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Towards a Plan-Based Synthesis of Illustrated Documents

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Towards a Plan-Based Synthesis of Illustrated Documents

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Towards a Plan-Based Synthesis of Illustrated Documents

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Abstract

A major drawback of existing systems for the synthesis of multimodal documents is that they generate textual and graphical parts mostly independently of each other. Consequently, the relation between text and graphics remains opaque in such documents. This report* starts from the assumption that not only the generation of text, but also the generation of multimodal documents can be considered as a communicative act in the achievement of certain goals. A plan-based approach seems adequate for the realization of a system able to automatically generate illustrated documents. First, we show that the distinction between main and subsidiary acts proposed by textlinguists is also suitable for text-picture-combinations. Starting from this distinction, we formulate strategies which relate both to text and picture production. The joint planning of text and pictures is regarded as a fundamental prerequisite for the coordination of different modes.

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1. Introduction

Intelligent user interfaces as components of help systems, control panels, or expert systems of the next generation must be able to present information in a flexible manner appropriate to various presentation situations (cf. [Wahlster et al. 89]). This includes integrating the context-sensitive verbalization and visualization results into a multimodal output. There is no doubt that in many situations text-picture-combinations convey information more precisely and efficiently than text. Examples are manuals for technical devices or scientific textbooks in which graphical illustrations are extensively used to clarify complicated passages. However, one should not conclude from this that mixed presentations automatically contribute to the success of a communication. Among other things, we have to consider that the use of a picture cannot always be inferred from the picture itself. E.g., Wittgenstein points out that the picture of a boxer in fighting position can be used to show how a boxer should stand, how he should not stand, or how a certain man has stood, etc. (cf. [Wittgenstein 33]).

To ensure that a document is intelligible, text and pictures have to be tailored to each other. Such a tailoring requires knowledge concerning the functions of textual and pictorial document parts and the relations between them. If, as in our case, illustrated documents are to be automatically designed and realized, this knowledge has to be explicitly represented.

2. Related Research

While the generation of text-picture-combinations is a relatively new research topic within AI, there are already important contributions from philosophy, linguistics and psychology.

A comparison of pictures and language generally forms the basis of philosophical and linguistic approaches (cf. Wittgenstein´s picture theory of propositions in [Wittgenstein 33], the attempts in [Novitz 75] and [Kjorup 78] to apply speech act theory to pictures and Muckenhaupt´s use theory for pictures and text in [Muckenhaupt 86]). All studies agree that not only text, but also pictures can be used to perform communicative acts.

A large number of psychological studies focus on the various functions of pictures in illustrated documents (cf. [Willows&Houghton 87]). One important result is the observation that text-picture combinations are only advantageous if they complement each other. If the relation between text and pictures is unclear, pictures have no positive effect on the understanding processes (cf. [Ballstaedt et al. 81]). Other work is concerned with the question of which kind of information should be conveyed by pictures and which by text (cf. [Bieger&Glock 86] and [Wintermantel et al. 89]).

In AI, systems for the automatic design of multimodal presentations mostly rely on existing approches for generating text and designing graphics.

An overview of the most importants results in the area of text generation is provided by [Kempen 87] and [Zock&Sabah 88]. A relevant subproblem with respect to our own research is the determination of the contents and the structure of a text. Besides schema-based approaches (cf. [McKeown 85], [McCoy 89] or [Paris 89]), research focuses on plan-based strategies (cf. [Appelt 85], [Hovy 88] or [Moore&Swartout 89]). Plan-based methods start from the assumption that an author performs acts during the generation of text in order to achieve certain goals (cf. [Searle 69]). For our research, the work of Hovy, Moore and Swartout is of primary interest since they are concerned not only with the generation of single sentences, but also with the generation of coherent text. They use the RST-theory proposed by Mann and Thompson (cf. [Mann&Thompson 87]) which describes the structure of texts by means of so-called rhetorical relations, such as *Elaboration* or *Motivation.*

Present approaches for the generation of graphics can be distinguished by their underlying objectives. Important work includes the presentation of relational information by business graphics (cf. [Mackinlay 88]), the synthesis of icons (cf. [Friedell 84]), the graphical presentation of action sequences (cf. [Feiner 85]), the visualization of natural language descriptions (cf. [Adorni et al. 84]), the generation of mental images (cf. [Kosslyn 80]) or the representation of knowledge concerning graphical presentation techniques by semantic networks (cf. [Zdybel et al. 81], [Geller&Shapiro 87] and [Arens et al. 88]).

Although there is a broad interest in the design of systems which combine graphical and textual output (cf. [Sullivan&Tyler 89] and [Arens et al. 89]), the two modes are treated largely independently of each other. A notable exception is the COMET system (cf. [Feiner&McKeown 90]). After constructing a common content description by using schemas, the system decides which information should be presented by text and which by graphics. It is, however, questionable whether the contents can always be fully worked out without knowing which modes will be chosen.

3. The Act Structure of Text-Picture Presentations

The aim of our work is to develop a system able to generate documents in which text and pictures are smoothly integrated. We start from the assumption that not only the generation of text, but also the design of multimodal documents can be thought of as a communicative act in the attainment of certain goals. Often goals cannot be met by a single act because necessary preconditions have to first be satisfied by subordinated acts. In addition, it may be reasonable

to perform further acts which are not absolutely necessary, but which support the main act. According to textlinguistic studies we distinguish between *main acs* (MA) and *subsidiary acts* (SA)[1]. Since main and subsidiary acts, in turn, can be composed of main and subsidiary acts, we get a hierarchical act structure. The structure of a document is, however, not only determined by its act structure, but also by the functional relations between main and subsidiary acts (e.g., textual acts can *elucidate* pictorial acts) or the contents they convey (e.g., pictures can show a *sequence* of events). Further examples of relations between pictorial document parts or pictorial and textual parts we have investigated are *Organization, Motivation, Enablement, Background, Elaboration* and *Contrast*. In addition there are relations such as *Condition* or *Concession* which only occur between text passages. To explain the terminology introduced, let's have a look at the document fragment in Fig. 1.

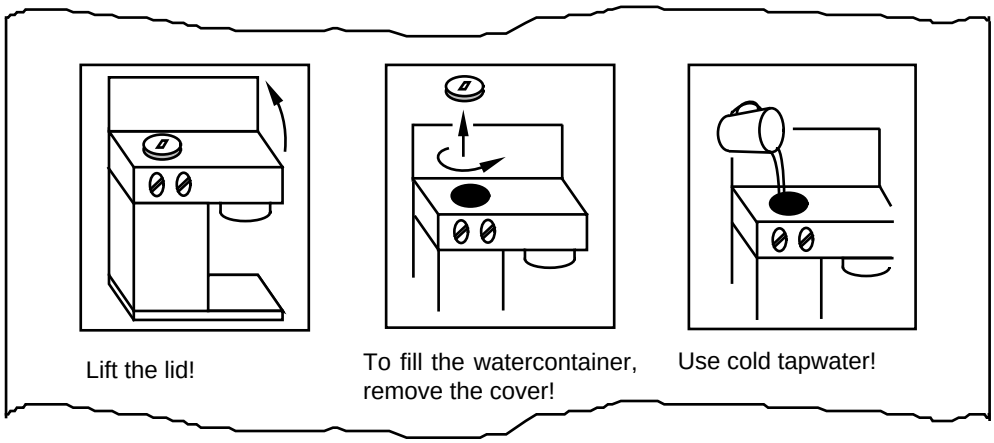

Fig. 1: Part of the Instructions for an Espresso-Machine[2]

The goal of this document fragment is to instruct the addressee in filling the watercontainer of an espresso-machine. This goal is achieved by telling him which subactions to perform. First, the addressee is explicitly asked to lift up the lid (MA), and a picture specifies how this action has to be carried out (SA, Enablement). The generation of the picture is also subdivided into a main act, namely the showing of the position of the lid after lifting it up, and a subsidiary act, the depiction of the whole device to facilitate orientation (Background). Afterwards, the addressee is asked (MA) to remove the cover of the watercontainer. To motivate that request, the goal, i.e. the filling of the watercontainer, is mentioned (SA, Motivation). In addition, a picture illustrates how the cover has to be removed (SA, Enablement). The last part of the document fragment is an example of an implicit request. If the addressee knows that the filling

[1] This distinction between main and subsidiary acts essentially corresponds to the distinction between *global* and *subsidiary speech acts* in [Searle 69], *main speech acts* and *subordinate speech acts* in [Van Dijk 80], *dominierenden Handlungen* and *subsidiären Handlungen* in [Brandt et al. 83] and between *nucleus* and *satellites* in the RST-Theory proposed in [Mann & Thompson 87].

[2] The document fragment is a slightly modified and translated version of the instructions for the Philips espresso-machine HD 5649.

action is necessary to achieve his goal, it obviously suffices to show by means of a picture how to perform the action (SA, Enablement). In the given example, the main act of asking the addressee to pour in water follows implicitly from the situative context and the subsidiary act[3]. The text (SA, Elaboration) supplements the picture (MA of the enabling act) by referring to details which are difficult to present graphically, namely to pouring in *cold* tapwater. As in the first and second picture, not only objects which are directly involved in the opening and filling of the watercontainer, such as the watercontainer, the cover and the water, are shown, but also the upper part of the whole espressomachine (SA, Background). The structure of the document is summarized in Fig. 2. In the following, we focus on the question of how to build up an intelligible document starting from a given presentation goal.

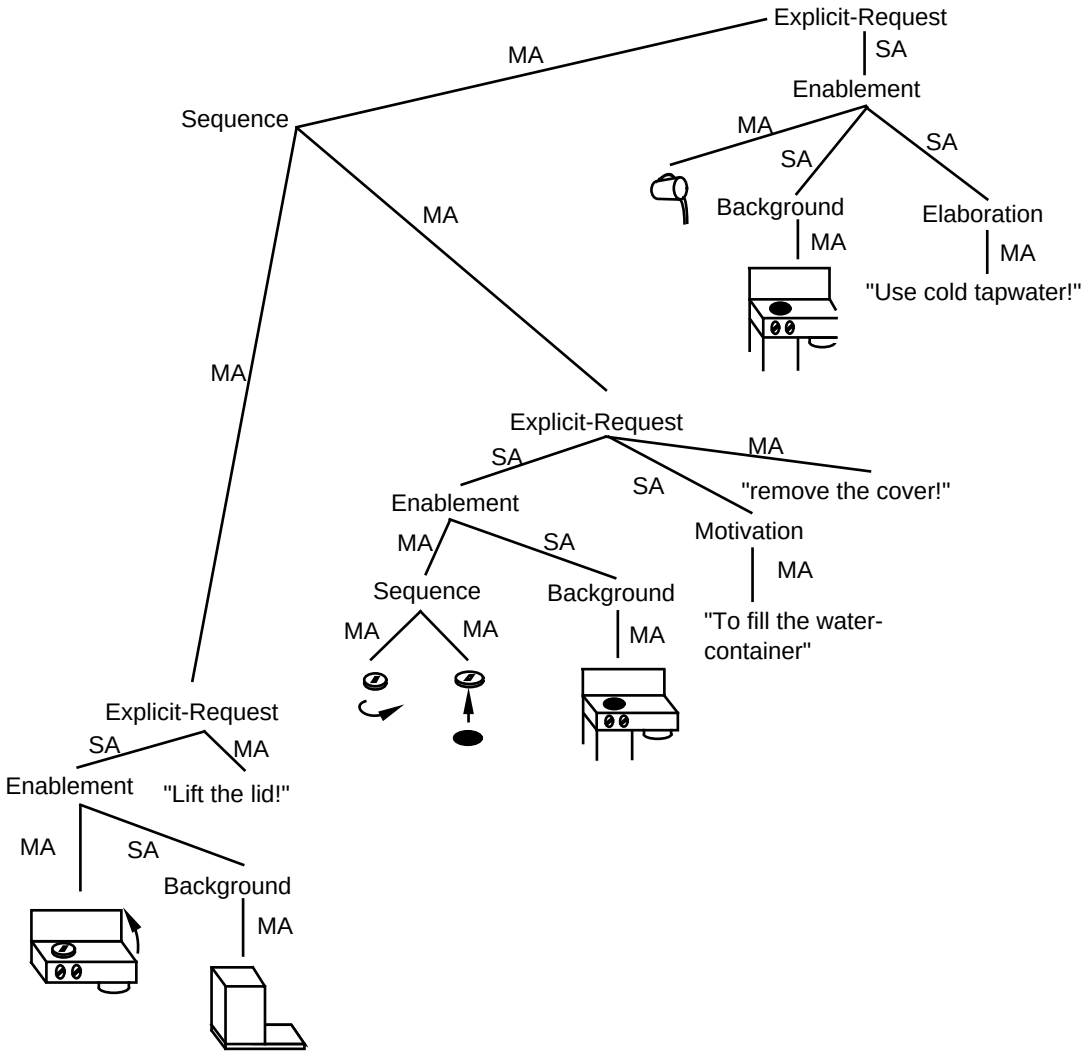

Fig. 2: Act Structure of the Document Fragment in Fig. 1

[3] The occurrence of not explicitly performed main acts is also discussed in [Brandt et al. 83].

4. Presentation Strategies

We assume that the author of a document has a repertoire of *presentation strategies* at his disposal which can be selected and combined according to the tasks. The main and subsidiary acts introduced in the last section form the kernel of such presentation strategies.

To represent the presentation strategies, we follow the approach proposed in [Moore&Paris 89] and [Moore&Swartout 89] for the operationalization of the RST-theory. Following textlinguistics studies (cf. [Brandt et al. 83] and [Rosengren 83]), we also permit strategies which contain no main act and allow for the combination of several main acts in a communicative unit if none of them is subordinated. Within a presentation strategy, we can refer to an act either by specifying the goal or by indicating the presentation strategy to be used. The effect of a strategy can describe a functional relation, such as *Background*, or characterize a presentation goal, such as ensuring that the addressee knows the result of an action (cf. [Moore&Paris 89]). For the representation of presentation goals, we use the modal operators GOAL, BEL and BMB (cf. [Cohen&Levesque 87]). The expression (GOAL P p) stands for: The presenter P has goal p. (BEL P p) means: P believes that p is satisfied. (BMB P A p) is the infinite conjunction: (BEL P p) & (BEL P (BEL A p)) & (BEL P (BEL A (BEL P p))) & ... and represents unilateral mutual belief between P and A. To express that P and A mutually know for which uniquely determined x a formula p is satisfied, we use the abbreviation (BMBR P A p). With each presentation strategy, we associate *applicability conditions* in order to indicate whether a strategy can be applied in a specific situation. As examples, we list some presentation strategies which can be used along with others in building up the document fragment shown in Fig. 1.

(1)
Header:
(EXPLICIT-REQUEST P A ?act)
Effect:
(BMB P A (GOAL P (DONE A ?act)))
Applicability Conditions:
(GOAL P (DONE A ?act))
Main Acts:
(REQUEST P A ?act)
Subsidiary Acts:
(MOTIVATE P A ?act)
(ENABLE P A ?act)

Strategy 1 can be applied by a presenter P to explicitly request an addressee A to perform an action. The first subsidiary act serves as a motivation; the second provides information which enables the addressee to perform the action. To present this information, Strategy 2 can be used. It provides for the graphical presentation of the result of the action (SHOW-STATE) and the drawing of an arrow from the initial state to the final state (SHOW-DIRECTION).

(2)
```
Header:
        (ENABLE-BY-ILLUSTRATION P A ?act)
Effect:
        (ENABLE P A ?act)
Applicability Conditions:
        (BEL P (ISA ?act ELEMENTARY-MOTION))
Main Acts:
        (SHOW-STATE P A (RESULT ?act) ?picture)
        (SHOW-DIRECTION P A (DIRECTION ?act) ?picture)
Subsidiary Acts:
        (ATTRACT-ATTENTION P A ?picture)
        (ELUCIDATE P A (MODE ?act) ?picture)
```

The main acts in Strategy 2 on their own cannot guarantee that the intended goal will be achieved. If the presenter uses, e.g., a picture which has been generated elsewhere, he has to ensure that the addressee focuses on the picture. This can be accomplished by explicitly requesting the addressee to look at the picture.

(3)
```
Header:
        (ATTRACT-ATTENTION-BY-REQUEST P A ?picture)
Effect:
        (ATTRACT-ATTENTION P A ?picture)
Main Acts:
        (BMB P A (GOAL P (DONE A (LOOK-AT A ?picture))))
```

Even if the addressee looks at the right picture at the intended moment, one cannot be absolutely sure that he recognizes the presenter's intention; i.e. that he knows which information he is expected to extract from the picture. In general, it can be a very difficult task to find out if he is able to do so. Among others, one has to consider how effectively the relations between the parts of a document are conveyed and if the addressee is familar with the presentation techniques used. E.g., if the presenter uses a picture lexicon, it is very likely that the intention involved is recognized. Currently, we assume for the sake of simplicity that the function of a picture is recognized if there is a piece of text in which the picture is focused on and if a common goal, e.g. presentation of an object, can be assigned to this text piece and the picture. In formulating this condition, we presume that the function of a text follows from the text and that the function of a picture can be inferred from the accompanying text. If the function of a picture is assumed not to be recognized, the following strategy can be applied.

(4)
```
Header:
        (ELUCIDATE-BY-REQUEST P A ?info ?picture)
Effect:
        (ELUCIDATE P A ?info ?picture)
Applicability Conditions:
        (BEL P (CONTAINS ?info ?picture))
Main Acts:
        (BMB P A (GOAL P (DONE A (EXTRACT A ?info ?picture))))
```

Now, let's turn to the main act in Strategy 2 which is subdivided into two subacts: the graphical presentation of the result of the physical action to be carried out by the addressee and the drawing of an arrow from the initial to the final state. The result of a physical action involving motion can be described by depicting the spatial relations between objects in a picture. A spatial relation is presented by depicting the subject and the reference objects and by positioning their depictions. Instead of discussing the corresponding strategies (cf. [André 90]) in more detail, we concentrate on the depiction of objects (cf. 5). When showing a picture, we have to ensure that the addressee relates the pictured objects to the same world objects as the presenter. We assume that the addressee recognizes the connection between an object ?x and its depiction ?px if there are no world objects in focus which are as similar or even more similar to ?px as ?x. If there is another object which resembles ?px to the same degree as ?x, then the addressee will most probably not be able to establish the link between ?px and ?x. In this case, Strategies 6 and 7 can be used to depict ?x as a part of a more complex object in order to resolve ambiguities.

(5)
Header:
(SHOW-OBJECT P A ?x ?px ?picture)
Effect:
(BMB P A (IDENTIFIED-REFERENT A ?x ?px ?picture))
Applicability Conditions:
(BEL P (PERCEPTUALLY-ACCESSIBLE A ?x))
Main Acts:
(DEPICT-OBJECT P A ?x ?px ?picture)
Subsidiary Acts:
(BMB P A (IDENTIFIABLE A ?x ?px ?picture))
(*opt* (BEL P SPACE-AVAILABLE-P)
(FACILITATE-LOCALIZATION P A ?x ?px ?picture))

The optional subsidiary act marked by *opt* in Strategy 5 will only be carried out when enough space is available. If this condition is satisfied, additional objects are depicted to facilitate the spatial orientation of the addressee. Depending on whether ?x is in the visual focus or not, adjacent object parts are indicated or ?x is depicted as part of a larger object (cf. [André 90]).

(6)
Header:
(ENABLE-IDENTIFICATION P A ?x ?px ?picture)
Effect:
(BMB P A (IDENTIFIABLE A ?x ?px ?picture))
Applicability Conditions:
(BEL P (PART-OF ?x ?z))
Main Acts:
(BACKGROUND P A ?z ?pz ?picture)

(7)
Header:
(GRAPHICAL-SUPPLEMENT P A ?x ?px ?picture)
Effect:
(BACKGROUND P A ?x ?px ?picture)
Main Acts:
(SHOW-OBJECT P A ?x ?px ?picture)

5. Building up Text-Picture-Presentations

For the automatic design of a document, the strategies presented above are considered operators of a planning system. During the planning process, the planner tries to find strategies that are either directly specified by name or whose effects match the presentation goal. The planner then checks whether their applicability conditions hold. If several strategies are possible, metarules are applied. For the definition of such rules, we can fall back on psychological studies which investigate the efficiency of presentation modes depending on the kind of information used. E.g., according to [Bieger&Glock 86] and [Wintermantel et al. 89] spatial information in instructions is perceived faster if pictures are used. To ensure that graphics are used in preference to text for the presentation of spatial information, we use the following rule:

(8) IF (GOAL P (BMBR P A (LOCATION ?loc ?obj)))
THEN (DOBEFORE *graphics-strategies* *text-strategies*)

After the selection of a strategy, the main and subsidiary acts have to be carried out unless the corresponding presentation goals are already satisfied. E.g., if the system believes that the addressee is willing to perform an action, it is not necessary to motivate him. Whether a subsidiary act is performed before or after the main act is conditional upon its dependency on the main act. E.g., to ensure by a subsidiary act that the addressee is able to relate an object depiction to the intended world object, knowledge about the picture is necessary. In this example, the main act, namely the production of the picture, has to be carried out first. After that, the picture can be examined in a subsidiary act by anticipating[4] the addressee´s understanding processes (cf. section 4). Elementary acts, such as INFORM or DEPICT-OBJECT, are performed by the text and graphics generators. Information concerning the contents and the structure of pictures and text is handled by a document memory which is accessed, eg., when it is necessary to generate natural language references to parts of pictures. If one of the generators is not able to encode the required information or needs additional information, the planner tries to modify the initial plan. In Fig. 3, some of the acts required for building up the first part of the instructions shown in Fig. 1 are listed.

[4] For the anticipation of a hearer´s understanding processes, see [Schirra 89].

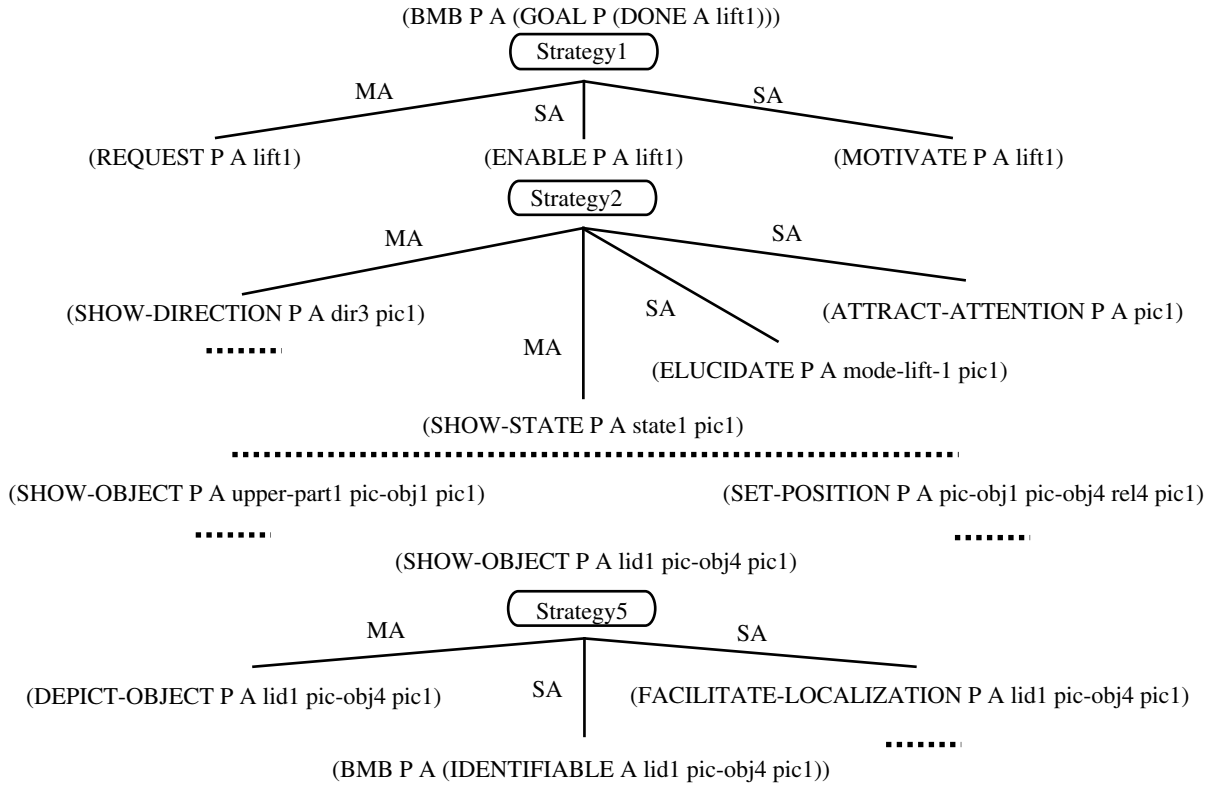

Fig. 3: Portion of a Plan for the Generation of a Request

6. Summary

In this paper, we have argued that not only texts but also pictures and text-picture-combinations can be seen as means to achieve certain goals. Following linguistic work, we distinguished between main and subsidiary acts. Since these acts refer both to the generation of text and the design of graphics, they allow for the integrated planning of text and graphics. Our approach is advantageous especially with respect to the following issues:

- *Complementarity*
  As each goal is realized exactly once, text and graphics complement each other. However, when defining the presentation strategies one has to ensure that they do not, at the outset, infringe on the principle of complementarity.

- *Coherence*
  Since the planner only generates document parts which are linked by those functional relations represented in the presentation strategies, text and graphics are always related to each other.

- *Cohesion*

  In order to guarantee that the addressee recognizes the relation between text and graphics, cohesive links are necessary. Since our approach explicitly represents which goal a presenter wants to meet with a certain document part, we are able to refer not only to the structure and contents of graphics, but also to their function.

A prototype of the presentation planner and parts of the two generators have been implemented in Commonlisp on a MacIvory Lispsystem running Release 7.2. Our current investigations focus on the interaction between the presentation planner and the generators. In the future, further modes such as gestures and animations will be integrated.

7. Acknowledgments

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