Priority Petri Net Multimedia Model for Non-deterministic Events of Multimedia Presentations

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Abstract: Nowadays, the use of multimedia for presentation needs has been widely used by various parties. Multimedia authoring translates the input data in the form of spatial and temporal layouts into a multimedia document. Multimedia documents are in the form of multimedia programming languages such as Synchronized Multimedia Integration Language. One of the problems in this translation process is the existence of a non-deterministic event which makes the translation process difficult. The objective of this study is to find a good method for translating multimedia authoring where the input is given has non-deterministic events and priority based on user input. The multimedia model needs to be modified to anticipate non-deterministic events in the temporal layout. In this study, a method called Priority Petri Net is proposed which is applied to a multimedia model. The results on multimedia authoring using the Priority Petri Net model obtained good results. However, the translation process takes a little longer time than using the regular Petri Net model. The use of the Priority Petri Net model makes the translation process better. Future research can be carried out by making various modifications to the multimedia model to obtain a good process and fast processing time as well.

1 INTRODUCTION

Multimedia is a way of communication today, multimedia components such as video, audio, text, animation, images are widely used as a communication medium. The multimedia components are combined to create an attractive multimedia presentation. The multimedia presentation is created using a tool called Multimedia Authoring. Multimedia Authoring combines every multimedia component used to produce a multimedia document (Picinin, Farines, Santos, & Koliver, 2018). Several multimedia programming languages are widely used as multimedia documents such as Synchronized Multimedia Integration Language (SMIL) and Nested Context Language (NCL) (Bulterman, 2018; Joel André Ferreira Dos Santos & Muchaluat-Saade, 2012).

Multimedia has been widely used in various fields such as education, business, sports, entertainment, and others (Hakim & Solechan, 2018; Wijaya, 2019; Yousafzai, Chang, Gani, & Noor, 2016). The use of multimedia increases the absorption of presentation material on the audience who is listening to presentations through the use of multimedia. Humans can remember more if they both hear and see at the same time. Therefore multimedia has turned into interactive multimedia to increase audience participation, this participation will increase the delivery rate of presentation material (Kazanidis, Palaigeorgiou, Papadopoulou, & Tsinakos, 2018). These days interactive multimedia has been used for finance, e-commerce, social networking, E-Learning: training, teaching aids, learning media, entertainment: games, cultural communication: museum and gallery information. Interactive multimedia is the use of computers to create and combine images, text, audio, moving images (video and animation) by combining tools and links (or hyperlinks) that allow audiences to interact, navigate, create and communicate. An interactive multimedia presentation is a hypervideo consisting of various media which is navigated through hyperlinks (Meixner, 2017).

There are two kinds of interactive multimedia: Online Interactive Multimedia and Offline Interactive Multimedia. Online interactive multimedia is

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interactive media that is conveyed via LAN, intranet, or the internet. Examples of online interactive multimedia are websites, Yahoo Messengers, and so on. This type of media has a broad target and covers the wider community. Offline interactive multimedia is interactive media that is not delivered through data communication channels. Examples of offline interactive multimedia are interactive CDs: Company Profile, Learning Media. This media target is not too broad and only covers people in certain areas. The use of online and offline interactive multimedia does not always stand alone but can also complement each other (Tanti & Buhalis, 2017).

A multimedia presentation can be represented by a spatial layout and a temporal layout. The spatial and temporal layout needs to be verified so that it can be processed further. (Joel A.F. Dos Santos, Braga, Débora, Roisin, & Layaïda, 2015). Figure 1 is an example of a multimedia representation, in this example, there are 6 multimedia components (A, B, C, D, E, and F) which can be either image, video, text, or animation.

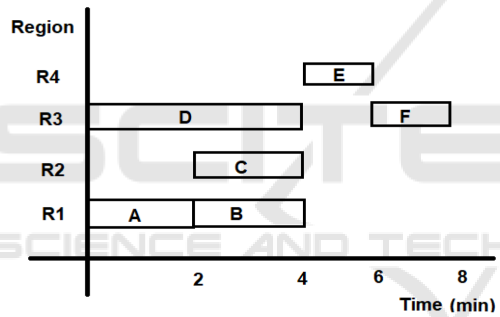

Figure 1: Example of multimedia presentation.

In this example, each multimedia component is located in an area called a region (R1, R2, R3, and R4). The region is a part of a larger area called the root layout as shown in Figure 2.

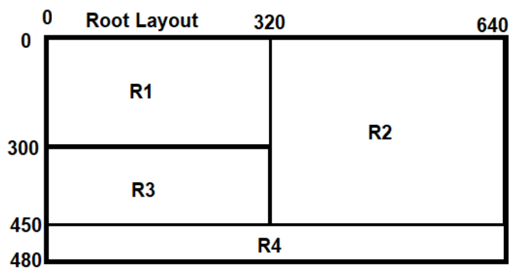

Figure 2: Example of regions.

In Figure 1 it can be seen that component B is played when component A is finished; component E is played when components B, C, and D are finished; and component F is played when component E is finished. Problems will arise if there are components with no known duration. For example, if component D has no known duration, it will be difficult to determine when component E will start playing as shown in Figure 3. This condition is called a non-deterministic event.

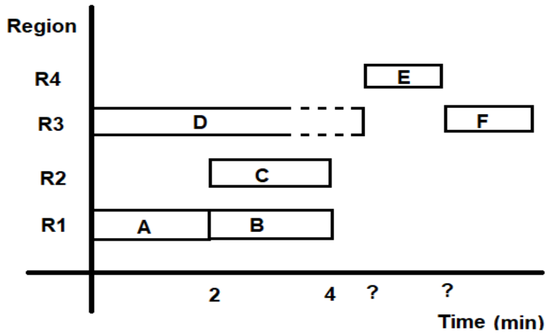

Figure 3: Non-deterministic event.

This problem is often combined with interference from the audience with the button for interaction. Audience input can affect the start, stop, and duration of the multimedia component when it plays. Problems with non-deterministic events and buttons occur frequently and need to be solved.

A multimedia presentation in the form of spatial and temporal layout needs to be processed in several steps so that it can become a multimedia document (Bouyakoub & Belkhir, 2011, 2012) The first stage is to carry out the modeling process. The existing multimedia models in the previous study are Petri Net, Hoare Logic, Language of Temporal Ordering Specifications (LOTOS), Simple Interactive Multimedia Model (SIMM) (De Mattos & Muchaluat-Saade, 2018; Mekahlia, Ghomari, Yazid, & Djenouri, 2017; Sampaio & Courtiat, 2004).

Petri net is a model for representing discrete distributed systems. The problem for non-deterministic events is a form of problem that is suitable to be modeled using the Petri net. Petri net is a model that can be modified or have many extensions. Examples of Petri net extensions are as follows: Colored Petri net, Hierarchy Petri Net (Bouyakoub & Belkhir, 2008), vector addition with state (VASS), Dualistic Petri net (dP-nets), and others. So that in this study, modifications will be made to the Petri net to solve the problem of non-deterministic events. This research contributes to modification and applies it to non-deterministic event problems, which the proposed method used is Priority Petri Net.

2 RELATED WORKS

A Multimedia Presentation must be processed with the Kernel Mechanism as shown in Figure 4 (Wijaya, Maksom, & Abdullah, 2021b).

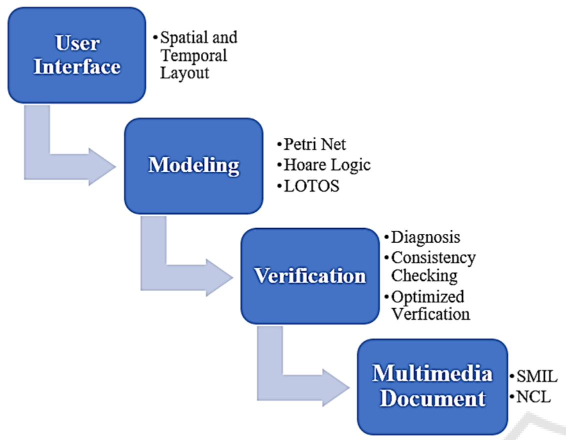

Figure 4: Kernel mechanism.

2.1 Petri Net

Petri Net is a multimedia model that is widely used in Multimedia Authoring. Petri Net uses graphics as a representation of multimedia presentations. There are several symbols in Petri Net, namely "arc", "place", "transition", and "token" as shown in Figure 5 (Belkhir & Bouyakoub-Smail, 2007).

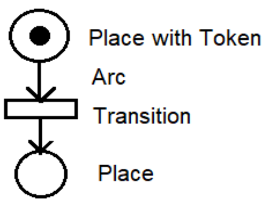

Figure 5: Petri Net symbol.

"Place" is a symbol of the multimedia component in a multimedia presentation. "Transition" is a transition that occurs when a multimedia component ends and another multimedia component starts. "Token" is the status of a place that is currently being played. "Token" will move from "place" to "place", this process is called "Fire". "Arc" connects "place" and "transition" to guide the movement of "token". All these symbols will form a representation of the multimedia document.

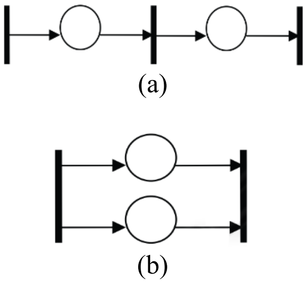

Figure 6: (a) Sequential Petri Net. (b) Parallel Petri Net.

In simple terms, Petri Net is formed sequential and parallel, examples of sequential and parallel images are shown in Figure 6.

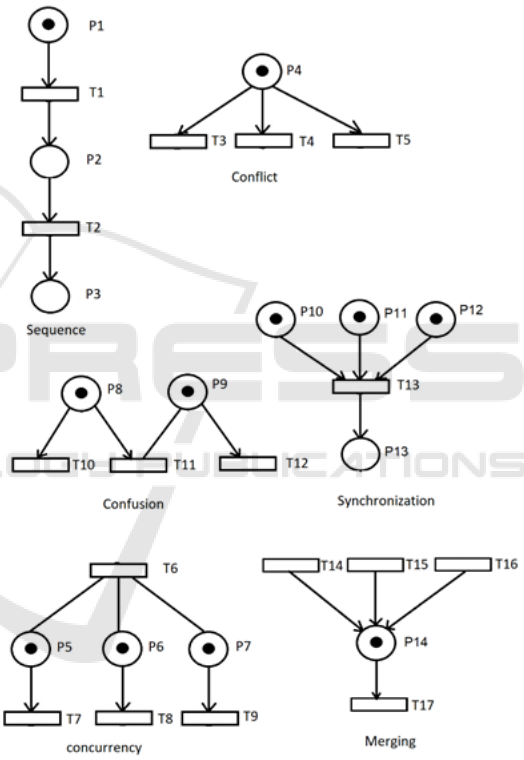

Figure 7: Primitive structure of Petri Net.

For more advanced forms, Petri Net has several forms called Primitive structures such as conflict, confusion, synchronization, concurrency, and merging as shown in Figure 7.

The sequential structure has a clear sequence, token activation from place P1 to place P2 then to place P3 which activates sequentially. Likewise, concurrency structures have a clear form, tokens will move according to the existing transition.

The structure of conflict and confusion has an unclear form, the token in place of P4 activates three transitions, but when one is activated, the other two transitions are disabled, the token in place of P8 activates T10 and T11, but if T10 is active then T11 becomes inactive. This causes the conditions for the two structures to be similar.

The synchronization structure has a clear form if the process at place P10, place P11, and place P12 has been completed then the three will be synchronized by starting place P13. Meanwhile, the merging structure is not the same as the synchronization structure. In the merging structure, the three transitions T14, T15, T16 do not need to be fired at the same time, or three transitions fire before T17.

In 1998, the use of the Petri Net as a model for multimedia was initiated. The study entitled "A Graphical Interface for creating and playing SMIL documents (GRiNS)" is a Multimedia Authoring Tool that can translate multimedia documents (Bulterman, 1998). In 2005, the Petri Net model was refined and used as a graphics-based multimedia processing paradigm (Bulterman & Hardman, 2005).

Yang Chun Chuan in 2003, made modifications to the Petri Net by simplifying the places that are not synchronized (C. C. Yang & Yang, 2003). For example, if there is a multimedia program like in SMIL:

```
<seq>
     <par endsync=id(V1)>
        <video src=V1/>
        <audio src=A1/>
        <image src=I1/>
      </par>
     <par endsync=id(A2)>
        <video src=V2/>
        <audio src=A2/>
        <image src=I2/>
      </par>
</seq>
```

The Petri Net graph for an example of this program is as shown in Figure 8. In this example there are two parallel groups, in the first group, there are 3 multimedia components, each one video (V1), audio (A1), and image (I1). Likewise, in the second group, each one contains video (V2), audio (A2), and image (I2). The difference is that for the first group the synchronization place is V1, while in the second group the synchronization place is A2.

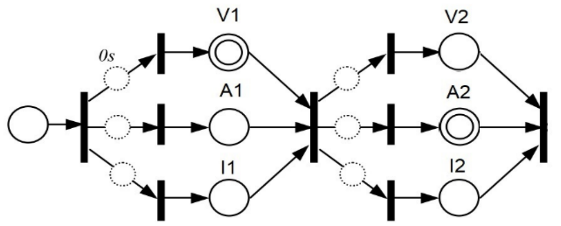

Figure 8: Petri Net model for the example.

Figure 8 can be simplified by eliminating places that are not part of the synchronization. In the first group, the place symbols for A1 and I1 are removed, in the second group the place symbols for V2 and I2 are removed. The result of this simplification is shown in Figure 9. The simplification model is called the Real-Time Synchronization Model (RTSM).

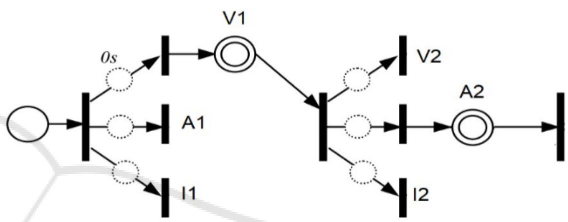

Figure 9: Simplified Petri Net (RTSM).

2.2 Non-deterministic Event

Yang Chun Chuan in 2008 conducted a study entitled "Extension of Timeline based Editing for Non-deterministic Temporal Behavior in SMIL 2.0 Authoring", in that study the concept of Dividable Dynamic Timeline (DDTL) was introduced (C. Yang, Chu, & Wang, 2008). In a multimedia presentation, audience interaction is possible. These interactions can take the form of buttons being pressed by the audience. This button functions to change the multimedia components that are played. Examples of multimedia programs that involve interaction from the audience:

```
<seq>
     <par endsync=id(I1)>
        <video src=V1/>
        <Image src=I1 begin=Btn1
                      end = Btn2/>
        <Audio src=A1/>
      </par>
     <par end=Btn3> </par>
      .
      .
      .
</seq>
```

In the example program, there is a non-deterministic event with the symbol "?". The scenario of the multimedia presentation is that there is an image component (I1) that becomes the synchronization of a parallel-group. In the group, there are a video (V1), an image (I1), and an Audio component (A1). Component I1 will play if Btn1 is clicked and will end if Btn2 is clicked. After the group ends, it will not proceed to the next group, if the Btn3 button is not clicked. Graph Petri net for this example is shown in Figure 10.

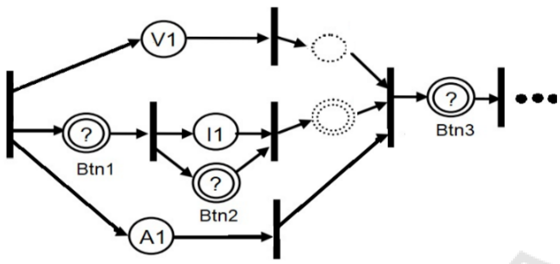

Figure 10: Petri Net with non-deterministic event.

The methods used in dealing with non-deterministic event problems are divide/split operations and merge operations.

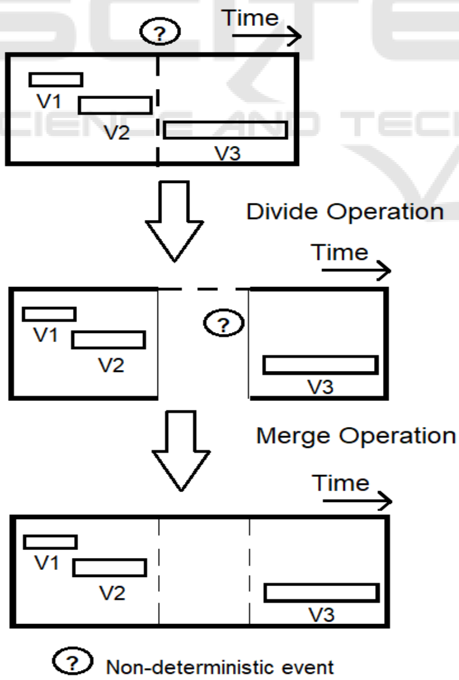

Figure 11: Divide and merge operation.

Figure 11 is an example of DDTL, in this example, there are 3 multimedia components video 1 (V1), video 2 (V2), and video 3 (V3). Between V2 and V3 there is a non-deterministic event, in the DDTL method the divide operation will be carried out first at that point. After the divide operation is performed, it will be connected again using the merge operation.

3 METHODS

A multimedia authoring must-have multimedia authoring attributes to function properly. Multimedia Attributes consist of Formal Verification Model, Editing, Services, and Performance. Attribute editing provides convenience for authors to create multimedia presentations such as ease of use and expressivity. Service attributes are facilities provided by multimedia authoring tools to verify so that there are no errors in multimedia documents. Attribute Performance is to provide an overall overview of a multimedia authoring tool. The attribute Formal verification model is a process model of multimedia presentation that is modeled properly (Wijaya, Maksom, & Abdullah, 2021a).

To fulfill the attribute attributes of Multimedia Authoring, it is imperative that multimedia authoring be able to process a multimedia presentation that contains non-deterministic events. This study proposed a method with priority Petri Net to deal with non-deterministic event problems.

3.1 Priority Arc

An "arc" is divided into “Priority Arc” and “Normal Arc”. Priority arc is distinguished by a line that is thicker than the normal arc as shown in Figure 12. Priority Arc determines the process of moving tokens from one "place" to the next transition. Normal arc and priority arc function to determine the firing path of the token, but the time the token moving/firing is determined by the priority arc.

(a) (b)

Figure 12: (a) Priority arc. (b) Normal arc.

Priority arc will determine or function as a synchronizer in a parallel-group. Priority arcs can function both in groups where there are no non-deterministic events or in groups where there are non-deterministic events.

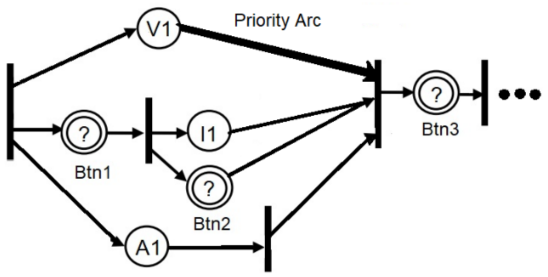

Figure 13: Example 1 of Priority Petri Net.

Figure 13 is the Priority Net graph of example 1 using the priority arc. In this example, the priority arc is on V1, which means that V1 is the determining time for the firing token to occur. Regardless of the lack of pressure on Btn2 by the Audience, this does not interfere with the firing token process in all places in the parallel group.

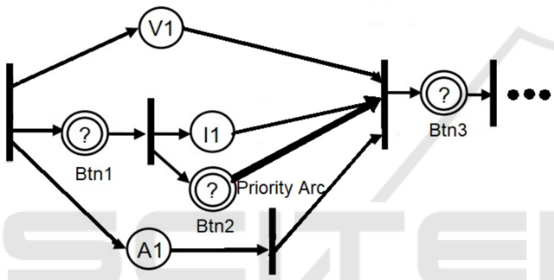

Figure 14: Example 2 of Priority Petri Net.

Figure 14 is the Priority Net graph of example 2 using priority arc. In this example the priority arc is in Btn2, this means that Btn2 is the determining time for the firing token to occur. In this case, pressing the button on Btn2 by the audience will cause a firing token to occur in all places in this parallel group.

Priority Petri Net is defined as six-tuple:

- Transition :

$$tr=\{tr_1, tr_2, \ldots, tr_x\} \quad (1)$$

- Place :

$$pl=\{pl_1, pl_2, \ldots, pl_y\} \quad (2)$$

- Button :

$$btn=\{btn_1, btn_2, \ldots, btn_z\} \quad (3)$$

- Place and button :

$$pb= pl \cup btn \quad (4)$$

- Normal arc :

$$na= \{tr \times pb_n\} \cup pb_{tr} \quad (5)$$

- Priority arc :

$$na= \{tr_n \times pb_p\} \cup pb_{tr} \quad (6)$$

Where :

x = number of transition
y = number of places
z = number of buttons
n = normal
p = priority

Each place has:

- Media identity
- Status: token or no token
- Start time
- End time
- Duration time

Transition (tr_x), fires immediately with synchronization of priority arc. Once activated, transition (tr_x) will remove tokens from each input place and add tokens to each output place.

By using the Priority Petri Net graph, it is necessary to modify the temporal layout to accommodate the Priority arc and non-deterministic events. The multimedia components contained in the temporal view are divided into regular boxes and thicker boxes. A thicker box indicates that the multimedia component is a priority arc. Likewise for non-deterministic events that need to be marked with a "?" on the multimedia component to indicate the interaction button from the audience.

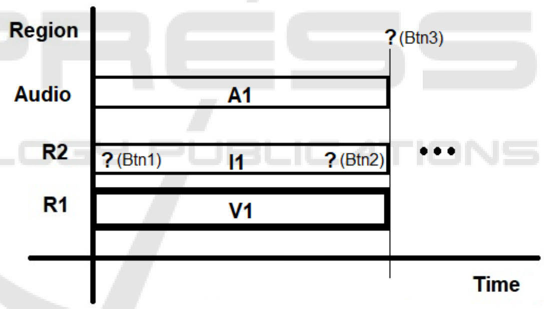

Figure 15: Example 1 of temporal layout.

Figure 15 is an example of 1 temporal layout where priority is given to the video component (V1) as a priority for the parallel group synchronization. The "?" at the beginning and the end of I1 denotes the start button and end button for component I1. The vertical thin line at the end of the group represents the synchronization position. Figure 16 shows example 2 of a temporal layout, to which priority is given to the Btn2 button which will end the play of Image 1.

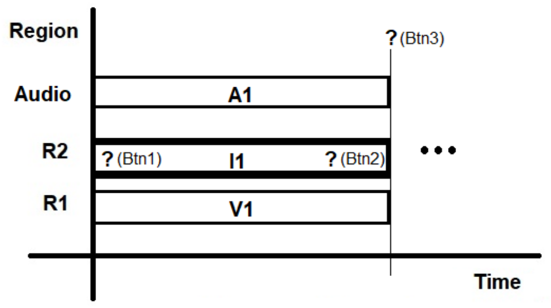

Figure 16: Example 2 of temporal layout.

3.2 Implementation Steps

The steps for implementing Priority Petri Pet for non-deterministic events in multimedia presentations are as follows:

- Entering multimedia component data into the system such as start time, end time, and duration.
- Entering non-deterministic event data on the system.
- Entering data on the relationship between multimedia components and non-deterministic events.
- Designing on spatial and temporal layouts.
- Arrangement processing in six tuples of Priority Petri net.

The performance measurement of the implemented model uses CPU execution time. CPU execution time is the total computational time CPU spends on a given task. The formula used for CPU execution time is as follows:

$$T = I \times CPI \times C \quad (7)$$

Where:
T = Execution time per program in seconds
I = Number of instructions executed
CPI = Average CPI for program
C = CPU clock cycle

4 RESULTS AND DISCUSSION

Experiments from Priority Petri Net were considered from two aspects, namely the fulfillment of the multimedia authoring attribute (editing attribute) and processing time.

In attribute editing, the method proposed by Priority Petri Net is seen from the temporal layout. The temporal layout is the interface that the author can access to create a multimedia presentation. The tools considered in the temporal synchronization paradigm are temporal editing, spatial editing, interactivity, presentation view, ordinary use support, priority, and non-deterministic support (De Mattos & Muchaluat-Saade, 2018).

Table 1: Tool comparison.

Temporal Synchronization Paradigm	Tool 1	2	3	4	5
Temporal Editing			√	√	√
Spatial Editing	√	√	√	√	√
Interactivity	√	√		√	
Presentation view			√	√	
Ordinary support		√		√	
Priority support					√
Non-deterministic support					√

1 = Composer
2 = NEXT
3 = LimSee2
4 = STEVE
5 = Priority Petri Net

In table 1, it can be seen that in this study, there is more emphasis on the core processes for spatial and temporal layout as well as Priority Support and Non-deterministic support. In multimedia authoring, several attributes need consideration, namely editing, services, performance, and formal verification (Wijaya et al., 2021a). The purpose of this study is to solve the problem of non-determinitic events, so the focus of this study is on editing and support for non-determinitic events. Whereas in other comparison tools, it can be seen that each tool emphasizes the temporal synchronization paradigm which is the focus of its research.

Figure 17 shows the number of temporal synchronization paradigm in each tool. The Composer and NEXT tools emphasize interaction with the author and the spatial editing view. The LimSee2 tool has complete editing features, both temporal and spatial editing views. The LimSee2 tool also has ordinary support and has a presentation view. STEVE tool has a complete feature and has a good interaction with the author. The interface of the STEVE tool also has an attractive appearance. Whereas, this study focused on input from the factor in the form of spatial and temporal layouts and to process non-deterministic events.

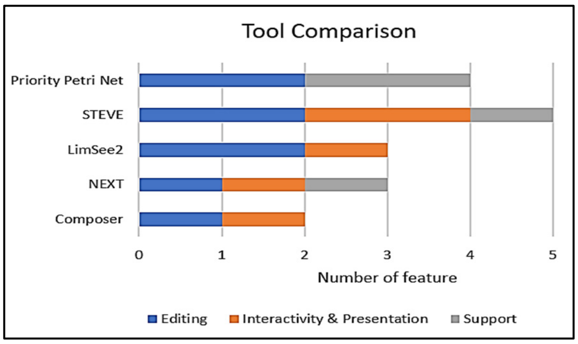

Figure 17: Tool comparison.

Table 2: Experimental time comparison.

Number of Multimedia Components	Petri Net (ms)	Priority Petri Net (ms)	Difference Percentage
5	352	403	14%
10	419	465	11%
15	474	513	8%
20	529	565	7%
25	580	617	6%
30	616	649	5%

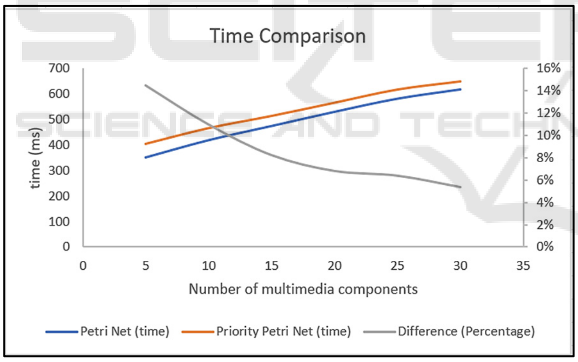

Figure 18: Experimental time comparison between Petri Net and Priority PetriNet.

Table 2 and Figure 18 show the experimental results comparing the processing time between Petri Net and Priority Petri Net. Experiments were carried out using a computer with an Intel® Pentium® CPU 4417U 2.30GHz 4 GB RAM specification. Experiments were carried out by changing the number of multimedia components from 5 to 30. The experimental results show that the processing time on the Priority Petri Net produces a longer processing time than the processing time on the Petri Net. The difference percentage is the difference in processing time on the Petri net and Priority Petri net. With the increase in the number of multimedia components, the percentage difference in time is getting smaller. Future research can be carried out by making various modifications to the multimedia model to obtain a good process and fast processing time as well.

5 CONCLUSIONS

A multimedia authoring that fulfills the multimedia attribute must consider the problem of non-deterministic events. This is because interaction with the audience is very important for an interactive multimedia presentation. The process of multimedia authoring is to use a multimedia model, which is currently widely used in the Petri Net model. A Petri Net can be modified into a Priority Petri Net to handle non-deterministic event problems. Experimental results on Priority Petri Net produce multimedia authoring that can handle non-deterministic events, but the processing time required is a little longer.

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