FORMAL DESIGN OF SMIL DOCUMENTS

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Abstract: This article introduces a new formal technique based on extended timed Petri nets, called SMIL-Net for the modelling and the verification of SMIL presentations. We also propose a technique for the temporal and hyper-temporal consistency checking of the document based on the SMIL-Net model.

1 INTRODUCTION

Synchronized Multimedia Integration Language (SMIL) (Hoschka,1998) (Ayars,2001) 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. This paper thus focuses on the SMIL-based presentations.

The complexity of SMIL documents can lead authors, in certain cases, to specify synchronization relations which could not be satisfied during the presentation of the document, thus characterizing the occurrence of inconsistencies, making it necessary to use formal techniques for their specification and for verifying their logical and temporal properties (Sampaio,2003) (Huiqun,2002) (Yang,2000). This article introduces a new formal technique based on extended timed Petri nets, called SMIL-Net (which means SMIL - Petri Net) for the modelling and the verification of SMIL presentations (Smail,2004). The major innovation of the SMIL-Net model is the modelling of the hyper-temporal dimension of SMIL documents, and the verification of temporal and hyper-temporal consistency within the same model.

The paper is organized as follows: First of all, we present the SMIL-Net model in section 2. The conversion techniques from SMIL to SMIL-Net are presented in section 3. The methods for detecting temporal and hyper-temporal inconsistencies are explained in section 4. Finally, section 5 concludes this paper.

2 SMIL-NET

The elements in SMIL-Net include places, tokens, transitions and arcs.
we define three kinds of places to model the different time-dependant elements of SMIL: The regular place represents a media element and its associated duration. The link place represents a linking element (*a* and *area* elements of SMIL) and its activation interval. Finally, the virtual place represents a synchronization attribute (*begin*, *end, dur*).
The model defines two types of tokens: State tokens that define the state of the place, and Control tokens that act on the state of the place. These tokens are transported by different types of arcs: The simple arc is used to transport state tokens. The virtual arc is used to transport control tokens. The dynamic arc is used to model hyperlink firing. The master arc controls the firing of *master* transitions.
To model the different semantics of SMIL, three types of transitions are defined (subset of the transition semantics defined in TSPN model (Senac,1995) (Senac,1996-a) (Senac,1996-b)): The *simple transition* fires if all its input places are active and have unlocked tokens. The *Master transition* fires if the place having a master arc is active and has an unlocked token. The *First transition* fires if one of its input places is active and has an unlocked token.
The next section will illustrate the use of these different elements in the modelling of SMIL elements.

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3 CONVERTING SMIL DOCUMENT TO SMIL-NET

In this section, the synchronization and hypermedia elements of SMIL are examined, and the mechanisms that convert these elements to SMIL-Net are presented.

We assume that the syntax of the input SMIL script has been checked before starting the transformation.

3.1 Converting a Media Object

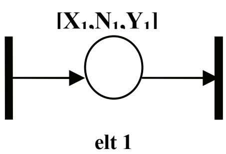

Figure 1: Converting a media object.

A media object is represented by a regular place and a pair of ordinary transitions (Ts, Te).

However, the attributes associated with the element require some more conversion. Since the *"begin"* attribute specifies the time for the explicit begin of an element, one *virtual place* representing the begin time with the specified duration is added in front of the element. The *"end"* attribute specifies the explicit end 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 object to end with the value specified in the end attribute. The *"dur"* attribute specifies the explicit duration of an element, thus a *virtual place* between the actual start transition and the end transition is added. The end transition is also a *master transition* .

3.2 Converting the <seq> Element

The <seq> element defines a sequence of elements in which elements play one after the other. Since the children of a <seq> element form a temporal sequence, we concatenate each child of <seq> one by one in SMIL-Net,

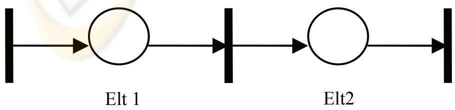

Figure 2: Converting a <seq> element.

3.3 Converting the <par> Element

The <par> element defines a simple parallel time grouping in which multiple elements can play back at the same time. Thus, all children of <par> should be within the same pair of transition (Ts, Te).

There are three variations for <par> according to the value of the *"endsync"* attribute. The *"endsync"* attribute controls the end of the <par> element, as a function of children end time. Legal values for the attribute are *"last", "first",* and *"id-ref".*

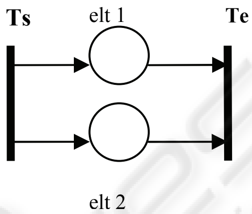

Figure 3: Converting the <par> element.

The value of *"last"* requires <par> to end with the last end of all the child elements, so **Te** is modelled by a simple transition. The value of *"id-ref"* requires <par> to end with the specified child. So we change the end transition **Te** to a *Master transition*, and the arc between the specified child and transition to a *master arc*. The value of *"first"* requires <par> to end with the earliest end of all the child elements. Therefore, we should change the end transition **Te** to a *First transition* so that the child that ends first will fire the transition. Other synchronization attributes, such as *"begin", "end",* and *"dur",* could also be associated with <seq> and <par> elements, but the conversion is similar to that in the media object elements.

3.4 Converting the <a> Element

The functionality of the <a> element is very similar to the functionality of the <a> element in HTML, it defines a link which can be activated by one of its child elements without influencing their synchronization.

The link <a> is active during all the interval of activation of the source element, thus its interval of activation is [0,*,*source-duration*].

The <a> element is modelled by a *link place* and a dynamic arc to fire the link. When the active duration of the source element begins, the link place receives a *pause token* and waits for user interaction. If an interaction happens during the activation interval of the link (which is, in this case the same as the active interval of the source element), the dynamic arc is transformed to a simple arc and the following transition (the link) fires.

There are three variations for <a> element according to the "*show*" attribute. The *"show"* attribute specifies how to handle the current state of the presentation at the time in which the link is activated. Legal values for the attribute are *"new"*, *"pause"*, and *"replace"*. The *"pause"* value requires the source to be paused while playing the destination element, so we use virtual arcs with *pause/resume tokens* to pause and resume the source element. The *"replace"* value require the destination element to replace the source element and to play in the same context, so the firing of the transition retrieves a token to the source place in order to disable it. The *"new"* value requires the destination element to play in a new context without affecting the source element.

3.5 Converting the <area> Element

The functionality of the <a> element is restricted in that it only allows associating a link with a complete media object. The <area> element allows associating a link with spatial and/or temporal portions of an object.

When the <area> element is associated with a spatial portion of an object, it has the same temporal behavior as the <a> element since it stills active during all the duration of the source object.

When the <area> element is associated with a temporal portion of an object using attributes such as *begin* and *end* attributes, the interval of activation associated to the link place is restricted to [*begin*,*,*end*].

The <area> element also accepts the *'show'* attribute, the SMIL-Net associated with the <area> element with the different values of the *'show'* attribute is the same as in the <a> element with a different activation interval for the link place.

4 TEMPORAL AND HYPER-TEMPORAL VERIFICATION

The complexity of SMIL documents can lead authors, in certain cases, to specify synchronization relations which could not be satisfied during the presentation of the document, thus characterizing the occurrence of temporal inconsistencies. For this reason, we associate verification techniques to SMIL-Net to detect temporal inconsistencies.

The hyper-temporal inconsistencies resulting of the definition of inconsistent temporal links are also an important aspect of the verification process, and are detected by SMIL-Net.

4.1 Temporal Verification

The time conflict is defined in (Yang,2000) as the case of conflicting values of attributes in the SMIL script.

There are two types of time conflicts for SMIL presentations, the *intra-element* time conflict and the *inter-elements* time conflict.

4.1.1 The Intra-element Time Conflict

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

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

4.1.2 The Inter-elements Time Conflict

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

In SMIL-Net, the firing time of transition should be earlier than that of the following transition. It implies that if the values of attributes set by the author make the firing time of a transition later than the firing time of some following transition, it results in the inter-elements time conflict.

The inter-element time conflict could be detected by comparing the computed firing times of transitions.

Thus, it is necessary to calculate the firing time for all the transitions in the SMIL-Net.

To compute the firing time for each transition, we have to reduce the SMIL-Net by removing all non-temporal elements.

Then, the firing time for each transition is computed by traversing the reduced SMIL-Net transition by transition from the initial state. The computation rule for calculating the firing time of a transition depends on its type: For simple transitions, 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". For First transitions, 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”. For *Master transitions,* 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*”. When the firing time of each transition is computed, we traverse the SMIL-Net again from the initial place and locate the pair of transitions at which the conflicting firing times occur. The corresponding pair of elements with the conflicting transitions is therefore the source of the inter-elements time conflict.

4.2 The Hyper-Temporal Verification

The hyper-temporal inconsistency is concerned with the definition of temporal links pointing on a non-active object. This case of inconsistency is detected when the activation interval of the link place is not included in the duration interval of the source place.

In the case of local links, we should ensure that the link firing may not lead to temporal inconsistency. Thus, we assume that the link fires, we replace the dynamic arc by a simple arc, and we apply the temporal verification techniques seen above on the obtained SMIL-Net.

5 CONCLUSION

This paper introduces a new forma model, based on the temporal extensions of Petri nets for modelling and verifying temporal and hyper-temporal consistency of SMIL documents, called SMIL-Net.
The main contributions of this work are:

- The definition of a formal model covering both of the temporal and the hyper-temporal aspects of SMIL documents.
- The definition of an approach to automatically translate SMIL documents into SMIL-Net specification.
- The temporal and hyper-temporal consistency checking based on the same model.

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