A Visual Approach for Modeling Spatiotemporal Relations

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ABSTRACT
Textual programming languages have proven to be difficult to learn and to use effectively for many people. For this sake, visual tools can be useful to abstract the complexity of such textual languages, minimizing the specification efforts. In this paper we present a visual approach for high level specification of spatiotemporal relations. In order to accomplish this task, our visual representation provides an intuitive way to specify complex synchronization events amongst media. Finally, to validate our work, the visual specification is mapped to NCL (Nested Context Language), the standard declarative language of the Brazilian Terrestrial Digital TV System.

Categories and Subject Descriptors
I.7.2 [**Computing Methodologies**]: Document Preparation - *Hypertext/hypermedia*.

General Terms
Design, Experimentation, Human Factors, Languages.

Keywords
Visual specification, Visual representation, Synchronization, Spatiotemporal relations, Connector, NCL, SBTVD.

1. INTRODUCTION
Visualization is a process of transforming information into a visual form to help users to understand its meaning. It provides a visual interface between two powerful information processing systems — the human being and the computer. Information visualization includes the development of visual approaches for communicating information structures to humans, allowing these to interact with those structures through direct manipulation [5].

The visual display of synchronization relations is not a recent research direction, but has still attracted people from diverse areas such as HCI (*Human-Computer Interaction*), databases, medical informatics, multimedia, and from the specific field of Information Visualization (IV). Although the work already done has lead to commonly accepted and useful visual representation choices, much work still remains to be done, especially for the representation of temporal relations and complex temporal patterns [2].

Whilst designing a visual approach for specification of spatiotemporal relations, one has to take into consideration at least the following principles:

- *Simplicity:* Simplicity is the idea that an approach can be understood and used by a user in a faster way when compared to textual specification. Complex representation includes a large overhead in learning before it can be used;

- *Translatability:* The most important benefit of using a visual model is to provide a mapping functionality, that is, a way to transform from a visual representation to a declarative language specification. In other words, a beautiful visual notation without code generation is useless.

Following these directives, the main goal of this paper is to present a visual authoring approach for spatiotemporal relations [7]. Regardless of all existent formalisms for visual languages [3], we aim at exploiting some advantages of visual representation, like reducing the overall development time. Such visual representation can be mapped in a time-based markup language, and used regardless of which are the document components that will be related. This feature is useful especially for declarative languages focused on the specification of media synchronization. In the current stage of this work, the visual specification is mapped to NCL (*Nested Context Language*) [8], the standard declarative language of the Brazilian Terrestrial Digital TV System (SBTVD-T).

This paper is organized as follows. First we briefly survey the state of the art, pointing out some basic concepts with regards the specification of synchronization relations (Section 2). Then, in Section 3, we present our graphical vocabulary for modeling spatiotemporal relations. As a validation of the proposed ideas, we show how the visual representation is mapped to NCL code. Finally, Section 4 is reserved to conclusions and future work.

2. BACKGROUND
Media objects are the basic units of a multimedia/hypermedia document. Media objects can be of different types, such as text, images, graphics, video, audio and even imperative scripts (Lua[1] scripts in the case of SBTVD-T). These units are combined in a multimedia scenario by different types of relationships among them [6].

Besides the traditional referential relationship, hypermedia applications frequently must deal with other temporal and spatial relationships among their media assets. Spatiotemporal relationships

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[1] http://www.lua.org/

usually are represented in XML-based languages by compositions or links.

Defining synchronization relationships using compositions makes the authoring task easier, since the author can specify with a single composition what would be alternatively specified using several links. However, languages usually offer a limited set of compositions to describe synchronization relations. This is the case of SMIL (*Synchronized Multimedia Integration Language*)[2], in which there are only three composition types: parallel; sequential; and exclusive. As a consequence, complex relationships must be built through a hierarchy of basic compositions, and this may impair the approach inherent advantage of facilitating the authoring process.

Using links, the relation expressiveness depends on the source authoring language. In HTML (*HyperText Markup Language*)[3], for example, links are unidirectional and represent the common navigation behavior through user interactions. HTML links have low expressiveness and, in addition, are embedded in the node content, preventing reuse of the same resource without inheriting previously defined relationships.

Other languages allow the definition of a link as a first-order entity, such as SMIL, XLink (*XML Linking Language*)[4] and NCL. In SMIL, links are considered a type of document component, and they can be either triggered by user interaction or by other triggering conditions, such as temporal events. XLink provide independent link repositories that can be reused in several documents. In NCL, a link belongs to a composite node and represents a relationship among nodes recursively contained in that composite node. NCL composite nodes, which do not have embedded semantic relationships, can be reused, but links alone cannot.

Some declarative languages still distinguish the relation specification from the relationship, which involves not only the relation definition but also its participants. In XLink, for example, the definition of participating resources and the definition of traversal rules are done with different child elements of an extended link. However, the traversal behavior is embedded in the link definition and cannot be handled independently.

In NCL, a relation, represented by an NCL connector element, is defined independent from relationships, represented by NCL links. A link always refers to a connector and defines a set of participant components to play the roles defined by the referred connector. Therefore, different links of the same type can be created reusing the same connector, defining different sets of participating resources. Connectors can be defined by an NCL profile called XConnector [7], and can compose a connector base that can be reused among NCL documents.

3. MODELING AND VISUALIZING SPATIOTEMPORAL RELATIONS

Given the expressiveness provided by the XConnector profile [7], which can be used to extend the linking modules of other XML-based languages, such as XLink, HTML and SMIL, in this section we first discuss the event-driven model on which the XConnector

language is based. Then, we propose visual metaphors, and present how they are mapped to XConnector elements. Finally, an example is defined in order to illustrate how useful the visual approach can be when compared to the textual specification.

3.1 The Synchronization Model

In NCL, spatial and temporal relationships among events are defined using links. Events are time occurrences (e.g. the presentation of a node content, the selection of a node content and the attribution of a value to a node property). An event state machine represents the life cycle of an event, independent from its type, as shown in Fig. 1.
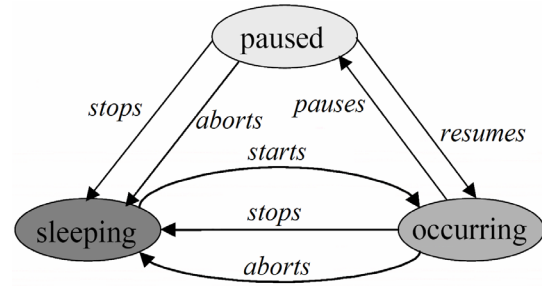

Fig. 1. Event state machine.

The event state transitions are labeled with names that denote actions being executed on a media object (as shown on Fig. 1). This is explored in NCL, which take these terms as reserved words in order to reduce the verbosity of the multimedia connector authoring.

3.2 The Visual Vocabulary

When defining the visual vocabulary, our first concern was to select visual metaphors that were intuitively meaningful to authors. Therefore, we opt for using symbols which are generally used on remote controls and on user interfaces of media players.

For DTV (*Digital TV*) profiles, NCL relations are based on the causality paradigm[5], where an action expression is triggered when a condition expression is satisfied. Table 1 presents the simple conditions and simple actions expressions, and the symbols used to represent them graphically.

As an example, take into consideration a connector equivalent to the Allen's temporal operator MEETS [1], here called "onEndStart". The condition of the relation is determined by the "onEnd" role, and the resulting action is expressed by the "start" role. Fig. 2 displays the visual and textual (in NCL) specifications of this connector.

A condition expression may be simple (<simpleCondition> NCL element) or composite (<compoundCondition> NCL element). A compound condition has a logical operator attribute ("or" or "and") relating its child elements (simple conditions or other compound conditions, recursively). If the qualifier establishes an "or" logical operator, the action will be fired whenever any condition occurs. If the qualifier establishes an "and" logical operator, the action will be fired after all the children conditions occur. If not specified, the default value "or" must be assumed.

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[2] http://www.w3.org/AudioVideo

[3] http://www.w3.org/html/wg/

[4] http://www.w3.org/TR/xlink/

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[5] Only causal relations were taken into account by the NCL profile for the SBTVD.

Table 1. Icons for simple conditions and simple actions.

Icon	Role Name		Transition Value	Event Type
	Condition	**Action**		
	onBegin	start	*starts*	presentation
	onEnd	stop	*stops*	presentation
	onAbort	abort	*aborts*	presentation
	onPause	pause	*pauses*	presentation
	onResume	resume	*resumes*	presentation
	onSelection	-	*starts*	selection
	onBegin Attribution	-	*starts*	attribution
	onEnd Attribution	-	*stops*	attribution
	-	set	*starts*	attribution

Table 2. Icons for conditions and actions qualifiers.

Icon	Qualifier	Semantics
or	or	True whenever any associated condition occurs
and	and	True immediately after all associated conditions had occurred
seq	sequential	All actions must be executed in sequence
par	parallel	All actions must be executed in parallel

3.3 A more complex example

Imagine a connector called "onSelectionORonBeginSetStart" used in an interactive application for digital TV. A relationship based on this relation is such that when either a viewer presses the red key of a remote control during a TV program presentation or the breaking news start, the main video must be resized, and additional information is exhibited. This example was designed just to illustrate the expressiveness of our visual approach, showing up the use of parameters and compound elements.

The condition of this relation is satisfied by either the selection of a key of the remote control ("onSelection" role) or the start of the presentation of a media object ("onBegin" role). The resulting action is composed by two simple actions. The first one is a resize action, that is, the attribution of a new value to a "bounds" property of a media object playing the "set" role, and the second is the start of the presentation of a media object playing the "start" role. Such connector is described textually and visually in Fig. 3. As can be noticed in this figure, the remote control's key and the resize values are described using parameters, whose values are defined by the link specification.

```
<causalConnector id="onEndStart">
    <simpleCondition role= "onEnd"/>
    <simpleAction role= "start"/>
</causalConnector>
```
a)
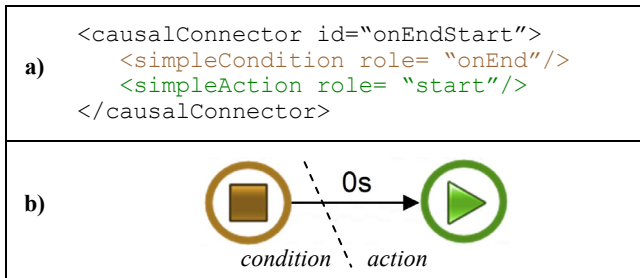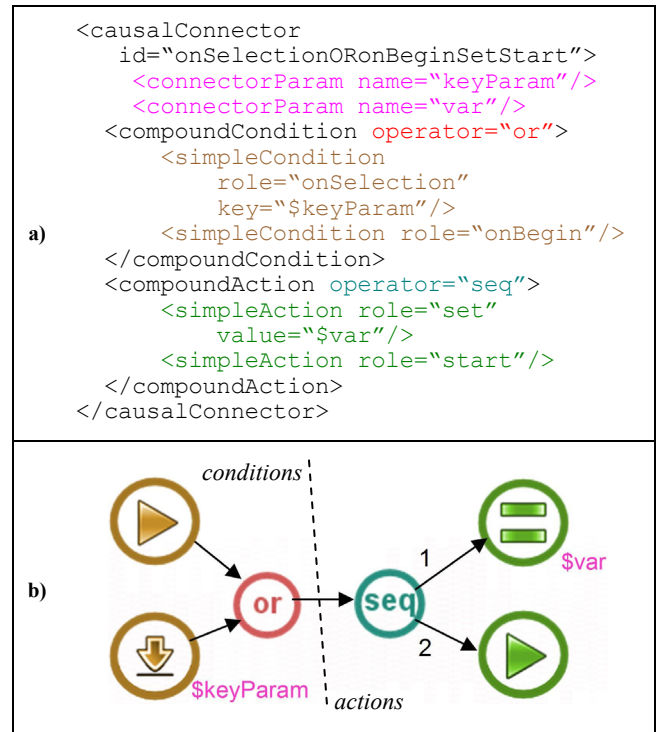
b)

condition   *action*

Fig. 2. "onEndStart" connector: a) textual and b) visual representations.

An action expression may also be simple (<simpleAction> NCL element) or compound (<compoundAction> NCL element). Compound actions have an operator attribute ("par" or "seq") relating its child elements. Parallel ("par") and sequential ("seq") compound actions specify that the actions must be performed in any order or in a specific order, respectively. In the latter case, a numbering label is used to define visually in which order the actions will be executed (see example Section 3.3). Table 2 illustrates the symbols that are used for representing operators related to compound relations.

Still, a delay attribute can be defined for a condition expression specifying this is true after a time delay from the time the transition occurs. The same can be done for an action expression, specifying that the action must be fired only after waiting for the specified time. In our visual approach, this feature is represented by labels along arrows connecting conditions and actions expressions, as exemplified by the label "0s" (Fig. 2). Customized delays can be specified through the delay attribute of condition or action elements.

```
<causalConnector
    id="onSelectionORonBeginSetStart">
    <connectorParam name="keyParam"/>
    <connectorParam name="var"/>
  <compoundCondition operator="or">
      <simpleCondition
          role="onSelection"
          key="$keyParam"/>
      <simpleCondition role="onBegin"/>
  </compoundCondition>
  <compoundAction operator="seq">
      <simpleAction role="set"
          value="$var"/>
      <simpleAction role="start"/>
  </compoundAction>
</causalConnector>
```
a)

b)

conditions   *actions*

Fig. 3. "onSelectionORonBeginSetStart" connector: a) textual and b) visual representations.

Trying to improve the modeling process, our prototype also supplies a textual notation. While the spatiotemporal relation is defined, a textual feedback is set up for the author. For this example, the tool presents a textual summary: "WHEN < onSelection > WITH key="$keyParam" OR < onBegin > DO SEQUENTIALLY < set > WITH value="$var", < start >".

Fig. 4 illustrates a use case of the defined "onSelectionORonBeginSetStart" connector in a NCL link specification. In this code, the red key and the new size values are defined through <bindParam> NCL elements.

```
<ncl>
...
<connectorBase>
...
  <!--onSelectionORonBeginSetStart connector-->
...
</connectorBase>
...
<link xconnector=
    "onSelectionORonBeginSetStart">
  <bind role="onSelection"
      component="mainVideo">
    <bindParam name="keyParam"
        value="RED"/>
  </bind>
  <bind role="onBegin"
      component="breakingNews"/>
  <bind role="set" component="mainVideo"
      interface="bounds">
    <bindParam name="var"
        value="10%,10%,50%,50%"/>
  </bind>
  <bind role="start"
      component="moreInfo"/>
</link>
...
</ncl>
```

Fig. 4. Using a connector to define a NCL link.

4. CONCLUSIONS

This paper proposes a visual specification of synchronization relations. As a proof of concept for the proposed ideas, a prototype was developed and incorporated into the *Composer* authoring tool [4]. We believe that the proposed high level mechanism provides a more efficient and easier way to create spatiotemporal relations. The verbosity in defining relations is usually high. In NCL, for example, from a total of 45 XML elements, one third is dedicated to the authoring of connectors and links.

The independence between the specification of relations and relationships allows defining relationship templates. As a future work, we intend to generalize and to map this visual approach also for defining templates for compositions. These templates would carry out implicit presentation semantics defined by relationships among their child components.

Although a preliminary study was carried out during the initial design of this work, a deeper revision of HCI aspects is still needed to evaluate and to determine whether the proposed metaphors are easier and quicker to understand and do not lead to ambiguous interpretations (thus ensuring an easy formulation of relations, and minimizing the possibility of errors).

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