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# A Hierarchical Petri Net Model for SMIL Documents

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## 1. Introduction

The increasing number of services and products proposed on the Web is mainly marked by the proliferating use of rich media to transmit information. The static Web as it was known during the glorious years of HTML is disappearing to let place to a more dynamic and interactive Web. Synchronized Multimedia Integration Language (SMIL) (SMIL1.0,1998) was developed by the World Wide Web Consortium (W3C) to address the lack of HTML for multimedia over the Web. It provides an easy way to compose multimedia presentations. With the W3C efforts, SMIL is becoming the most popular language in authoring multimedia presentations and it is supported by the newest versions of browsers.

In authoring a SMIL multimedia presentation, the author always wants to guarantee the correctness of the SMIL script, not only syntactically but also semantically. However, the complexity of the SMIL synchronization model is such that it is difficult to guarantee the validity of a scenario using non formal methods. On the other hand, the formal techniques based on mathematical models offer a complete formal semantics and propose formal techniques for consistency checking, but are in general time consuming. In order to respect the interactivity constraint in an authoring environment, a formal model for SMIL documents must offer the best compromise between formal verification capabilities and efficiency in terms of computation time.

Although many research studies were dedicated to multimedia documents authoring, only few of them has addressed temporal consistency checking problems. Yet, it is clear that the temporal consistency of a document has a direct impact on the quality of the presentation and consequently on the client satisfaction (consider the case of a presentation that stops playing before its end, a part of its semantic is lost).

In order to address the lack in SMIL modelling and verification solutions, we have defined a hierarchical temporal extension of Petri Nets, named H-SMIL-Net (Hierarchical SMIL-Petri Net) (Bouyakoub & Belkhir, 2008), for the incremental authoring of SMIL multimedia documents. The H-SMIL-Net model is mapped on the SMIL hierarchical temporal structure to better fit with the modelling needs of this language. The H-SMIL-Net model is based on the SMIL-Net model defined in (Bouyakoub & Belkhir, 2007). In order to better fit with SMIL authoring requirements, we have implemented the H-SMIL-Net model within an interactive authoring environment for SMIL documents.

## 2. Overview of SMIL

We give a brief overview of the SMIL synchronization elements. A more detailed definition can be found at (SMIL 1.0,1998;SMIL 2.0,2001; SMIL 2.0,2005;SMIL 2.1,2005;SMIL 3.0,2008).
SMIL is an XML-Based language for the specification of multimedia presentations. Using SMIL, an author can describe the temporal behaviour of a presentation, associate hyperlinks with media objects and describe the layout of the presentation on the screen. The latest version of the language is SMIL 3.0 (SMIL 3.0,2008), but the temporal model remains unchanged since the second version.
In this study, we focus on the most used temporal elements of SMIL, including:

- The time containers <seq> and <par>,
- The set of media object elements such as <img>, <video>, <audio> and <text>... etc.
- The time attributes *begin*, *end* and *dur.*

The <seq> and <par> elements, defined since the first version SMIL 1.0, are the basis of the SMIL temporal model. The <seq> element defines a sequence of elements played one after the other (Figure 1); whereas the <par> element defines a parallel grouping in which multiple elements can be played at the same time (Figure 2).

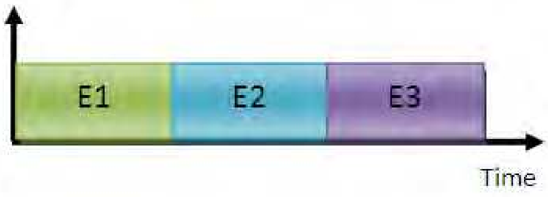


Fig. 1. The Seq element

Three semantics are defined for the termination of a <par> element, according to the value of the "*endsync*" attribute:
- *Last*: the <par> finishes when all its child elements finish,
- *First*: the <par> finishes since one of its child elements finishes,
- *Master*: the <par> finishes when the master element (defined by the ID attribute) finishes.

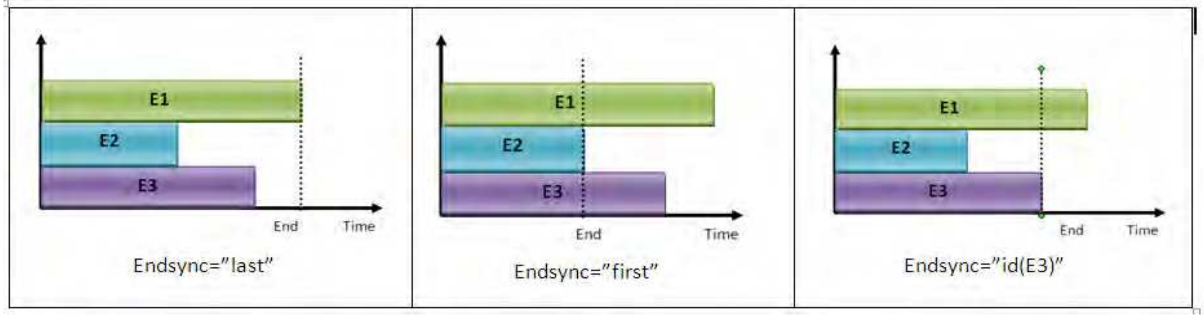


Fig. 2. The Par element

The media object elements allow the integration of media objects into a SMIL presentation, by reference to their URI (Uniform Resource Identifiers).
Besides, the synchronization attributes *begin, dur* and *end* could be associated with these synchronization elements:

- The begin attribute specifies the explicit begin of an element.
- The end attribute specifies the explicit end of an element.

- The dur attribute specifies the explicit duration of an element.

The effect of these time attributes is illustrated in Figure 3.

Since any temporal relationship among multimedia objects could be represented by the combination of parallel and the sequential elements with proper attribute values, it is easy to see that SMIL could be used to specify all synchronization relationships (Yang, 2000).

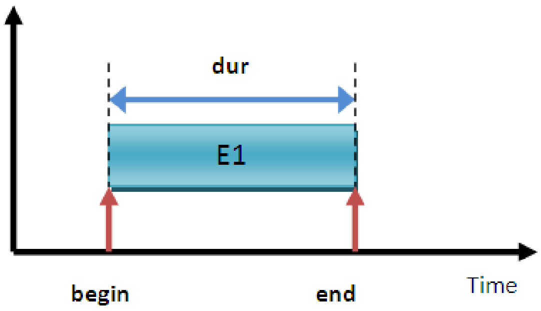


Fig. 3. The time attributes

The complexity of the SMIL temporal specification can lead authors, in some cases, to specify synchronization relations which could not be satisfied during the presentation of the document, thus characterizing the occurrence of temporal inconsistencies. The time conflict is one type of temporal inconsistency, it is defined in (yang,2000) as the case of conflicting values of attributes in the SMIL specification. Two types of conflicts are defined: The intra-element time conflict which is the case of conflicting attributes within a single element and the inter-elements time conflict which is the case of conflicting attributes among different elements. The SMIL specification defines some conventions to ignore one of the conflicting attributes, but the obtained behaviour can be different from the author’s specification; besides, the obtained temporal behaviour depends on the implementation of the SMIL player. A detection mechanism for time conflicts is then necessary.

## 3. Related works

Several models have been used for the specification of the temporal behaviour of SMIL documents.

In (Jourdan et al, 1999), the SMIL temporal relationships are modelled as a CSP (Constraint Satisfaction Problem). The temporal elements are modelled by variables and the temporal relationships are represented by constraints. The obtained constraints system can be analyzed using a constraints solver in order to find a formatting solution and to detect temporal inconsistencies. However, the computation time of the solvers constitutes a limitation to the use of this approach.

In (Sampaio et al, 2004), RT-LOTOS (Real Time LOTOS) formal technique is applied to the modelling of SMIL documents. The RT-LOTOS specification is automatically derived from the SMIL document. The verification of the temporal properties is made on the reachability graph derived from RT-LOTOS. Then, model checking techniques are applied to detect temporal inconsistencies. This approach presents two issues: First, the verification of the temporal properties requires the use of an intermediate model: the reachability graph. Secondly, the number of states of the reachability graph can grow rapidly when the complexity of the SMIL file increases.

In (Newman et al, 2003), the process algebra π-calculus (an event-based formalism derived from CCS: Calculus of Communicating Systems) is used to model the temporal synchronization of SMIL documents. The SMIL relations are represented graphically using a "storyboard". The storyboard is then translated to π-calculus formulas and the obtained system can be analyzed mathematically (using the algebraic laws of π-calculus) to study some safety properties of the system. However, no mechanism for temporal verification has been defined in this study.

In (Bossi et al, 2007) the authors propose a formal semantic for the verification of SMIL documents using a formal system based on the Hoare Logic. A set of inference rules is defined to describe how the execution of a piece of SMIL code changes the state of the playback. Media items definitions are evaluated through axioms, while for <par> and <seq> compositions more complex rules are needed. This complexity increases when adding temporal attributes, or when dealing with composite elements imbrications. Although this approach offers a formal semantic for SMIL timing, it seems too complex to comply with authoring requirements, even though the author says few words about an authoring environment based on the defined semantic.

Many temporal models for SMIL documents are based on temporal extensions of Petri Nets. Petri Net-based models provide a good method to specify temporal relationships (Ramchandani, 1974).

A modified Petri Net model, object composition Petri Net (OCPN) (Little et al, 1990), has been proved to have the ability to specify any arbitrary temporal relationship among media elements. However, when dealing with the real time issues and the complex synchronization constraints of SMIL, this model is not powerful enough to capture all the timing and synchronization semantics of SMIL documents.

(Chung et al, 2003) proposes a new model which is an enhancement of OCPN by adding typed tokens and a new set of firing rules. This model can capture the timing and synchronization semantics of the SMIL presentation. However, no verification techniques are proposed to check the consistency of the SMIL specification.

The RTSM model (Real Time Synchronization Model) proposed by (Yang, 2000) is also based on the OCPN model. In RTSM, two types of places are defined and new firing rules are proposed. The RTSM model can capture temporal semantics of SMIL scripts and detects the temporal conflicts within the same model. However, the verification is not incremental and requires the parsing of the whole RTSM. Moreover, the translation from SMIL to RTSM results on a loss of the SMIL temporal structure (parallel and sequential activities).

The SAM model (Software Architecture Model) used by (Yu et al, 2002) is a combination of two complementary formal notations: Petri nets and temporal logic. SMIL Synchronization elements are modelled by Petri nets whereas safety and liveness proprieties are specified using logic formulas. Formal techniques such as reachability tree, deductive proof and structural induction are used to check some proprieties of the SMIL specification. However, no mechanism of temporal verification is explicitly defined in this study.

Most of the cited models require the use of an auxiliary model to prove the temporal consistency of the SMIL specification, whereas it is more efficient to work on the same model (time and memory space saving). Besides, none of these models propose a structured and incremental modelling of the SMIL specification; consequently, the modification of a single temporal element requires the verification of the whole specification. Moreover, in order to better fit with the SMIL features, it seems more interesting to define a formal model mapped on the SMIL temporal model rather than adapting existing approaches to this complex language.

We have proposed in a previous work a temporal extension of Petri Nets, named SMIL-Net (SMIL Petri Net) (Bouyakoub & Belkhir, 2007). This model was proposed to address the lack of existing models in the modelling and the verification of the temporal and hyper-temporal dimensions of SMIL documents. We have adopted a global approach in SMIL-Net: at the end of the editing process, the SMIL temporal specification is first translated to a SMIL-Net and then verification techniques can be applied in order to check the temporal consistency directly on the model.

In order to offer earliest errors detection within the editing process, it seems more efficient to integrate the model within the authoring system for an incremental verification. However, although SMIL-Net answers a large part of the needs for SMIL documents authoring, the model needs to be enhanced in order to respect the time constraints of an interactive edition environment. In particular, the modelling and the verification should be done incrementally and offer a good response time. So, we have proposed a hierarchical extension of the SMIL-Net model for the incremental and structured edition. The enhanced model, named H-SMIL-Net (Bouyakoub & Belkhir, 2008), offers structured modelling possibilities permitting, on the one hand, to facilitate the modifications and on the other hand to support an incremental specification of the document. The model is mapped on the SMIL hierarchical temporal structure to better fit with the modelling needs of this language.

The Hierarchical SMIL-Net (H-SMIL-Net) model inherits most of temporal elements defined in SMIL-Net; so, the presentation of some SMIL-Net principles is necessary before presenting H-SMIL-Net.

## 4. The SMIL-Net Model

In this section, we give an overview of some SMIL-Net components redefined in H-SMIL-Net. The complete definition of the model can be found in (Bouyakoub & Belkhir, 2007).

### 4.1 SMIL-Net Components

SMIL-Net is a temporal extension of Petri Nets; it includes a set of places, transitions and arcs.

We focus on two types of SMIL-Net places in this study (Figure 4):

- The *regular place* represents the active entity of the system; it is used to model a media object and its internal duration.
- The *virtual place* represents a time delay, it is used to model the temporal attributes *begin*, *end* and *dur*.

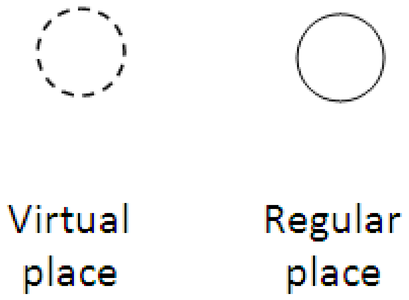


Fig. 4. Graphical representations of Places

The set of transitions defined in SMIL-Net (Figure 5) models the different termination semantics of SMIL elements:
- The *simple transition* fires when the delays associated to all its input places are finished. It models the termination of a simple element, a <seq> element, or a <par> element with a "*last*" semantic.
- The *Master transition* fires when the delay associated to one particular input place, designed by a master arc (designating the Master element), is finished. It represents the termination of the <par> element with a "*Master*" semantic.
- The *First transition* fires since the delay associated to one of its input places is finished. It models the termination of a <par> element with a "*First*" semantic.

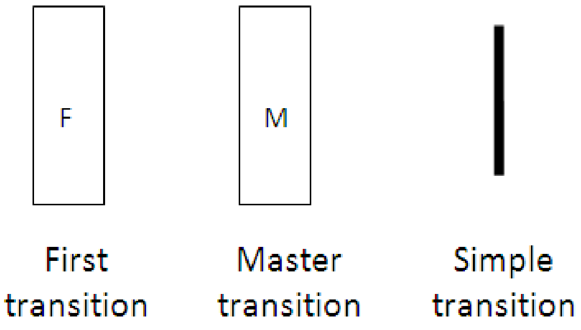


Fig. 5. Graphical representations of transitions

Two kinds of SMIL-Net arcs are used in H-SMIL-Net (Figure 6):
-The *ordinary arc* is used to transport tokens.
-The *master arc* also transports tokens, but in addition it controls the firing of a master transition.

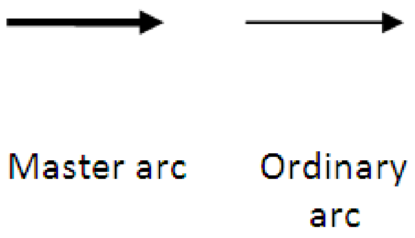


Fig. 6. Graphical representations of arcs

An example of SMIL-Net is shown in Figure 7. The SMIL-Net requires the audio, the video and the text to be played simultaneously. Since the transition T2 is a Master transition, it is fired just after the audio element is finished, no matter video or text elements are finished or not. After firing T2, img is displayed.

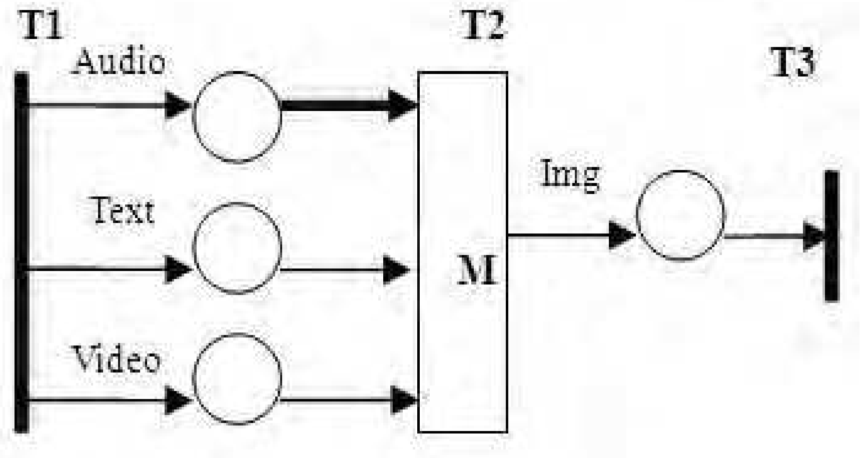


Fig. 7. An example of SMIL-Net

### 4.2 Calculating the Firing Time of SMIL-Net Transitions

The firing time for each transition is computed by traversing the SMIL-Net transition by transition from the initial state. The computation rule for calculating the firing time of a transition depends on its type:

- ***Simple transition**:* The firing time of the transition is the maximum value of the "firing time of the preceding transition" plus "the nominal duration of the following place of the preceding transition".
- ***First transition**:* The firing time of the transition is the minimum value of the "firing time of the preceding transition" plus "the nominal duration of the following place of the preceding transition".
- ***Master transition**:* The firing time of the transition is the value of the "firing time of the preceding transition" plus "the nominal duration of the place associated with a *master arc*".

### 4.3 Detection of Time Conflicts

(a) ***The Intra-element time conflict***

The intra-element time conflict is the case of conflicting attributes within the same element. Therefore, to detect the intra-element time conflict, we only need to examine the values of attributes associated to a single element.

Considering the SMIL-Net model for a single element in Figure 8, the respective values of "begin", "dur" and "end" for the element are "B seconds", "D seconds" and 'E seconds". It is easy to see that the case of B+D ≠ E results in an unreasonable physical meaning.

The intra-element time conflict is detected in SMIL-Net when a master transition has two master arcs coming from its input places (see Figure 8).

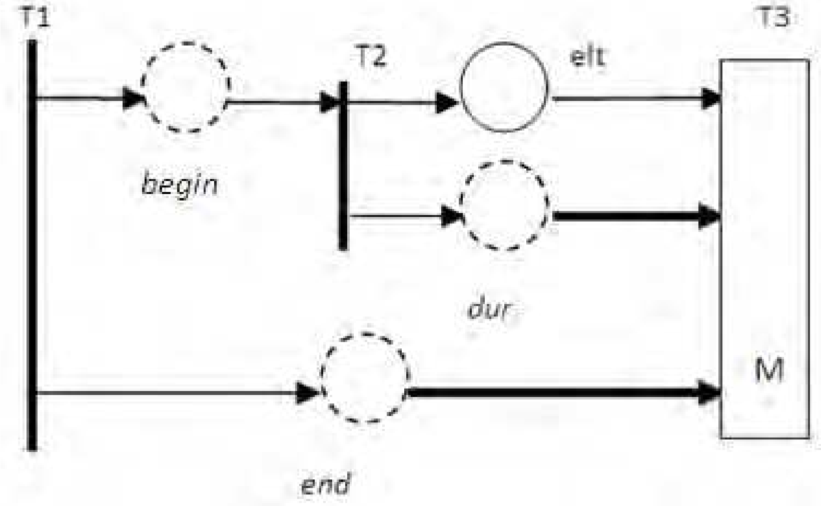


Fig. 8. Detecting the intra-element time conflict

(b) ***The inter-elements time conflict***

The inter-elements time conflict is the case of conflicting attributes among different elements.

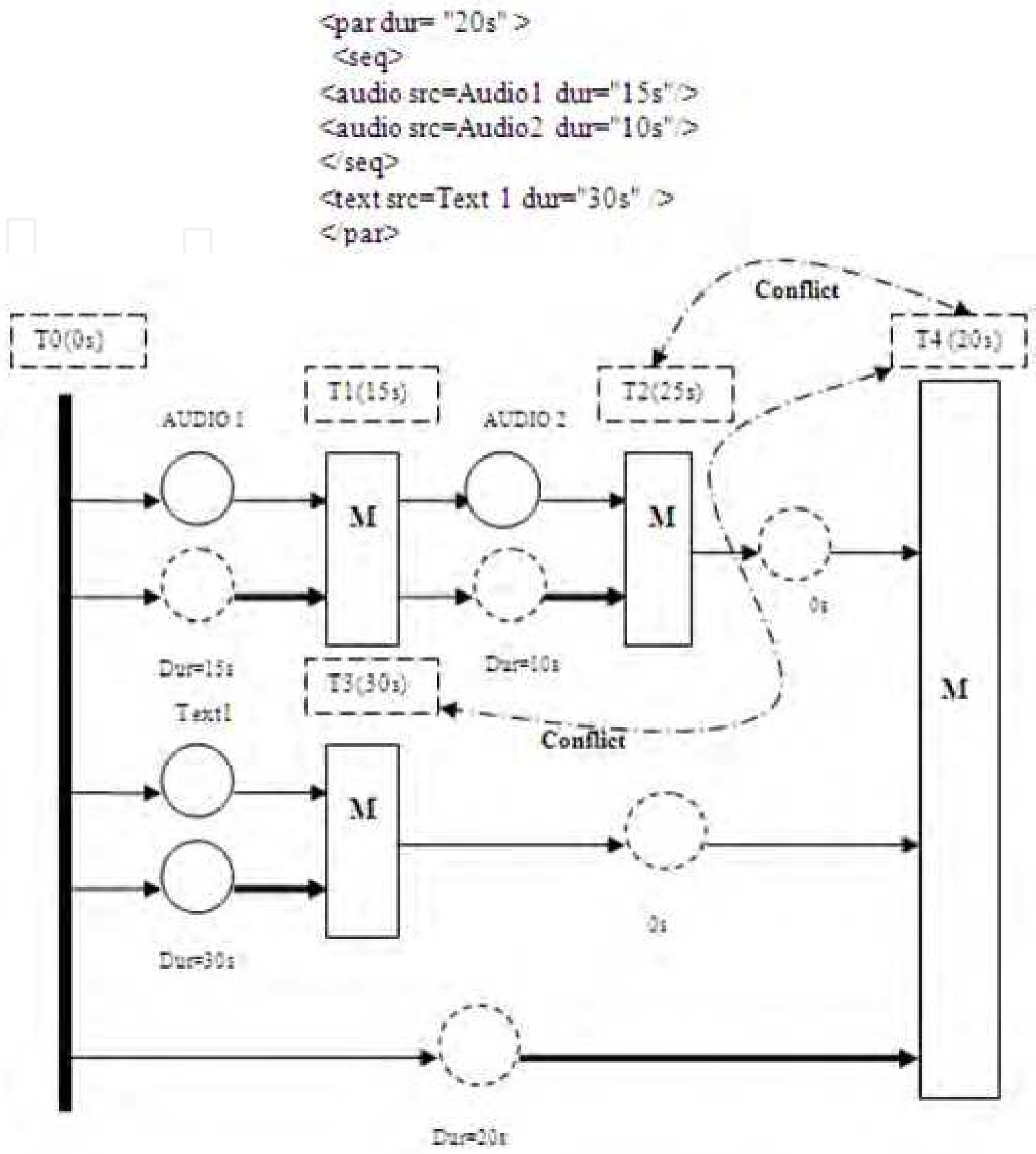
There is no easy way to detect the inter-element time conflict directly on the SMIL-Net, since it involves the attributes of more than one element.

In SMIL-Net, the firing time of a transition should be earlier than its following transition (temporal progression criterion). It implies that if the attributes values defined by the author make the firing time of a transition later than the firing time of some following transition, it characterizes an inter-elements time conflict.

The inter-elements time conflict could be detected by traversing the SMIL-Net and comparing the computed firing times of its transitions.

The Figure 9 shows an example of a SMIL script with an inter-elements time conflict and its SMIL-Net representation.

As illustrated in the Figure, the firing time for T2 is 25s whereas the following transition T4 fires at 20s; this situation characterizes a temporal conflict. In the example, two temporal conflicts are identified: (T2, T4) and (T3, T4). It implies that the elements in conflict are (Audio2, <par>) and (text, <par>).



```
<par dur= "20s" >
 <seq>
<audio src=Audio1 dur="15s" />
<audio src=Audio2 dur="10s" />
</seq>
<text src=Text 1 dur="30s" />
</par>
```

Fig. 9. Detecting the inter-elements time conflict

## 5. The H-SMIL-Net model

We present in this section the Hierarchical SMIL-Net (H-SMIL-Net) model, a hierarchical extension of the SMIL-Net model for the incremental and structured edition. The H-SMIL-Net model inherits all temporal elements defined in SMIL-Net. It is defined as a two-level tree:

- The atomic level (the leaves) represents the multimedia elements,
- The composite level (the nodes) represents the composite elements <par>, <seq> and the root <body>.

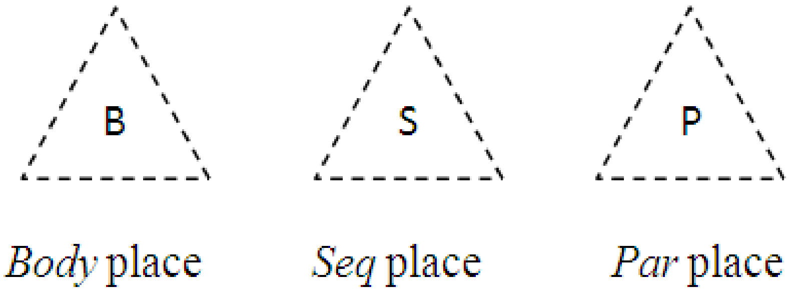


Fig. 10. Graphical representation of composite places

To model the composite elements, we define a new type of places: the composite places are abstract places representing the temporal behaviour of an equivalent H-SMIL-Net. A composite place is defined by its type (*par, seq* or *body*) and the root of the associated H-SMIL-Net. The representation of composite places is shown in Figure 10.

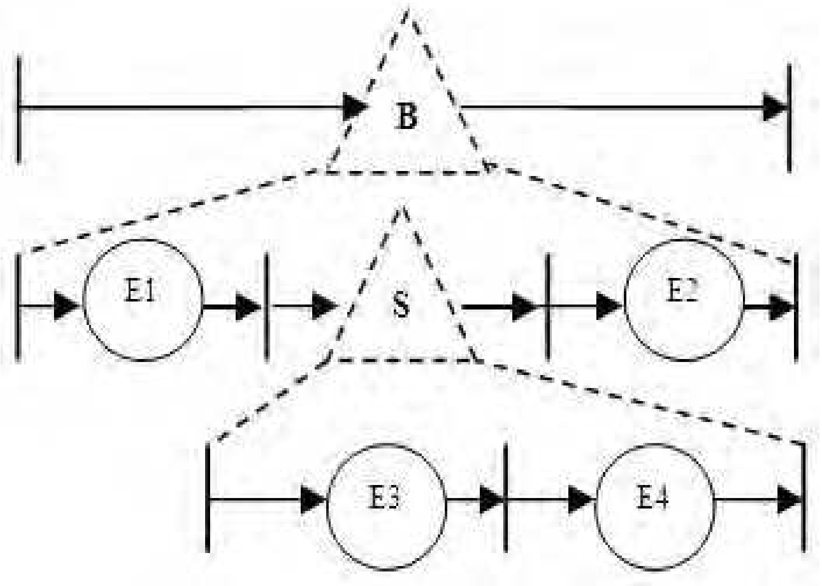


Fig. 11. An example of H-SMIL-Net

An example of H-SMIL-Net is shown in Figure 11. The H-SMIL-Net contains two composite places B (modelling a body element) and S (modelling a seq element). Each composite place is represented by a subnet modelling its child elements.

### 5.1 Formal definition

An H-SMIL-Net R with a root $P_0$ is defined as follows:
$R(P_0)=( P_0,(P , T , IN , OUT , M_0) , A , IVT , TT , TP , S , ABS, TA )$, where:
- $(P ,T ,IN ,OUT ,M_0)$ defines a Petri net.
- A is a set of arcs.
- IVT is a mapping from the set of places to a set of time intervals $[X_i, N_i, Y_i]$ defining the temporal interval of the place. $X_i$, $N_i$, $Y_i$ represents, respectively, the minimal, the nominal and the maximal duration of the object (or the Petri Net) associated to the place.

IVT:

$P \rightarrow \{ Q+ \cup \{ * \}\} X \{ Q+ \cup \{ * \}\} X \{ Q+ \cup \{ * \}\}$

$\forall P_i, i=1...N \in P, IVT (Pi)=[ X_i, N_i, Y_i ]$

The * value represents unknown duration. When $X_i= N_i=Y_i$ we put simply $[X_i]$

- TT is a mapping which associates a type to each transition of T.

TT: T → {simple, First, Master}

- TP is a mapping which associates a type to each place of P.

TP: P → {regular, virtual, composite}

- S defines the state of the place according to its type and the type of tokens it contains.

S: P → {suspended, active, inactive, #} where # is the state associated to the composite places that are abstract places and don't have a state therefore.

- TA is a mapping which associates a type to each arc of A.

TA: A → {Simple, Virtual, Master}

- ABS is the structural abstraction function that associates an H-SMIL-Net subnet to each composite place:

ABS: $P_{composite} \rightarrow$ {R / R is an H-SMIL-Net}

$P_0 \rightarrow R(P_0)=( P_0,(P , T , IN , OUT , M0), A, IVT, TT, TP, S, ABS, TA )$

Where: $P_{composite}$ = {p∈P/TP(p)="composite"}

Besides, we associate to each place a local clock to calculate the internal delays. A global clock is associated to all H-SMIL-Net in order to verify the global synchronization constraints of the model.

### 5.2 Formal semantic

The H-SMIL-Net semantic enhances the SMIL-Net one (Bouyakoub & Belkhir,2007) by the definition of new firing rules adapted to the composite places.

**Definition1.** The H-SMIL-Net modelling a composite place is delimited by an input transition and an output transition. An input transition is a transition that doesn't have any input place and an output transition is a transition that doesn't have any output place.

**Definition2.** When a composite place receives a token, its input transition is immediately fired and the underlying H-SMIL-Net is executed. The firing of the output transition indicates the end of the H-SMIL-Net representing the composite place, the token of the composite place is then unlocked and the following transition can be fired.

**Definition3.** An input transition is fired as soon as the associated composite place receives a token. Once fired, this transition puts a token in each output place and locks the token of the composite place.

**Definition4.** An output transition is fired when the firing conditions for the transition are satisfied. The firing of this transition unlocks the token within the composite place.

### 5.3 Abstraction of composite places

The definition of abstract places implies the definition of structural abstraction techniques. Considering the fundamental role played by time in SMIL, the abstract places must not only offer possibilities of structural abstraction but also temporal abstraction. Thus, we associate to the H-SMIL-Net model the following techniques of structural and temporal abstraction.

***(a) Structural abstraction***

The structural abstraction defines the techniques allowing the replacement of a composite place by an H-SMIL-Net. The following algorithm explains how to replace a composite place by the underlying H-SMIL-Net:

*1) Replace the composite place by the associated H-SMIL-Net, delimited by input and output transitions.*
*2) Merge the adjacent transitions:*
*a) Merge the beginning transition of the composite place with the input transition of the subnet;*
*b) Merge the end transition of the composite place with the output transition of the subnet.*

The recursive application of structural abstraction techniques on the set of composite places permits to derive the SMIL-Net model, what allows the hierarchical model to inherit all verification techniques proposed for SMIL-Net.

An example of structural abstraction is shown in Figure 12. The composite place S (Figure 11) is replaced by its equivalent subnet and the adjacent transitions are joined.

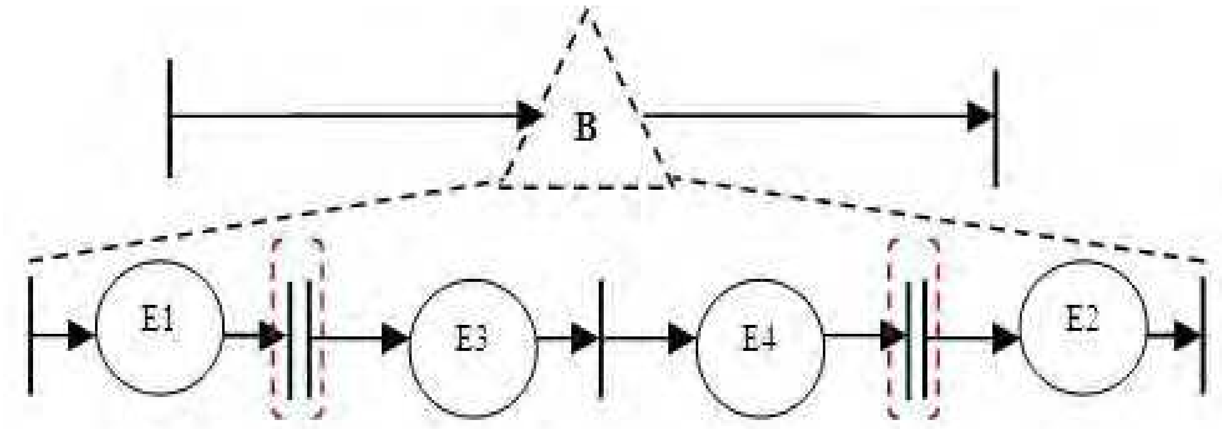


Fig. 12. Structural abstraction

***(b) Temporal abstraction***

An abstract place should reproduce in an abstract way the temporal behaviour of the underlying H-SMIL-Net. The nominal delay of a composite place C is calculated by the following algorithm:

*a) Consider the H-SMIL-Net R(C) modelling the composite place C. If the delays of all elements of C are resolved, go to step c).*
*b) For each composite child element C' of C whose delay is unresolved go to step a) while considering the H-SMIL-Net R'(C').*
*c) If all child elements of C have resolved delays then calculate the nominal duration of R, noted $D_r$, which is equal to the firing date of the end transition $T_e$ of R while supposing the date of its beginning transition $T_b$=0.*
*d) The delay $D_r$ is the nominal delay associated to the composite place C.*

An example of calculating composite elements delays is shown in Figure 13.

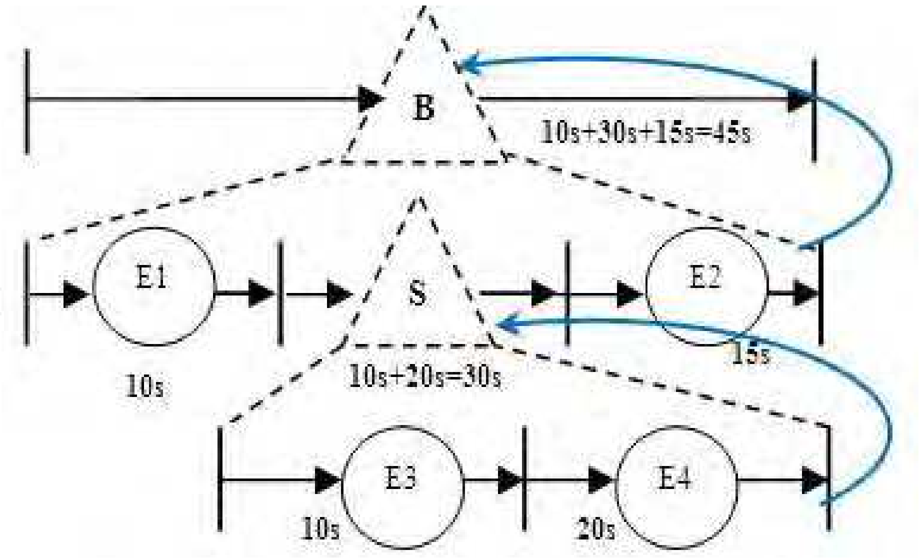


Fig. 13. Temporal abstraction

## 6. Temporal Verification

We associate to H-SMIL-Net an optimized verification algorithm restricting the verification to the minimal subnet affected by the modification. The verification algorithm is decomposed into two steps:

- Finding the root of the minimal subnet affected by the modification
- Temporal verification of the minimal subnet.

### 6.1 Research of the minimal subnet

After each editing operation, the H-SMIL-Net model is updated and the modifications are propagated towards the root in order to update the temporal delays of the H-SMIL-Net elements. As soon as the temporal delay of an element is not modified, it is no more necessary to propagate the modifications towards the superior levels, since time values will remain unchanged. So, to find the minimal subnet affected by the modification, we have just to find the first element that remains temporally unchanged after the modification. This element, called *the invariant*, is calculated by the following algorithm:

*a) Let C be the composite element containing the modified element and let $D_{before}$ be its initial delay. Calculate the new delay $D_{after}$ associated to the C element.*
*b) If $D_{before} \neq D_{after}$: consider C' the direct ancestor of C. if C' is the <body>element then go to d); otherwise go to a) while replacing C by C'.*
*c) If $D_{before} = D_{after}$ then C is the invariant. Break;*
*d) If we arrive to the root <body> without finding an invariant, it means that the modification affects the whole H-SMIL-Net.*

### 6.2 Temporal verification of the minimal subnet

Once the minimal subnet defined, we have to verify its consistency in order to accept or reject the modification. This verification is done in two steps:

**-** The transformation of the minimal H-SMIL-Net to an equivalent SMIL-Net by applying recursively the techniques of structural abstraction to the composite places.
**-** The application of the verification techniques defined for SMIL-Net (detection of conflict situations) on the obtained SMIL-Net.
If no conflict is detected then the modification is accepted, otherwise it is rejected by the system.

## 7. Modelling SMIL Elements with H-SMIL-Net

The H-SMIL-Net models the most used SMIL temporal elements including the time containers <seq> and <par>, the class of media object elements such as <img>, <video>, <audio>, <text> and the time attributes "begin", "end", "dur". We assume that the syntax of the input SMIL script has been checked before starting the transformation.

***(a) Modelling a media object***
Media object elements allow the inclusion of media objects into a SMIL presentation. A media object is represented by a regular place and a pair of ordinary transitions (Ts, Te) as shown in Figure 14.

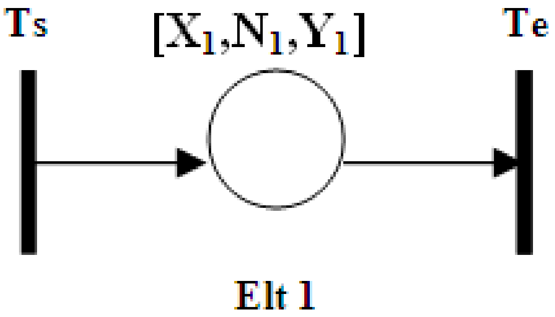
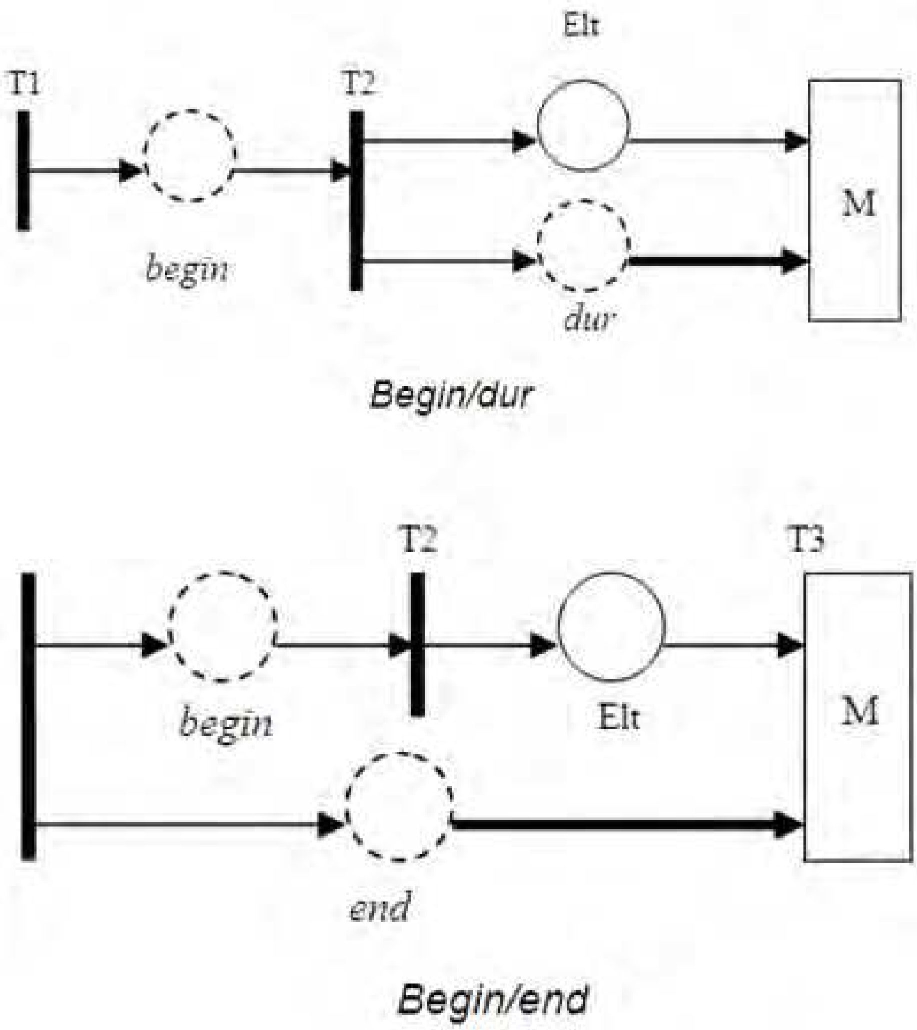


Fig. 14.Modelling a media element

The temporal interval of the element is defined by three time values:
- $X_i$ defines the minimal active duration of the media.
-$N_i$ defines the nominal duration of the media; it takes the value of the internal duration of the media element. When the element has not an internal duration (such as static text or image), $N_i = 0$.
- $Y_i$ defines the maximal active duration of the media.

***(b) Modelling time attributes***
Time attributes represent time delays, so they are modelled by virtual places with only a nominal duration which takes the value of the attribute (IVT=[$N_i$])
The *"begin"* attribute specifies the explicit begin time of an element, it is modelled by adding one virtual place representing the begin time with the specified duration before the element starting transition.
The *"end"* attribute specifies the explicit end time of an element, so one virtual place with the end value is added between the original start transition and the end transition. A master transition is added at the end to force the termination of the object at the time specified in the end attribute.

The *"dur"* attribute specifies the explicit duration of an element, thus a virtual place between the start transition and the end transition is added. The end transition is also a master transition. The Figure 15 illustrates the effect of the combination of these attributes.



Begin/dur

Begin/end

Fig. 15. Modelling time attributes

***(c) Modelling the <seq> element***

The <seq> element defines a sequence of elements played one after the other.

The children elements of the <seq> element could be any of the synchronization elements such as time containers or media objects, so the conversion is a recursive procedure.

Since the children of a <seq> element form a temporal sequence, we concatenate each child of the <seq>container one by one as illustrated in Figure 16.

Note that the end transition of an element and the start transition of the following element are merged in order to maintain model consistency.

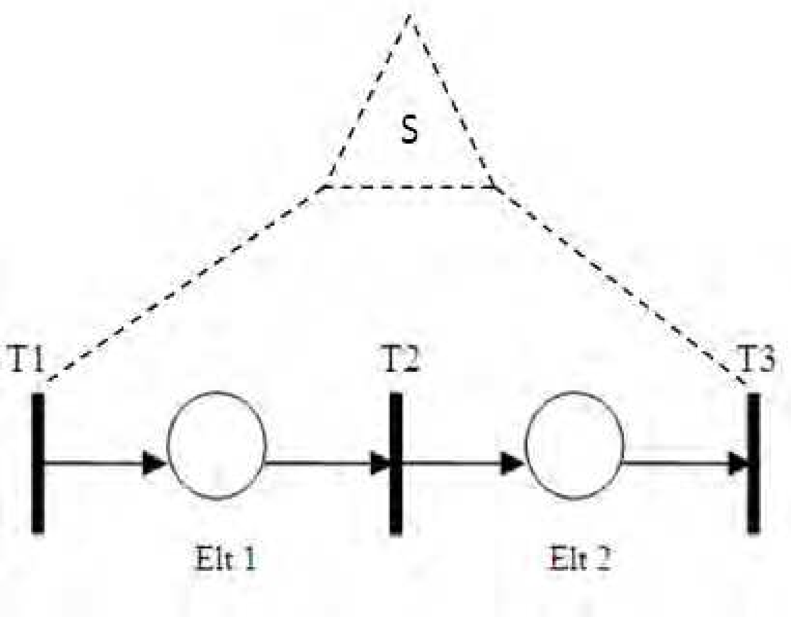
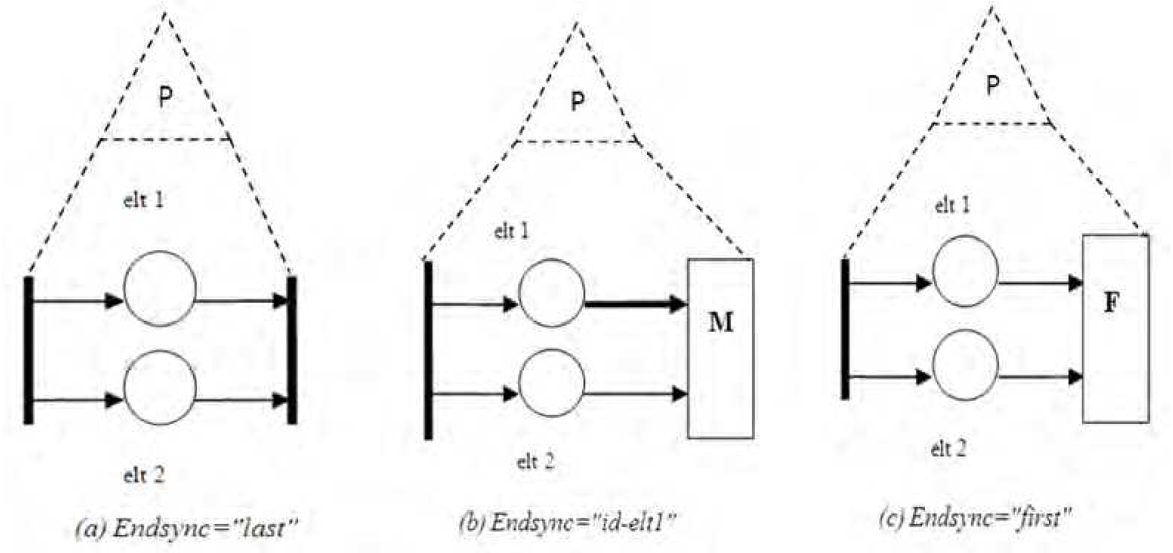


Fig. 16. Modelling the <seq> element

***(d) Modelling the <par> element***

The <par> element defines a parallel grouping in which multiple elements can be played at the same time. Thus, all children of <par> should be within the same pair of transitions (Ts, Te) as illustrated in Figure 17.



*(a) Endsync="last"*

*(b) Endsync="id-elt1"*

*(c) Endsync="first"*

Fig. 17. Modelling the <par> element

The "endsync" attribute controls the end of the <par> element. Legal values for the attribute are "last", "first" and '*id-value*'.

The 'last' value requires <par> to end with the end of all its child elements and the corresponding H-SMIL-Net is shown in Figure 17-(a), where transition **Te** could not be fired until the end of all the <par> children.

The 'id-value' value requires <par> to end with the specified child. So, we change the end transition to a *Master transition* and the arc between the specified child and the transition to a master arc as shown in Figure17-(b).

The 'first' value requires <par> to end with the earliest end of all the child elements. Therefore, we should change the end transition to a *First transition*, as illustrated in Figure 17-(c) so that the child that ends first can fire the transition.

Other synchronization attributes, such as "begin", "end' and "dur", could also be associated with <seq> and <par>, but the conversion is similar to that in the case of media object elements.

## 8. Implementation: An authoring tool for SMIL documents

Some authoring tools have been proposed for SMIL without imposing themselves to the users, in part because the constraints of the underlying language limit the realization of efficient authoring tools.

Our aim is to propose an easy-to-use temporal environment, with incremental authoring and consistency checking capabilities, based on the H-SMIL-Net model. So, we opted for an interface combining simplicity and ergonomics (see Figure 18)

The architecture is structured on four parts that interact all along an editing session:

- **Opening/saving module:** When opening an existing SMIL file, the system proceeds to lexical and syntactic analysis; before the translation to H-SMIL-Net.

- **Modelling module:** This module translates the document to the H-SMIL-Net model, which is the internal format used in all modules of our authoring tool.

- **Authoring module:** This module provides the functions permitting to create or to modify a SMIL document. In order to maintain the coherence of the specification, the environment doesn't allow the document to enter in an inconsistent state: Each editing operation is first reported on the H-SMIL-Net model and the local verification algorithm is applied. If the author's modification leads to an inconsistency, it is rejected by the system; otherwise it is accepted and the model is updated.

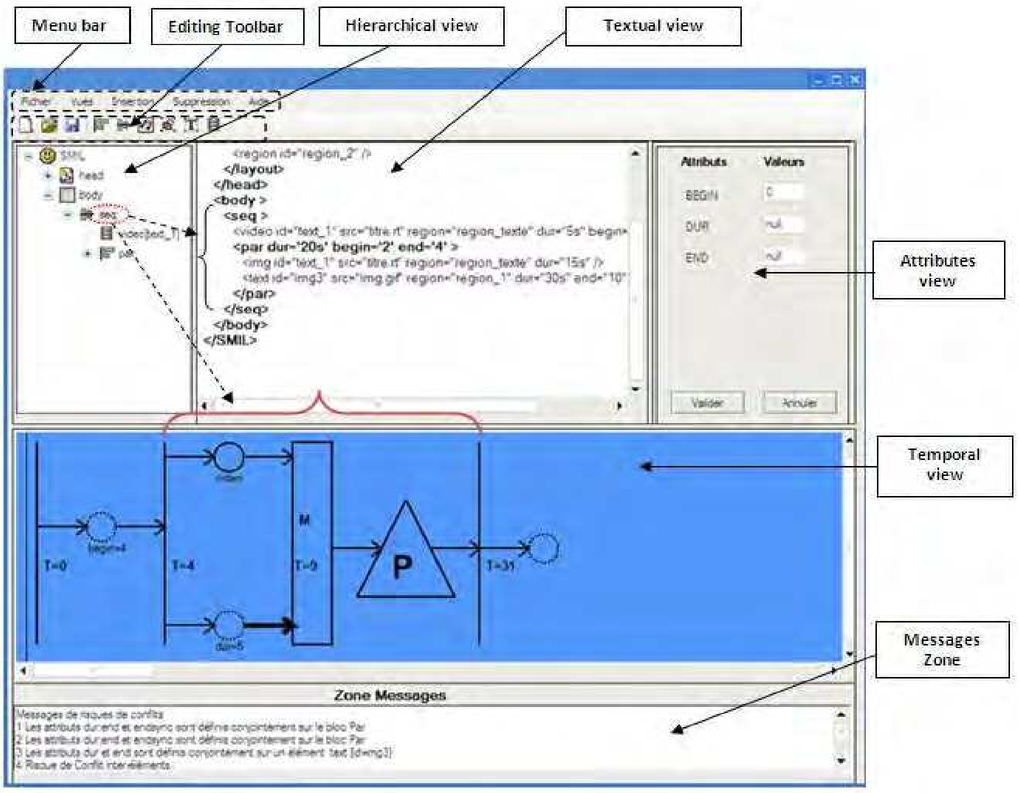
- **The user-interface:** This module offers a number of graphic tools allowing the author to create and modify the document. Four views are proposed:

- The textual view: It displays the source file of the SMIL script.

- The temporal view: This view displays the H-SMIL-Net representation of the SMIL specification. The author can open a composite element by a simple click, which has as effect the application of the structural abstraction algorithm on the selected place.

- The hierarchical view: It represents the document as a tree structure, what permits to visualize and modify the hierarchical structure of the document.

- The attributes view: It allows viewing and modifying the temporal attributes of the object selected in the hierarchical view.

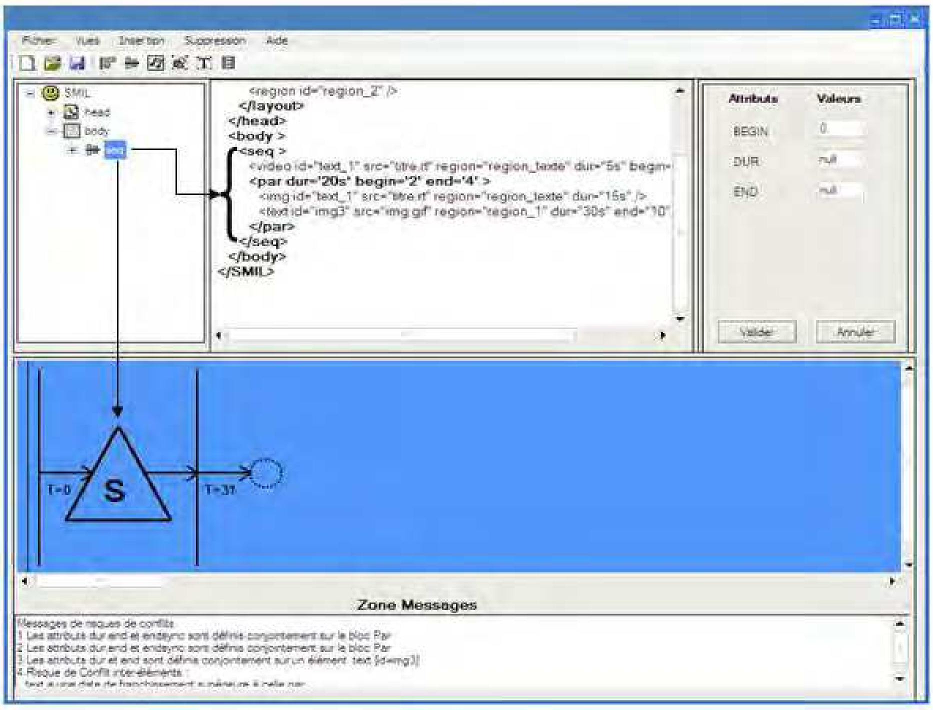


```
    <region id="region_2" />
  </layout>
 </head>
 <body >
  <seq >
    <video id="text_1" src="titre.rt" region="region_texte" dur="5s" begin=
    <par dur="20s" begin="2" end="4" >
      <img id="text_1" src="titre.rt" region="region_texte" dur="15s" />
      <text id="img3" src="img.gif" region="region_1" dur="30s" end="10"
    </par>
  </seq>
 </body>
</SMIL>
```

Zone Messages

Messages de risques de conflits
1 Les attributs dur end et endsync sont définis conjointement sur le bloc Par
2 Les attributs dur end et endsync sont définis conjointement sur le bloc Par
3 Les attributs dur et end sont définis conjointement sur un élément text [id=img3]
4 Risque de Conflit inter-éléments

(a) The composite place S is opened



```
    <region id="region_2" />
  </layout>
 </head>
 <body >
  <seq >
    <video id="text_1" src="titre.rt" region="region_texte" dur="5s" begin=
    <par dur="20s" begin="2" end="4" >
      <img id="text_1" src="titre.rt" region="region_texte" dur="15s" />
      <text id="img3" src="img.gif" region="region_1" dur="30s" end="10"
    </par>
  </seq>
 </body>
</SMIL>
```

Zone Messages

Messages de risques de conflits
1 Les attributs dur end et endsync sont définis conjointement sur le bloc Par
2 Les attributs dur end et endsync sont définis conjointement sur le bloc Par
3 Les attributs dur et end sont définis conjointement sur un élément text [id=img3]
4 Risque de Conflit inter-éléments :
text aura une date de franchissement supérieure à celle par

(b) The composite place S is closed

Fig. 18. Interface of the authoring tool

## 9. Conclusion

We have presented in this chapter a new approach for the modelling and the verification of the temporal consistency of SMIL documents within an interactive authoring environment.

The H-SMIL-Net model offers structured modelling capabilities permitting, on the one hand, to facilitate the modifications of the SMIL script and on the other hand to support an incremental specification of the document.

Moreover, the local approach adopted in H-SMIL-Net guarantees the consistency of the whole presentation through the verification of a minimal part of the model; leading to a considerable time saving.

The editing process followed in this study reflects the methodology followed by most authors: the document is specified in a series of steps going from general definition by components to a more detailed specification. This component-based edition is possible thanks to the hierarchical structure of H-SMIL-Net. Furthermore, the locality of the temporal verification in H-SMIL-Net permits a relative independence between the different components represented by composite elements.

This formal approach has been integrated within an incremental authoring tool for SMIL presentations. Thanks to the use of H-SMIL-Net, the obtained authoring tool offers a good compromise between the power of formal modelling and a reasonable verification response time.

In this first version of H-SMIL-Net, we have modelled the most used SMIL temporal elements. We aim to extend the model so as it can model all the temporal elements of SMIL.

The aim of the editor was to take advantage from the H-SMIL-Net possibilities in the authoring of the SMIL temporal structure. In the second version (which is under construction) we will integrate spatial and hypermedia aspects of SMIL in order to obtain a complete authoring environment for SMIL documents.

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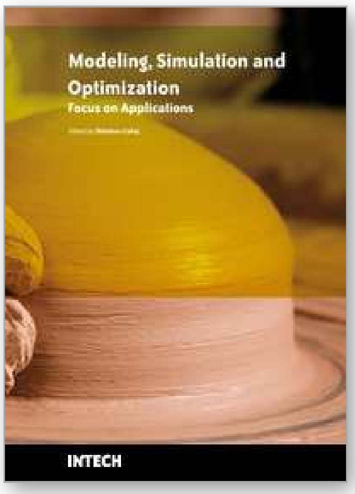

**Modeling Simulation and Optimization - Focus on Applications**
Edited by Shkelzen Cakaj

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The book presents a collection of chapters dealing with a wide selection of topics concerning different applications of modeling. It includes modeling, simulation and optimization applications in the areas of medical care systems, genetics, business, ethics and linguistics, applying very sophisticated methods. Algorithms, 3-D modeling, virtual reality, multi objective optimization, finite element methods, multi agent model simulation, system dynamics simulation, hierarchical Petri Net model and two level formalism modeling are tools and methods employed in these papers.

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