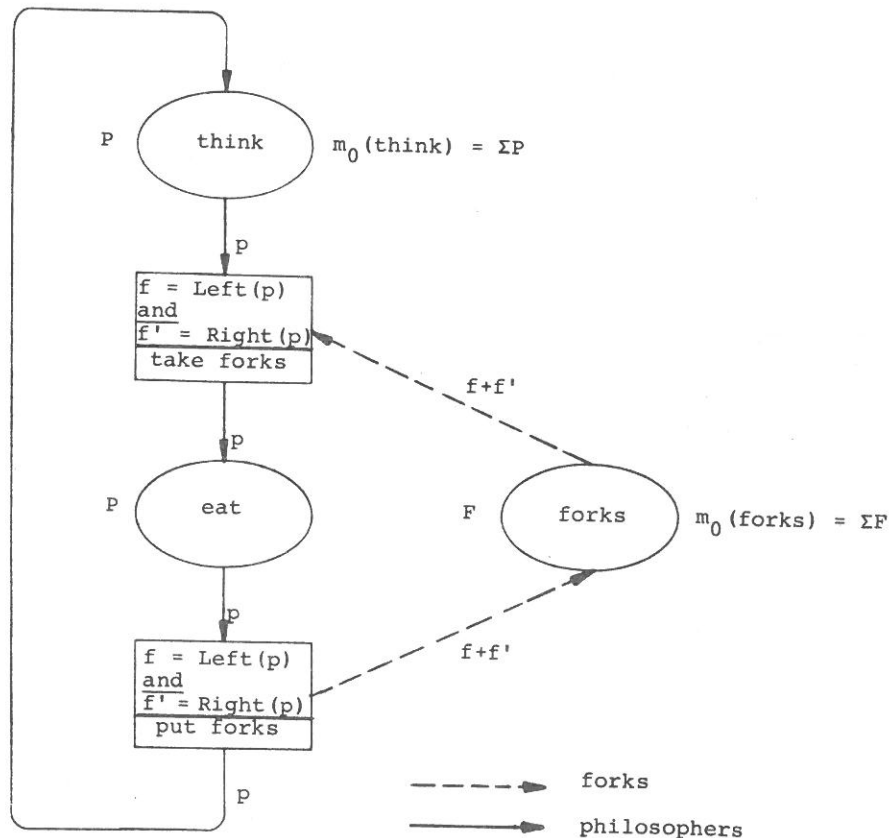
- net-structure  
(nodes and arcs)
- inscriptions  
(marking, set of colours, expressions on arcs, predicates)
- net-text  
(any kind of text on the graph, except inscriptions)
- associated-text  
(explanations beside the graph)
- layout  
(appearance and positioning)

The first four concepts denote disjoint components of a net whereas the layout concerns the appearance and positioning of the other components.

In the following we define the five concepts. The examples given in brackets refer to the following net:

### The dining philosophers

Five philosophers are alternately thinking and eating. To eat, a philosopher needs two forks, unfortunately there are only five forks on the circular table and each philosopher is only allowed to use the two forks nearest to him.



The net-structure consists of the nodes and their connecting arcs.

The inscriptions consist of the marking ( $m_0(\text{think}) = \Sigma P$ ), the sets of colours ( $P$ ), the expressions on the arcs ( $f+f'$ ) and the predicates ( $f = \text{Left}(p)$  and  $f' = \text{Right}(p)$ ).

The net-text consists of the name of the net (The dining philosophers), names of subnets and names of nodes (think). Moreover any other kind of text on the graph, except inscriptions, is net-text too ( $- - - \rightarrow$  forks).

The associated-text consist of the text beside the graph (.....to eat a philosopher needs two forks .....).

The layout consists of the appearance and positioning of the other components (the philosopher nodes are positioned on a line and the connecting arcs are fulldrawn).

We have attempted to choose the five concepts in order that each part of a net can be associated with exactly one component. However, there will always be some borderline cases, e.g. the use in our example of two different patterned arrows may be viewed as part of the layout as well as part of the inscriptions.

### 3 Technique concepts

Following [Munk-Madsen 78] (p. 58-61) we introduce 3 concepts for characterizing description techniques:

- . to structure
- . to refine
- . to formalize

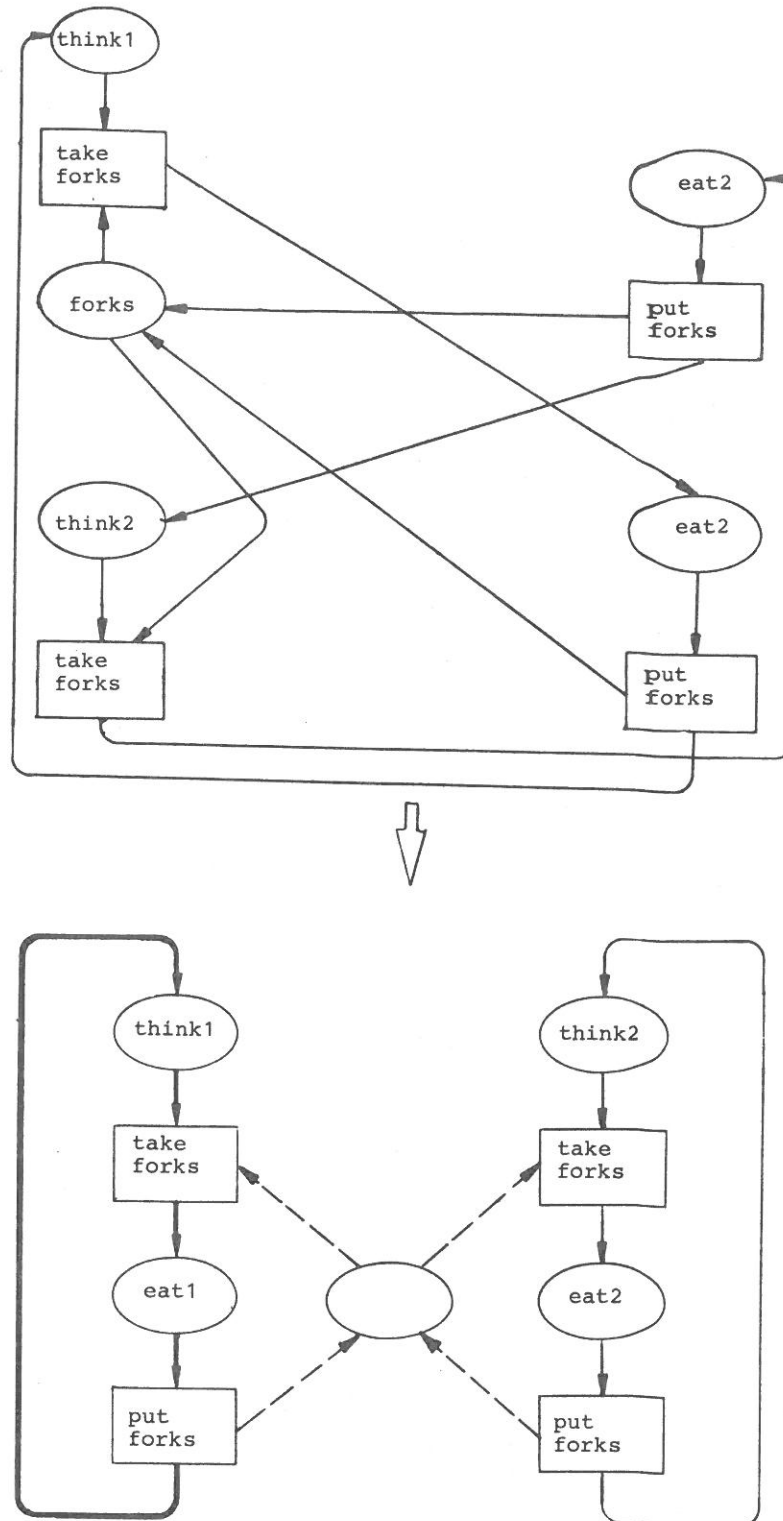
These three concepts are in fact suitable for the characterization of the descriptions themselves. Relativizing the concepts we may say that a description is more structured, refined or formalized than another description of "the same thing". In particular we shall characterize a technique by the description we get when employing the technique.

In the following we define the concepts and illustrate each concept by an example.

#### to structure:

When we structure, we link together the elements of the description representing those part of reality we consider as related. By structuring we emphasise what we consider as related and thereby what we consider as distinct.

example:

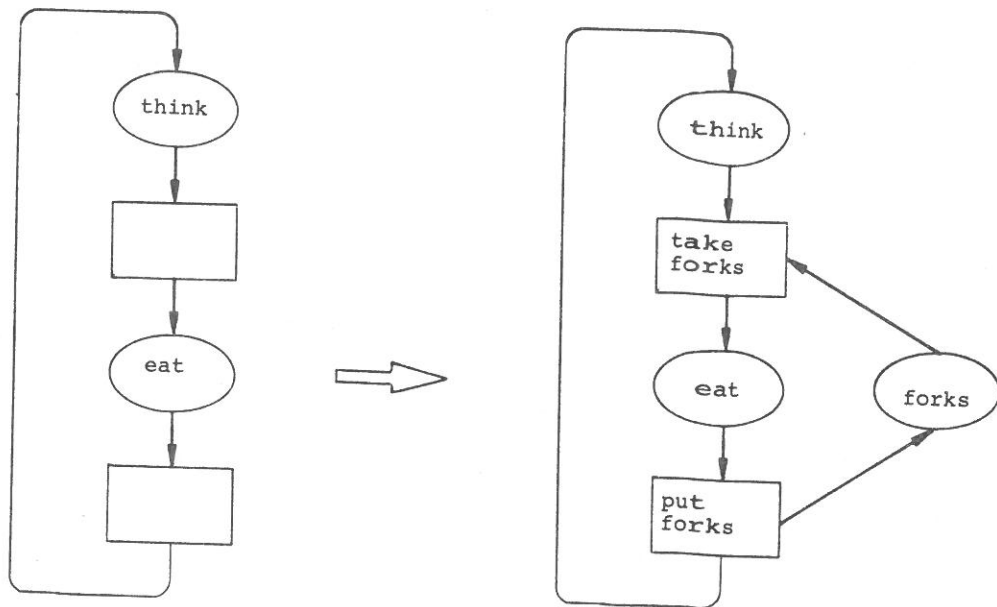


We have structured by positioning the nodes and arcs of each philosopher on an imaginary line.

to refine:

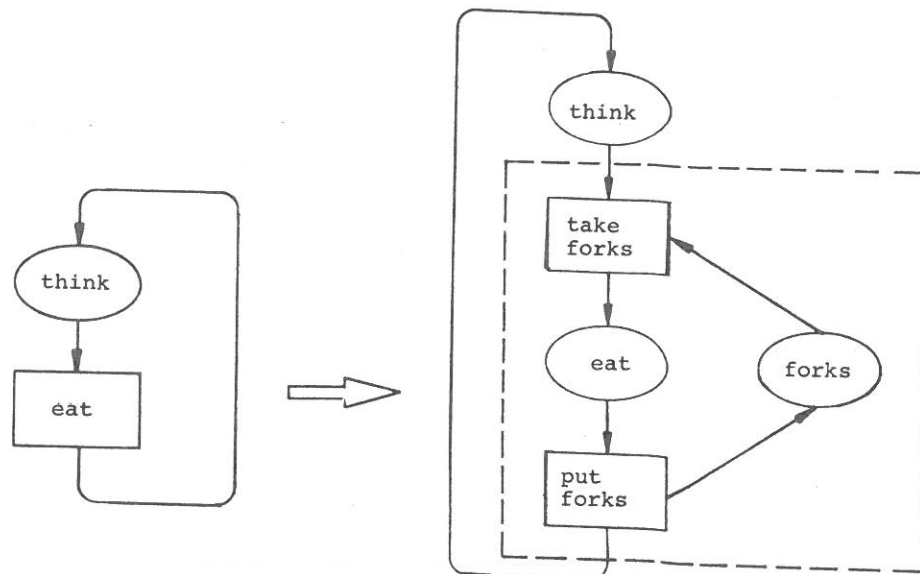
When refining we describe more properties or details. We distinguish between two kinds of refinements; refinement by addition and refinement by elaboration. When refining by addition we add some new properties and when refining by elaboration we describe more details of the same properties.

example:



We have added the philosophers' use of forks.

example:



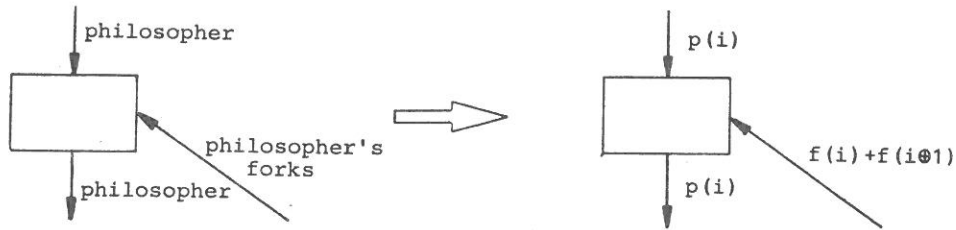
We have elaborated the property of eating.



to formalize:

When formalizing, we use description elements with a more precisely defined syntax and semantics.

example:



We have formalized the removal of forks.

#### 4 Techniques based on net morphisms

In the previous two sections we introduced two categories of concepts. In this section we use our concepts characterizing description techniques based on three categories of morphisms. We introduce the three categories informally and refer to the formal treatment in [Genrich, Lautenbach, Thiagarajan 80] p. 147-153. In brackets we note the the corresponding concepts in the above mentioned paper.

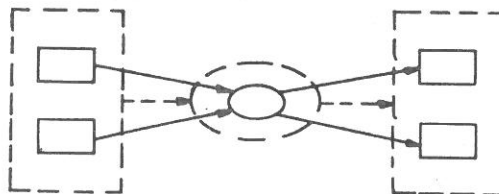
##### Strict surjective morphisms

(F-strict epimorphisms)

A strict surjective morphism is a surjective morphism having the property that if there is an arc joining two nodes in the image net then, in the domain net, there is a corresponding arc joining two nodes which are mapped into the two image nodes.

In the following the domain net is fulldrawn and the image net is dashed. The morphism is represented by positioning each node in the domain net within its image node in the image net.

example:



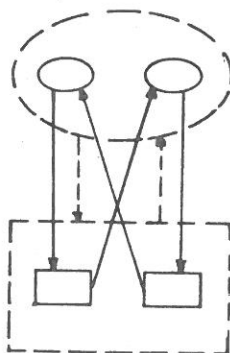
We split strict surjective morphisms into two disjoint categories, namely foldings and condensations.

### Foldings

(surjective folding)

A folding is a strict surjective morphism where places are mapped into places and transitions are mapped into transitions.

example:

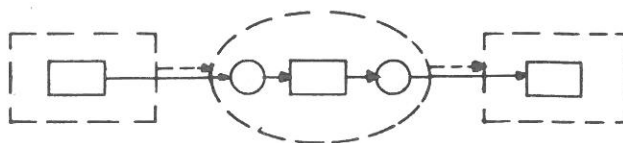


### Codensations

(strict surjective morphisms which are not foldings)

A condensation is a strict surjective morphism where at least one place is mapped onto a transition or at least one transition is mapped onto a place. Hence there are two domain nodes joined by an arc which are mapped onto the same node.

example:

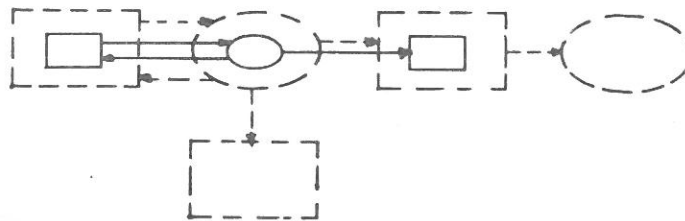


### Injections

(subnet injection)

An injection is a morphism where the domain net is a subnet of image net with identical net-structure.

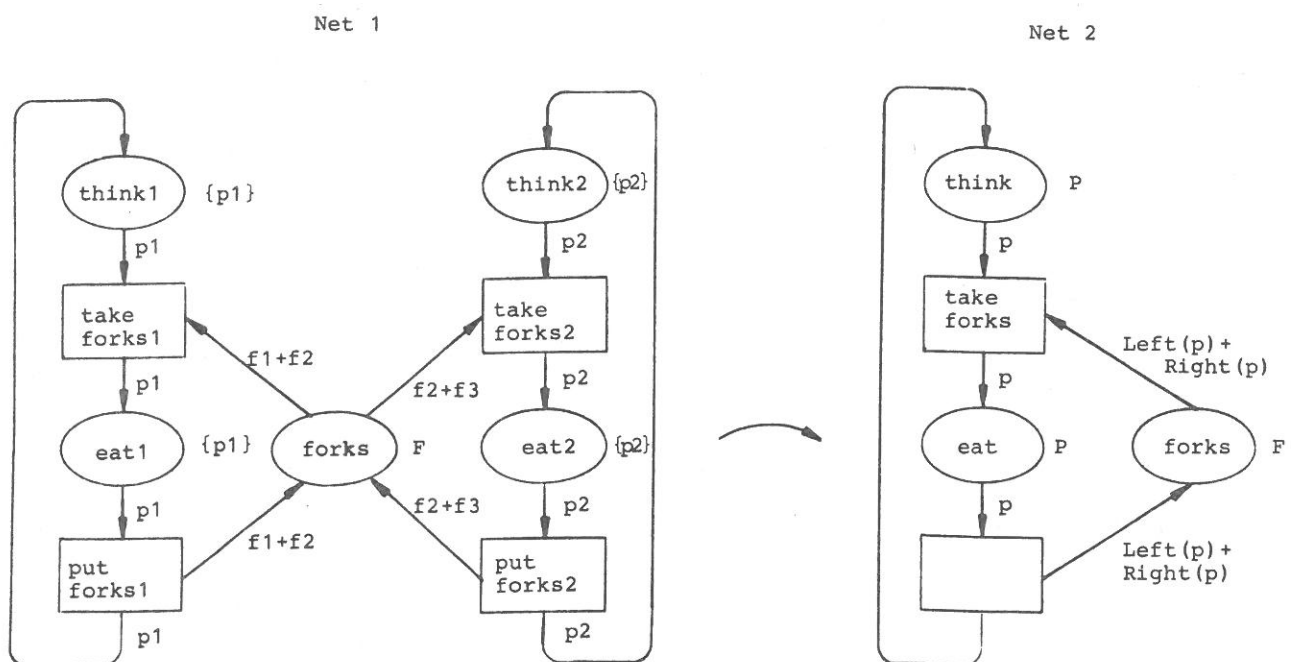
example:



In the following we consider techniques based on each of the three categories foldings, condensations and injections.

### Techniques based on foldings

We introduce the technique by means of an example,



The morphism mapping Net1 onto Net2 is a folding. "think1" and "think2" are mapped onto "think", "eat1" and "eat2" are mapped onto "eat" and "forks" are mapped onto "forks". The transitions are in a similar way mapped onto the corresponding transitions in Net2.

By this technique we have structured the net-structure of Net1, because the condensation expresses a similarity of "think1" and "think2", "eat1" and "eat2" and of the two pairs of transitions.

The net-structure of Net1 is a refinement of the net-structure of Net2.

The effect of the technique on the inscriptions depends on the choice of P and the expressions on the arcs. Let us look at two cases.

First case:

If we choose:

$$P = \{p1, p2\}$$

$$\text{Left}(p) = \begin{cases} f1 & \text{if } p=p1 \\ f2 & \text{if } p=p2 \end{cases}$$

$$\text{Right}(p) = \begin{cases} f2 & \text{if } p=p1 \\ f3 & \text{if } p=p2 \end{cases}$$

then both nets describe two philosophers sharing fork number 2. In other words the two nets are equivalent in the sense that they have the same firing sequences.

We have refined the inscriptions of Net2 compared to the inscriptions of Net1, for example we have refined the set of colours to make it possible to distinguish the two philosophers.

Second case:

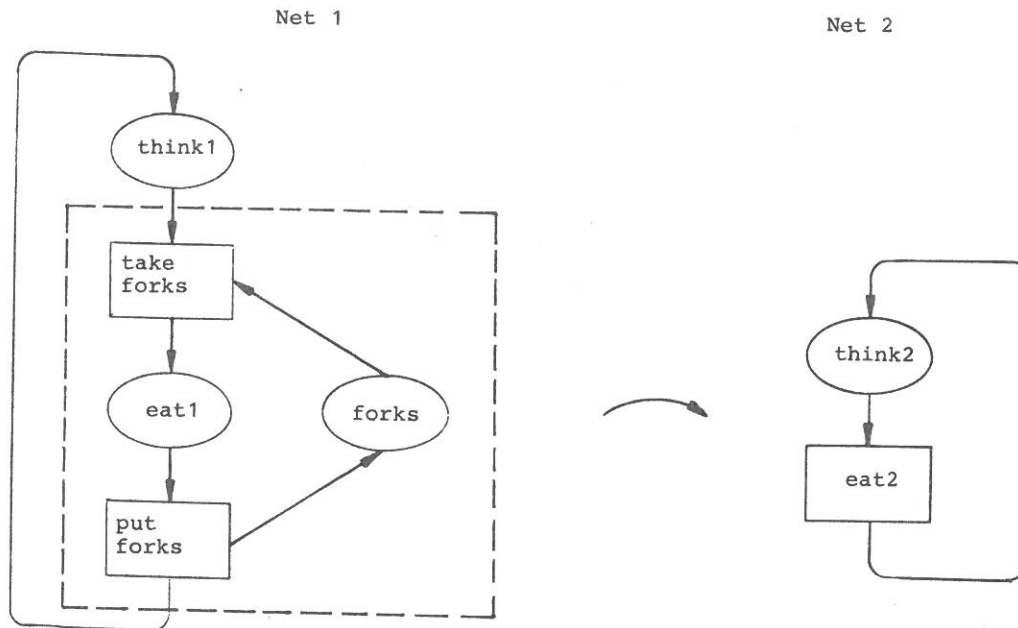
If we choose:

$$P = \{\epsilon\}$$

we are not able to distinguish the two philosophers and hereby we are not able to make sure that a philosopher gets the right forks. We have not refined the set of colours P, hence Net1 and Net2 are not equivalent.

### Techniques based on condensations

We introduce the technique by an example:



The morphism mapping "think1" onto "think2" and the subnet inside the rectangle onto "eat2" is a condensation.

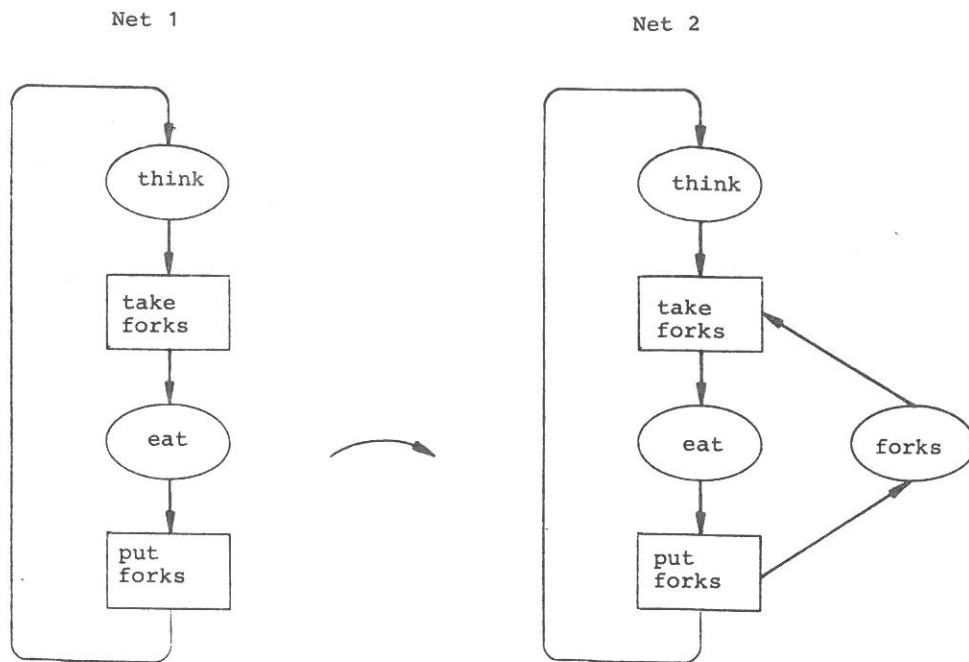
By this technique we have structured Net1 since the condensation ties everything inside the rectangle together.

The net-structure of Net1 is a refinement by elaboration of the net-structure of Net2, for example in Net1 we have also described the manipulation of the forks.

We can make the inscriptions more or less refined, but we can never make Net1 and Net2 equivalent, because we can't describe the state transition from "think1" to "eat1" in Net2.

### Techniques based on injections

We introduce the technique by an example:



The morphism mapping Net1 into Net2 is an injection. The nodes of Net1 are mapped onto the corresponding nodes of Net2.

The injection is a structuring of Net2 because the injection conveys that we consider Net1 as a coherent part of Net2.

The net-structure of Net2 is a refinement by addition of the net-structure of Net1 since we in the net-structure of Net2 describe more attributes than in the net-structure of Net1.

We have shown no inscriptions on the nets; usually we retain the inscription of Net1 in Net2.

### 5 Abstract storage structures

We shall consider yet another technique, namely abstract storage structures originally introduced in [Oberquelle 82].

Abstract storage structures are suitable for the description of objects and the associated operations. An abstract storage structure is described in detail in an implementation-net and applied as specified in an interface-net. So when using this tech-

nique we get three types of nets:

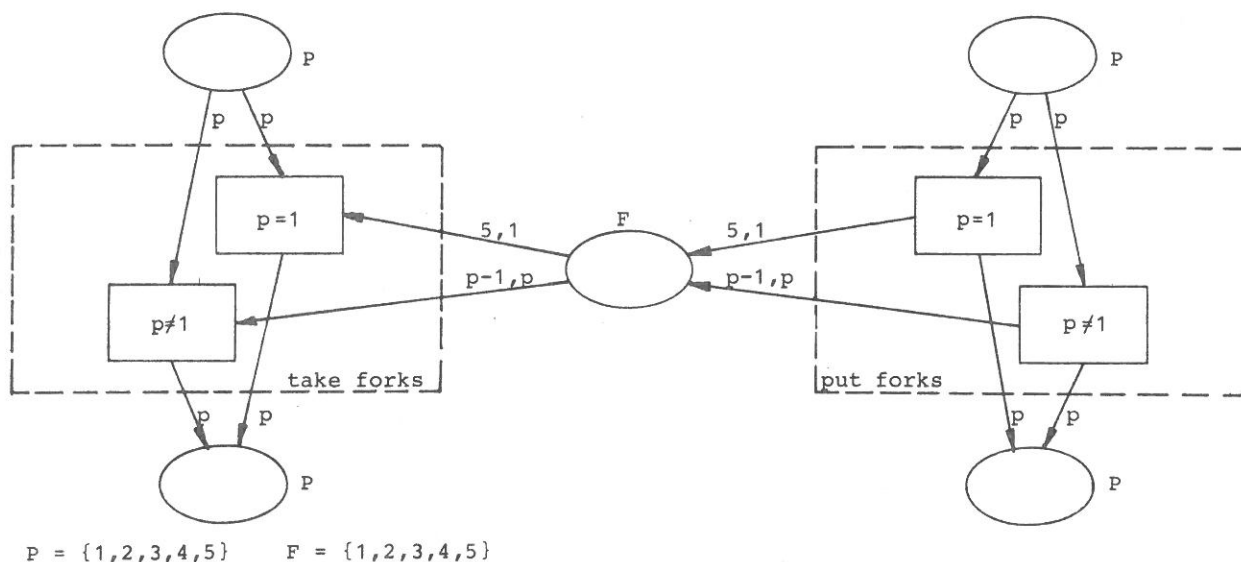
- . implementation-net
- . interface-net
- . application-net

In the following we characterize abstract storage structures. We compare the implementation-net with the interface-net and the interface-net with the application-net. As an example we describe how the dining philosophers use the forks. We consider the set of forks as an object with two operations "take forks" and "put forks".

### implementation-net

The implementation-net specifies in detail the place representing the object and the transitions representing the operations.

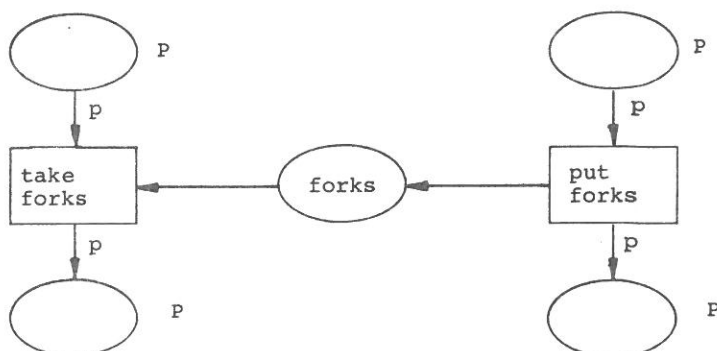
An implementation-net describing the dining philosophers use of forks may look like:



In this net you can see that the forks are represented by a set of colours F and how the marking of the "fork-place" is changed when a philosopher performs the "take forks" operation or the "put forks" operation.

### interface-net

The interface-net specifies how the environment is affected when performing the operations:



It is specified that the operations "take forks" and "put forks" both removes a philosopher from a surrounding place and puts the philosopher back on a surrounding place. But it is not specified how the forks are represented and manipulated.

The net-structure of the interface-net is less refined than the net-structure of the implementation-net. The relation between the two net-structures may be characterized as a folding. The folding is represented by dashed lines, the folding is the identity on nodes not surrounded by dashed lines.

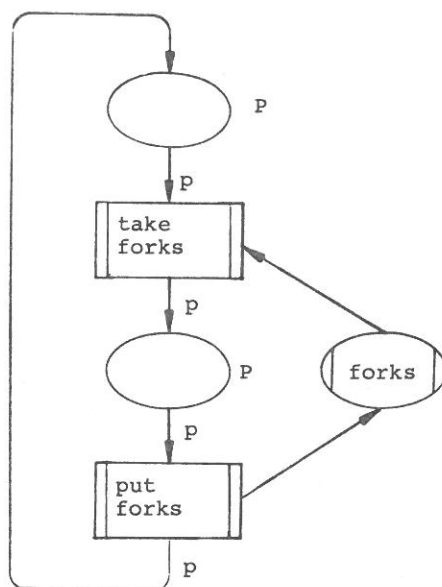
The folding expresses a structuring of the net-structure, e.g. the two transitions comprising "take forks" are similar.

The inscriptions on the interface-net are less refined than on the implementation-net, e.g. the inscriptions on the arcs connected to the "fork-place" are omitted and so is the set of colours F. In other words the inscriptions concerning the representation and use of forks are omitted.



### application-net

If we use the interface-net in a net describing "the dining philosophers" we get this net:



If exactly one operation is used and used only once then the relation between the part of the net-structure of the interface-net describing this operation and the net-structure of the application-net may be characterized as a subnet injection.

If one operation is used more than once or more than one operation is used then the relation between the two net-structures may be characterized as an injection of those parts of the interface-net describing the operations, followed by a folding identifying the places representing the object.

The injection and the folding express a structuring of the application-net since the morphism points out those parts of the application-net described by abstract storage structures.

In this example we have further more structured and formalized the layout by using a special appearance of those nodes specified by abstract storage structures. The layout of these nodes indicates which nodes are part of an abstract storage structure and hereby have a special semantics.

If we compare a description with abstract storage structures and one without describing the same then we can say that the use of abstract storage structures makes the net-structure and inscriptions less refined.

## 6 An example

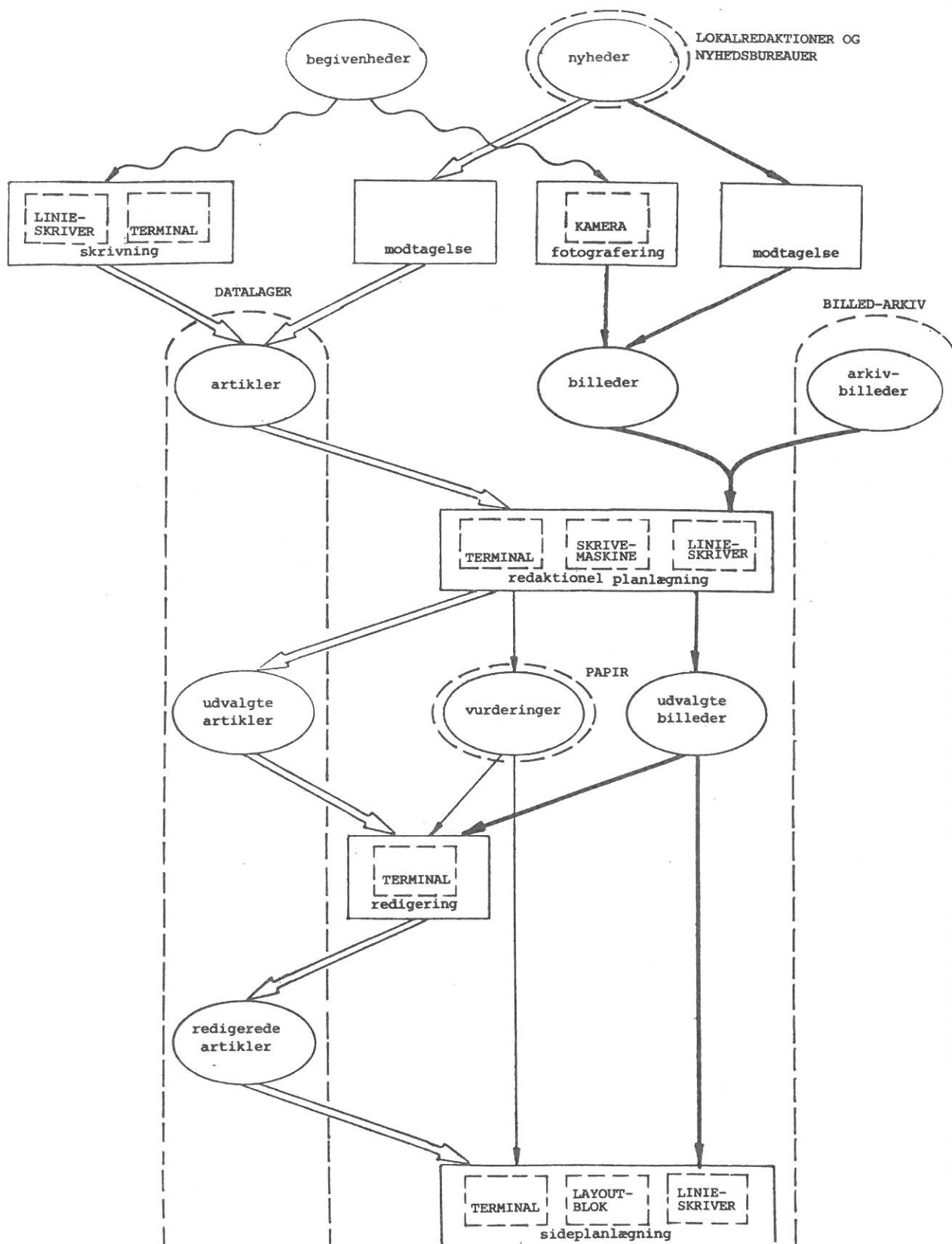
In the preceding sections we have justified our choice of concepts by specifying some rather simple techniques. But the only way our conceptual framework can prove its value is through many realistic examples. One such example has been worked out in [Hansen, Madsen 83]. There we have 15 pages of descriptions all describing different aspects of the production process at a Danish newspaper company. Due to lack of space we are here only able to present one of these descriptions.

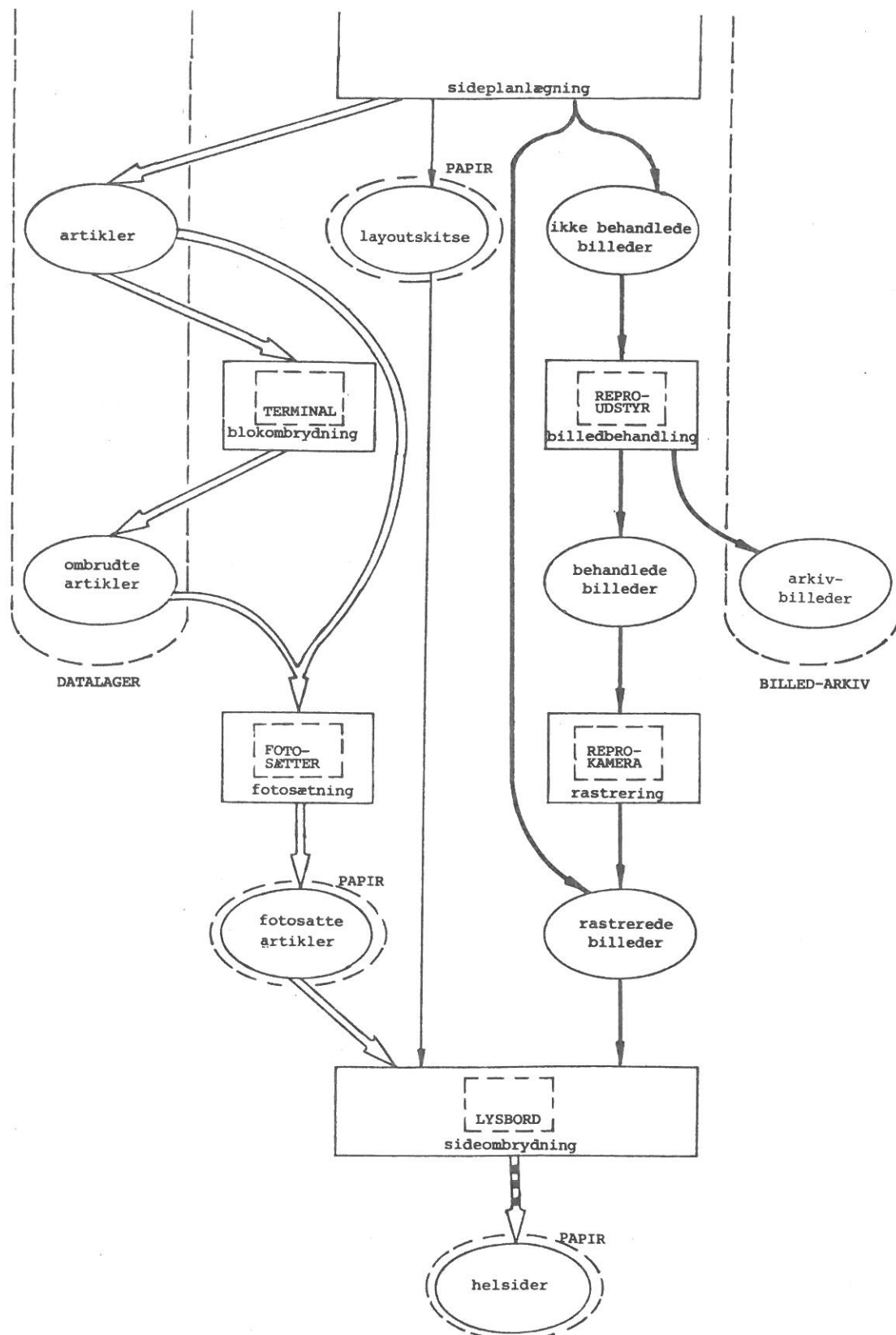
By means of the conceptual framework we characterize the techniques applied in the selected example, but being a realistic example we are not able to demonstrate all aspects of the conceptual framework, - in this example we are focusing on structuring techniques.

The description is a combination of a means/activity net and a channel/agency net. We have structured the layout by drawing the nodes of the means/activity net full drawn and by drawing the nodes of the channel/agency net dashed. Moreover the net-text of the means/activity net is in lower-case letters whereas the net-text of the channel/agency net is in upper-case letters.

We have structured the layout by having different appearance of the arcs representing the flow of articles, pictures etc. We have also structured the layout by positioning the transitions representing time-independent activities beside each other. Moreover all nodes are positioned top to bottom according to the main direction of movement of the production process.

We have structured the net by splitting the means-activity net into two subnets where the connection between them only consists of one transition, "sideplanlægning"; this transition has a special appearance. The split is made so that the first net primarily describes work done by journalists whereas the second net primarily describes work done by typographers and lithographers.





## 7 Conclusions

We have presented a conceptual framework for the characterization of Petri net description techniques. The conceptual framework enriches our language and enables us to give a more precise specification of new and existing description techniques, and hereby supports the communication of the techniques. We have applied the framework for the characterization of techniques based on three categories of morphisms, abstract storage structures and the techniques applied in a part of a realistic description. The usefulness of the conceptual framework can be verified only through many realistic applications.

The important point however, is that we feel that a conceptual framework (though perhaps not the one presented here) is essential for identifying and propagating net description techniques. And surely for making progress in applications of nets, it is essential that we develop and communicate net description techniques that can deal with large systems.

## Acknowledgements

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