

# Generating Text with a Theorem Prover

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## Abstract

The process of documenting designs is tedious and often error-prone. We discuss a system that automatically generates documentation for the single step transition behavior of Statecharts with particular focus on the correctness of the result in the sense that the document will present all and only the facts corresponding to the design being documented.

Our approach is to translate the Statechart into a propositional formula, then translate this formula into a natural language report. In the later translation pragmatic effects arise due to the way the information is presented. Whereas such effects can be difficult to quantify, we account for them within an abstract framework by applying a series of transformations on the structure on the report while preserving soundness and completeness of the logical content. The result is an automatically generated hypertext report that is both logically correct and, to a relatively high degree of confidence, free of misleading implicatures.

## 1 Introduction

Producing technical documentation is a time-consuming and expensive task. For instance, Reiter et al. (1995), report cases of engineers expending five hours on documentation for each hour spent on design and of airplane documentation sets which weigh more than the actual airplane being documented. Part of the reason for this problem is the gap between Computer Aided Design (CAD) tools and similar tools for assisting the documentation of those designs. Since research efforts focus primarily in the former, this situation is likely to get worse as the CAD tools get more powerful while documentation tools lag far behind.

In this paper we address the matter of automatic generation of technical documentation (Reiter et al., 1992; Reiter et al., 1995; Rösner and Stede, 1992; Svenberg, 1994; Punshon et al., 1997) by studying the problem of automatically generating documents describing the single step transition behavior of Statecharts.

From a natural language generation (NLG) per-

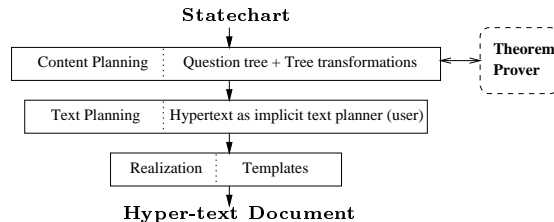


Figure 1: Conceptual view of the system.

spective, this problem is distinguished in that the formal correctness of the document being generated is crucial while felicitousness of the style is relatively unimportant. This leads us to a solution based on formally verifiable theorem-proving techniques which allows us to approach strategic NLG issues within a highly abstract and conceptually clear framework.

The system takes a statechart in the form of a labeled directed graph and translates it into a set of propositional formulae defining its transition behavior. A hyper-text natural language document is generated on-demand from this set of formulae in response to the reader's interaction with the application.

Figure 1 depicts a comparative (Moore and Paris, 1993; Paris et al., 1991; Hovy, 1988) conceptual view of the system while Fig. 2 shows the system architecture. A prototype has been fully implemented with the exception of the statechart axiomatization module.<sup>1</sup>

## 2 A Logical Semantics for Statecharts

The graphical language of statecharts as proposed by David Harel (Harel et al., 1987; Harel and Naamad, 1996), has been widely recognized as an important tool for analyzing complex reactive systems. It has been implemented in commercial applications like STATEMATE (Harel and Politi, 1998)

<sup>1</sup> A full description of this algorithmic translation of a statechart from its graphical formalism to the propositional logic input format used in this work is described in Garibay (2000).

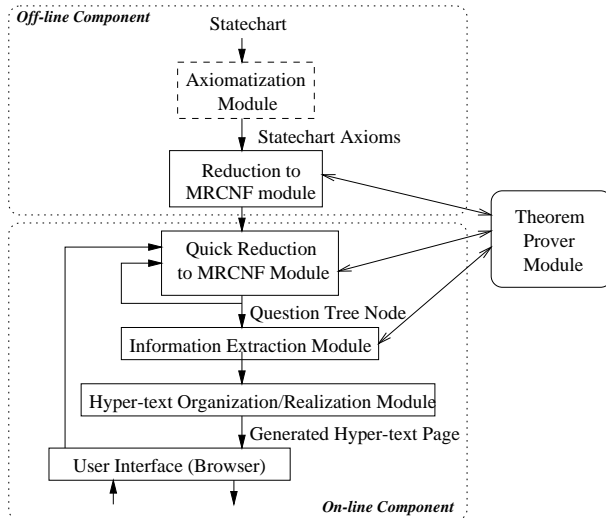


Figure 2: System architecture of the theorem prover based generator. The dotted box is not implemented.

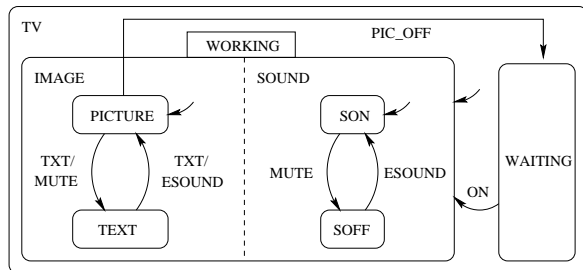


Figure 3: Example Statechart.

and RHAPSODY from ilogix (I-Logix Inc., 2000) and has been adopted as a part of the Unified Modeling Language (UML Revision Task Force, 1999; Booch, 1999), an endeavor to standardize a language of blueprints for software.

Statecharts (Fig. 3) are an extension of conventional finite state machines in which the states may have a hierarchical structure. A *configuration* is defined as a maximal set of non-conflicting states which are active at a given time. A *transition* connects states and is labeled with the set of events that trigger it, and a second set of events that are generated when the transition is taken. A *step* of the statechart relates the current configuration and the events that are active to the next configuration and the events that are generated. A configuration and the set of events that are active is referred to as a *status*.

We capture a step of a statechart as a pair of propositional models, one for the current status and one for the next status. In practice, we incorporate this into a single model with two versions of each propositional variable:  $P$  for the truth value in the current status and  $P_n$  for the truth value in the

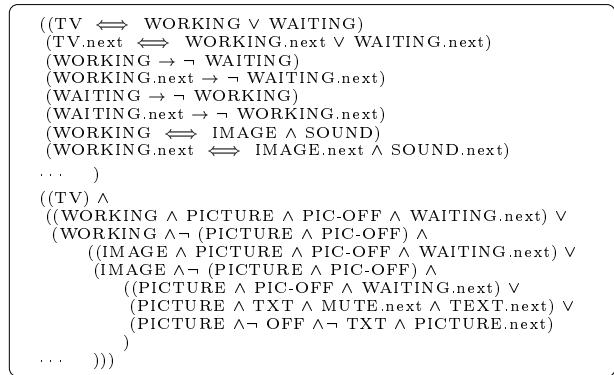


Figure 4: Section of the propositional logic translation of the example statechart (Fig. 3).

next status<sup>2</sup>. A full description of the algorithm for translating statecharts to sets of formulae can be found in Garibay (2000). For an example of this translation see Fig. 4.

### 3 The Minimum Clausal Theory of the Statecharts

At this point, we have a formula that entails the theory of the single step transition behavior of a Statechart. We can fulfill our requirement of generating a sound and complete report just by translating this formula into English. However, this approach presents a number of problems. For instance, the AND and OR connectives do not in general have the same meaning in English as they do in logic (Gazdar, 1979), furthermore, unlike in the logical formula the scope of the connectives in English is not, in general, well defined (Holt and Klein, 1999). To minimize the ambiguity, we need to take the formula to a form with minimal nesting of operators.

Potentially a more significant problem is the fact that much of the theory (the formula plus all its logical consequences) is obtainable only via complicated inferences. Since the reader understands the translation of the formula at an intuitive level, making only limited inferences, a direct translation will fail to communicate the entire theory. Hence, we would like to take the formula to a form that is closed, in some sense, under logical consequences.

We address both issues by using what we refer to as *minimal (fully) resolved conjunctive normal form (MRCNF)*. A formula is in a MRCNF if and only if it is in conjunctive normal form (CNF) and is closed under resolution, absorption and tautology (Fitting, 1990; Rogers and Vijay-Shanker, 1994). The closure under resolution is effectively a finite approx-

<sup>2</sup>These single step models will form the basis for a temporal model capturing the full behavior of the statecharts as described by Harel and Naamad (1996).

imation of closure under consequence, that is, every clause that is a logical consequence of the theory entailed by the formula is a direct consequence of some clause in the MRCNF. The other two operations guarantee minimality in size by removing clauses that are trivially true (tautology), and those that are proper super-sets of another (absorption). Hence, the translation will communicate not only the initial facts but also those inferred by resolution. Moreover, a formula in this form is just a conjunction of disjunctions—eliminating the scoping problem. If we interpret the disjunctions as implications, the translation into English will be just a sequence of implicative sentences that are to be interpreted conjunctively—a typical structure for such information in English.

#### 4 Organizing the Hyper-text Report: The Question Tree

A formula in MRCNF is organized in a way that resembles a sequence of implicative sentences. The problem now is the size of this sequence. Large to begin with, its size is increased by the transformation to CNF and closure under resolution. Hence, the translation of MRCNF directly into a sequence of statements would present an uninterpretable sequence of facts. If they are going to be understood by the reader there is a need for some kind of structure. The correct organization depends heavily on the reader’s goals and expectations. However, beyond the assumption that the reader’s generic goal is to obtain information about the transition behavior of the statechart under consideration, we do not make any assumptions about what the particular reader’s goals may be. Instead we present the report as a hyper-text document and allow the reader to interactively refine their goal by following hyper-links. Effectively, the reader’s queries focus the theory of the statechart in a particular aspect of its behavior<sup>3</sup>.

In this way, as in Reiter et al. (1992) and Levine et al. (1991), we use hyper-text as an implicit text planner, in the sense that we account for every possible model of the user/system interaction and let the actual reader decide which goal to pursue.

We will call the reader’s selections *choices*. Each choice the reader makes narrows the information we have to convey, limiting it to all and only the part that is logically consistent with that choice. We will say that the reader *refines* the theory by making the choice. At each point, the choices available to the reader are all the propositional variables that the theory is contingent upon. The reader effectively fixes the valuation of one of these variables to true or false. The system then adds the reader’s choice to the theory and recalculates the MRCNF. If

<sup>3</sup>In a process that will be precisely described shortly.

the newly obtained theory remains contingent upon some variables, the reader then will have available a new set of choices. If not, the reader will have reached a set of *non-contingent facts* (henceforth *facts*) which are consequences of all the previous choices.

While this process makes the information more accessible by giving it a logical structure, it does nothing to reduce the size of the report. We resolve this by generating the document on demand. While the refinement process (the core computation for on-demand generation) can potentially be very expensive in terms of time, the fact that we are adding singleton clauses to an already minimum set of clausal consequences allows us to use a simplified form of the theorem prover with asymptotic time complexity linear in the number of clauses.

We can visualize the process of the reader making choices as navigating a *question tree*, in which each branch is labeled with a choice and each node contains the theory of the Statechart as refined by the path of choices from the root to that node. In this tree, a reader’s choice is equivalent to the question: “What are the circumstances/situations if X is true/false?” The root is the full theory of the transition behavior of the Statechart. The children of a node are obtained by fixing the valuation of each of its contingent propositional variables in turn and recomputing the MRCNF. The leaves are non-contingent theories (those containing only facts)<sup>4</sup>.

Conceptually, the labels of each path from the root to a leaf together with each one of the facts in that leaf corresponds to all and only the valuations which are models of the original theory. Therefore, the question tree is sound and complete in the logical sense.

#### 5 Generating the Hyper-text Page under Pragmatic Considerations: Information Extraction Module

This tree turns out to provide a useful framework to address pragmatic issues—those that arise principally from the structure of the report itself (Gazdar, 1979). By addressing these issues in the context of the question tree, rather than in its realization as a report, we abstract away from a great deal of subtle semantic detail that would otherwise obscure the analysis. Our approach consists of applying a series of transformations that resolve these issues while preserving logical soundness and completeness of the document.

<sup>4</sup>In general this structure is a directed acyclic graph which Reiter et al. call the *question space* (Reiter et al., 1995), but since we work with a tree that spans it, we prefer *question tree*.

## 5.1 Promoting facts

In the question tree, the facts are either reported at the end of a chain of choices or are encoded in the choices themselves. A sequence of these choices is analogous to a chain of nested implications in which the antecedents are the choices made by the user and the consequence is the theory as refined by the choices. This refinement continues until we obtain a non-contingent theory—one in which all variables have valuations. Thus, the chain of implications eventually leads to a set of facts as its final consequence. The pragmatic problem in this case relates to the amount of information to be provided (Grice’s *Maxim of Quantity* (Grice, 1975)). This maxim states that speakers will make their contribution as informative as is required, but not more informative than that (Gazdar, 1979). Under this assumption, reporting a fact as a consequence of a sequence of choices explicitly denies that this fact is a consequence of any prefix of that sequence, in contrast to the logical semantics of implication. Such implicatures, while not consequences of the logical content, are valid inferences that people make on the basis of well established expectations about the communicative act.

To avoid this false implicature, we present the facts to the reader as soon as they become available, that is, as soon as they become non-contingent in the theory. The transformation, in this case, moves the facts from the leaves to the interior nodes. This transformation does not change the set of models represented in the tree simply because the movement of facts does not eliminate any path of the tree. Hence, the transformation preserves soundness and completeness of the tree.

In practice, the facts are just the singleton clauses of a theory, therefore we can realize this transformation by simply reporting singleton clauses as soon as they appear in the theory.

## 5.2 Reporting facts only once

On the other hand, facts in a theory are also facts in every consistent refinement of that theory. Hence, reporting all the facts at each node of the question tree leads us to report many of them repeatedly. In effect, every fact reported in a node will be reported in each of its children as well. This repetition of facts violates the “upper-bound” of Quantity—it reports more than is relevant. In this case Quantity requires us to report only information that is “new”.

In general, what is new will depend not only on what is reported but on inferences the reader is likely to have made (McDonald, 1992). We have, however, already committed to being explicit; our assumption is that the reader makes essentially no inferences, that they know all and only what we have explicitly reported. Therefore, we can satisfy the upper bound

of Quantity by reporting each fact exactly once on each branch—when it first becomes non-contingent. To do this, we simply keep a list of all facts that have been reported in the current branch; this is the extent of our model of the user.

This transformation does not change the set of models represented in the tree, since it only eliminates repeated literals.

## 5.3 Promoting single level implications

One of the difficulties in using Quantity is to determine what information is “required”. At each node of the question tree we have a current theory to report. The issue, in essence, is what to report at that node and what to report at its descendants. On one hand, it seems clear that we are, at least, required to report the non-contingent facts at each node. On the other hand, we don’t want to report the whole theory at the root.

Our intuition is that the degree to which facts are relevant is inversely proportional to the difficulty of interpreting them. Under these circumstances, un-nested implications (i.e., binary disjunctions) are simple enough that the reader is likely to expect them to be reported. From the perspective of the question tree, this suggests, that in addition to the facts at a node, we should also report, as implications, the facts at its non-contingent children (those that are leaves). We refer to the choices leading to non-contingent theories as *conclusive choices*. These are reported as single-level implications (“If X then ⟨some sequence of facts⟩”). This has the effect of promoting the leaves of the tree to their parent pages.

Note that a choice that is conclusive at some page will also be conclusive at each page in the subtree rooted at that page (or, rather, at each page reached by a sequence of choices consistent with that choice). In keeping with the principle of reporting a fact exactly once along each path, we must avoid reporting the implication at the descendent pages. To this end, after reporting each of the conclusive choices on a page, we report the remainder of the tree below that page under an “Otherwise” choice in which the theory has been refined with the complements of the conclusive choices. This has the effect of dramatically restructuring the tree: each of the non-contingent leaves is promoted to the highest page at which the choice that selects it becomes conclusive.

Once again this transformation reorganizes the branches of the question tree without changing the set of models it represents.

To find the conclusive choices we run the theorem prover on the current theory extended, in turn, with each literal upon which it is contingent. If the resulting theory is non-contingent, then that literal is a conclusive choice. To find the remainder of the tree

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So far:
* (the current configuration does not include the state WORKING)
* (the event OFF is not active)..

Facts:
* the next configuration will not include the state WORKING.

Independent of whether:
* the event PIC-OFF is active.

Depends on whether:
* the current configuration includes the states SON and SDF.
* the event MUTE is active.

Choices:
* If the current configuration includes the state SON [ then... ]
* If the current configuration does not include the state SON [ then... ]
* If the current configuration includes the state SDF [ then... ]
* If the current configuration does not include the state SDF [ then... ]
* If the event MUTE is active [ then... ]
* If the event MUTE is not active [ then... ]

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Figure 5: Example of generated hyper-text page.

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The following choices are conclusive:
* If the event OFF is active then:
- the next configuration will include the state WAITING,
  but will not include the states PICTURE or TEXT.
- the event MUTE will not be generated.
* If the next configuration includes the state WAITING then:
- the event OFF is active.
- the next configuration will not include the states PICTURE or TEXT
- the event MUTE will not be generated.

[Otherwise ...]

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Figure 6: Conclusive choices section (up), non-conclusive otherwise section (bottom).

to be reported under the “Otherwise” case we extend the current theory with the negation of each of the conclusive choices. If the resulting theory is inconsistent we will say that the conclusive choices are *exhaustive*, if the result is a contingent theory we will say that the conclusive choices are *non-exhaustive with non-conclusive otherwise*, and if the result is a non-contingent theory we will say that the conclusive choices, in this case, are *non-exhaustive with conclusive otherwise*.

#### 5.4 Aggregating pairs of single conditionals

It frequently happens that, at some page, two conclusive choices lead to the same model. In this case, we would report that each implies (among other things) the other. However, these two implications can be aggregated to form a biconditional. Furthermore, Quantity requires us to select the strongest connective that applies in any such case because if a weaker connective is selected it suggests that no stronger one applies (a *scalar implicature*). Consequently, we are actually compelled to aggregate these two facts into a single biconditional.

In practice, we use the theorem prover to either prove or disprove, for every implication, whether its converse is a theorem of the current theory. If proved then the biconditional is reported.

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Biconditional Implications:
- the next configuration will include the state SOFF if and only if
  the next configuration will not include the state SON.
One of the following must be the case:

Either:
- the current configuration includes the state SOFF,
  but does not include the state TEXT.
- the event ESOUND is not active.
- the next configuration will include the state SOFF,
  but will not include the state SON.
- the event ESOUND will not be generated.

Or:
- the current configuration includes the state SOFF,
  but does not include the state TEXT.
- the event ESOUND is active.
- the next configuration will include the state SON,
  but will not include the state SOFF.
- the event ESOUND will not be generated.

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Figure 7: Biconditional implications and models sections.

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Otherwise:
- the current configuration does not include the state TEXT
- the next configuration will not include the state SON.

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Figure 8: Conclusive otherwise section.

## 6 Hyper-text Organization and Realization Module

The organization of the hyper-text page generated from each node of the question tree visited by the user is shown in Fig. 5. At the top of the page we report (parenthetically) the set of choices that have led to this page. Next we report all of the new facts obtained from the current theory as described in sections 5.1 and 5.2. Then, the propositions that the theory is no longer dependent on (those which no longer occur in the theory) followed by the list of propositions on which it does depend. Finally we present the choices or, if there are any, the conclusive choices. In the first (Fig. 5), each choice is presented as an implicative sentence with a hyper-text link leading to another page (another node of the question tree). In the second (Fig. 6 top), we present the set of conclusive choices followed by one of the three possible cases (described in Section 5.3) for the “Otherwise” case. If the conclusive choices are exhaustive (the otherwise case is inconsistent), we report the biconditional implications (Section 5.4) followed by the final models (Fig 7). If they are exhaustive with a conclusive otherwise, we report the otherwise as another conclusive choice (Fig 8). Finally, if they are exhaustive with a non-conclusive otherwise, we report only an otherwise hyper-link (Fig 6 bottom).

The realization module is, in essence, a pattern matching and template filling process. Its basic component simply translates facts into fixed English language sentences.<sup>5</sup> Facts are represented by literals. These are classified into the following categories: *current state*, *current event*, *next state*, and *next event* and the literals in each category are syn-

<sup>5</sup>With added html mark-up.

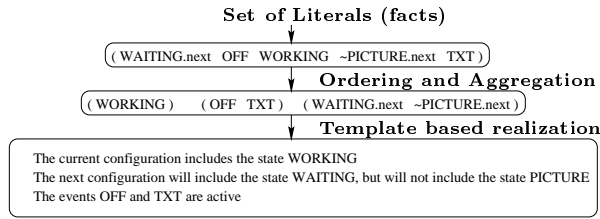


Figure 9: Example of realization.

tactically aggregated (Dalianis, 1999). The process is illustrated in Figure 9.

## A Page Generation Algorithm

The hyper-text pages in the System are generated on demand as shown in Figure 10. The algorithm that performs all the computation of the on-line component of the system (Fig. 2) is the page generation algorithm. This algorithm has two phases: the first one generates the node of the question tree corresponding to the user’s choice, the second one presents this node to the user as a new hyper-text page.

### A.1 Phase One

In practice, each node in the question tree is represented as a data structure that keeps track of the theory as refined by the choices leading to it. This includes the following fields: *theory*, *choices*, *dependencies*, *independencies*, *facts*, *reported facts*, *conclusive-dependencies-facts-list*, *conclusive choices*, *otherwise-theory*. The child node corresponding to the user’s choice is generated by filling this structure as follows:

*Input:*

*Theory* The Minimal Resolved CNF of the theory at this node.

*Choices made so far*

*Consequences* (not significant)

*Dependencies* (not significant)

*Independencies* (not significant)

*New independencies* (not significant)

*Facts* (not significant)

*Reported facts* All facts reported up to this node.

*Conclusive choices* (not significant)

*Corresponding theories* (not significant)

*Otherwise* (not significant)

*Output:*

*Theory* Minimal Resolved CNF of the theory of the parent node with the reader’s choice added.

*Choices made so far* The union of the parent node “choices made so far” and the reader’s choice.

*Consequences* Difference of the theory and the “Choices made so far”.

*Dependencies* The set of propositions which appear in non singleton clauses in the “Consequences”.

*Independencies* The set of propositions of the original theory which do not appear in the “Consequences”.

*New independencies*

“Independencies” less the parent “independencies” and the “choices made so far”.

*Facts* Difference between the set of singleton clauses in the “Consequences” and the parent node “reported-facts”.

*Reported facts* The union of the “facts” and the parent node “Reported facts”.

*Conclusive choices* A list of choices drawn from the dependencies that, when added to the theory and reduced to the minimal resolved CNF, yield a non-contingent theory, i.e., a theory containing only singleton clauses.

*Corresponding theories* The associated non contingent theories.

*Otherwise* Obtained by adding the logical complement of each conclusive choice to the theory and reducing to a minimal resolved CNF.

In the algorithm, we use the theorem prover to compute the *Theory*, *Conclusive choices* and *Otherwise* fields. For the *Theory* computation we extend the parent theory with a single fact, the user’s choice. Then, we use the theorem prover to recompute the MRCNF of the extended theory, which is the desired output. In practice, the particular case of recomputing the MRCNF of a theory after the addition of a singleton clause is done by a faster version of the algorithm that initially compute the MRCNF. To compute the *Conclusive choices*, we extend the parent theory, in turn, with each valuation of the variables upon which this theory is contingent. We reduce each of this extensions to MRCNF using this fast algorithm. Those reductions with only singleton clauses are non-contingent theories and the choices leading to them are conclusive.

For the *Otherwise* computation, we extend the parent theory with the conjunction of the logical complements of each conclusive choice. Then, we use the theorem prover to obtain the MRCNF representation corresponding to this extended theory. In practice, we extend the theory with one logical complement at a time and use the fast algorithm to recalculate the MRCNF representation.

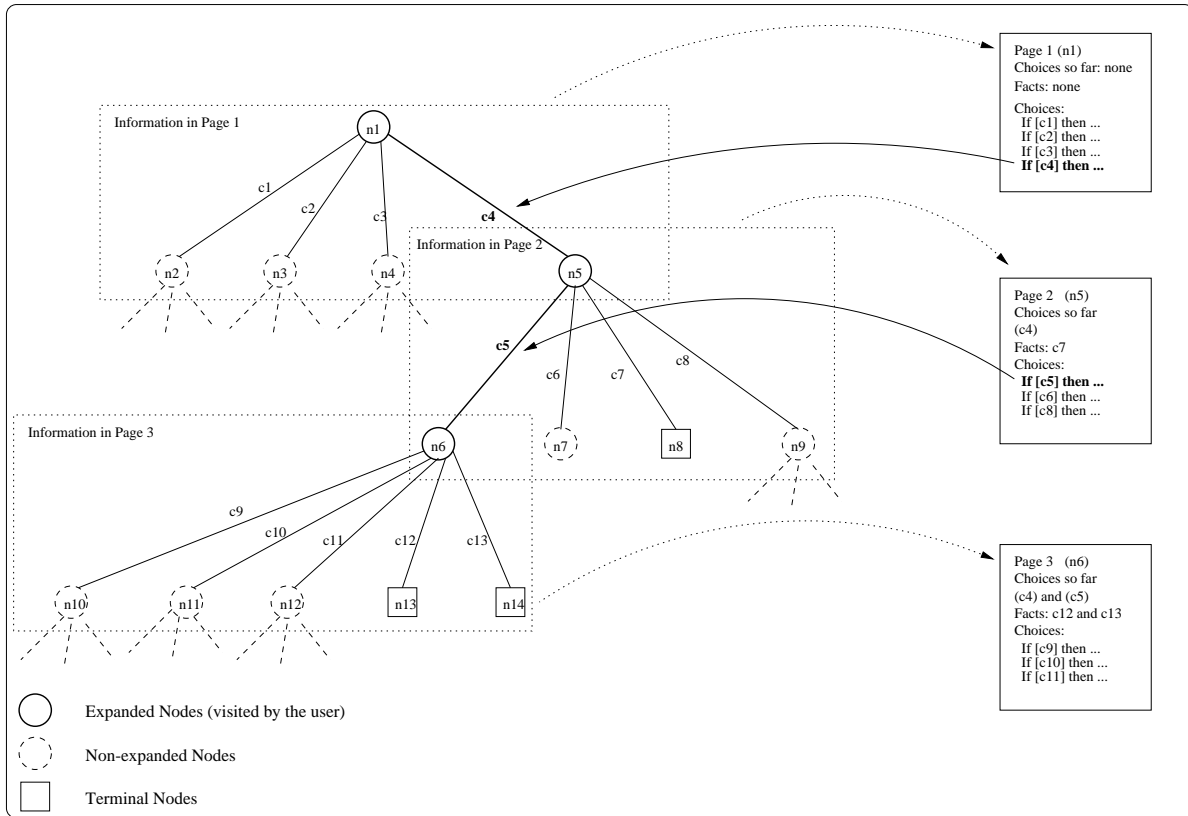


Figure 10: Question tree and pages generated.

## A.2 Phase Two

The HTML page is generated by filling out one of four templates. The first template generates a page corresponding to an internal node without conclusive choices. The second template applies to nodes with conclusive choices that are not exhaustive—those for which the otherwise case is not conclusive. The format of the page, under these circumstances, follows the first template, but instead of presenting choices, it presents the conclusive choices followed by a single otherwise link. This link leads to a node in which the complements of the conclusive choices have been selected.

The third template applies to nodes with conclusive choices that are exhaustive, in the sense that one of the choices has to be the case. These nodes are the ones with an empty MRCNF representation (inconsistent theory) in the *Otherwise* field. These nodes are leaves in the question space. The format of the page, follows the second template, but there is no otherwise case, instead a set of biconditional implications and a set of minimal models of the conclusive choices are listed. For us, a model is the MRCNF representation of a non-contingent theory (set of singleton clauses) associated with a conclu-

sive choice. The set of models associated with the conclusive choices are the set of such non-contingent theories and the minimal set of models are the ones that do not extend<sup>6</sup> any other model in the set. The biconditional implications are obtaining as follows. Obtain all the clauses in the MRCNF representation of the theory that contain only conclusive dependencies. Obtain all the binary partitions of these clauses (each partition is a potential biconditional). Then validate these biconditionals using the theorem prover. Effectively, we extend the theory with the negation of the biconditional and reduce it to its MRCNF representation. If this representation is empty (inconsistent theory) then the biconditional is valid and is reported.

The final template covers the situation in which the otherwise case leads to a non-contingent theory. Here the conclusive choices along with the otherwise case are exhaustive. The format of the page follows the third template with the exception that “otherwise” is listed among the alternatives.

The information extraction module provide the information needed to fill the templates. The hyper-

<sup>6</sup>In the sense that its singleton clauses are not a superset of any other model.

text organization module selects which template to use according with the information obtained. The realization module applies the templates and generates the HTML page.

## B Sample Sessions with the System

We offer three sessions with the system that corresponds to three different goals of the user. Each of them presents screen-shots of the interaction and comments about interesting sections of the results.

All the examples presented in this section have as a common input the *Television Control Statechart*. Figure 11 shows the graphical representation of this statechart together with the hyper-link which starts the generation process.

The typical generated page is split in two frames, on the left one we show the input of the system (a graphical representation of the statechart), in the right one the generated natural language description.

The generated document (Figure 12) corresponds to the root of the *question tree*. As we should expect, in this page there are no choices so far, no new determined facts, and no independencies, but we do have a list of dependencies (all states and events) and a list of choices.

### B.1 Sample Session 1

User goal: *Under what conditions is the state WAITING included in the next configuration?*

Suppose that we want to find out about the conditions that could lead to a next configuration of states containing the state *waiting*. Therefore, the hyper-link to choose for this case is “if the next configuration includes the state *waiting* then...” (Figure 13).

The result of following this link is shown in Figures 14 and 15. In the first one, among other things, the system inferred that (given that, by the user’s choice, the next configuration will include the state *waiting*) the current configuration of states cannot include the state *text*—the first of the *New Facts* in Figure 14. Note that, the first of the conclusive choices in this page says that if the current configuration does not include the state *picture* then, it must include the state *waiting* and the event *on* must not be active. These two conditions simply tell us that if *picture* is not in the current configuration the only way to have the state *waiting* in the next configuration is if *waiting* is already included in the current one and none of its associated transitions is taken.

Figure 15 shows the three models that are consistent with choice requiring *waiting* to be an element of the next configuration.

### B.2 Sample Session 2

User goal: *What will happen in the next configuration if the state PICTURE and the event OFF are currently active?*

To answer this question, we follow—from the root page—the hyper-link “if the current configuration includes the state *PICTURE* then...” this leads us to the page shown in Figure 16. From this page, we follow the hyper-link: “if the event *OFF* is active then...” This leads us to the page shown in Figures 17 and 18, which represents the answer to the user’s question.

We can expect, since *PICTURE* and *OFF* are active, that the next configuration will include the state *WAITING*, as is, indeed, shown in the *New Facts* section of this page (Figure 17).

Figure 18 shows the biconditional implications and the models that are consistent with the user’s choices. These models differ only in the selection of the state *SON* or *SOFF*, which are the orthogonal substates of *PICTURE*.

### B.3 Sample Session 3

User goal: *What happens if the current configuration includes the states PICTURE, SON, and the event TXT is active?*

The answer to this question is obtained by following the hyper-links: “If the current configuration includes the state *PICTURE* then...”, “if the current configuration includes the state *SON* then...”, and “if the event *TXT* is active then”. This sequence of choices lead us to the page shown in Figures 19 and 20.

In Figure 19, the first of the conclusive choices expresses an interesting fact: given that the state *PICTURE* and the event *TXT* are active in the current configuration, the only circumstance in which the state *TEXT* will not be in the next configuration is if the event *OFF* is active. This is because the transition labeled by *OFF* has higher precedence than the transition labeled by *TXT/MUTE*. Figure 20 shows the three models that are consistent with the user’s choices in this case.

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Figure 11: Sample session 1 screen 1.

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Figure 12: Sample session 1 screen 2.

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Figure 13: Sample session 1 screen 3.

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Figure 14: Sample session 1 screen 4.

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Figure 15: Sample session 1 screen 5.

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Figure 16: Sample session 2 screen 1.

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Figure 17: Sample session 2 screen 2.

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Figure 18: Sample session 2 screen 3.

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Figure 19: Sample session 3 screen 1.

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Figure 20: Sample session 3 screen 2.