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A Brief Review: Multimedia Authoring Modeling

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Abstract. *Multimedia Authoring is a way to develop a multimedia presentation. Multimedia content includes images, sounds, videos, texts, and animations. The Kernel Mechanism of Multimedia Authoring consists of the Multimedia Authoring Programming Language and the Multimedia Authoring Model. Multimedia Authoring modeling is designed to enable the Multimedia Authoring function appropriately. Since the beginning of designing multimedia authoring tools, various studies were conducted to create a multimedia authoring model. Multimedia Authoring models that have been studied in existing research are Petri Nets, Hoare Logic, and LOTOS. The three models use different approaches. Petri Net uses a model based on graph calculations, Hoare logic uses mathematical logic, and LOTOS uses a formal specification language. Each of these models has been developed and modified to have higher capabilities. This model modification has advantages over the original model. This review article discusses the development and modifications of these models.*
Keywords: Multimedia authoring, Petri net, Hoare logic, LOTOS, Spatio temporal

1. **Introduction.** Research on identifying temporal and spatial conflicts has been carried out by many researcher. One of them is the formal verification technique by using a formal model or formal language to ensure multimedia authoring is functioning properly. Multimedia documents in the form of markup languages including SMIL, NCL (Nested Context Language) [1] are examples of standard languages for multimedia or hypermedia documents. A multimedia document consists of multimedia presentation scenarios that can interact with users. Multimedia authoring tools must be able to help designers to verify the occurrence of these errors [2]. While only text and photographs with small file sizes (and therefore low resolutions) could be used about ten years ago, multimedia presentations of high quality can now be seen. Currently, the use of multimedia presentation has been developed in interactive multimedia instead of static multimedia [3]. Interactive multimedia has been widely used in various fields such as education, games, and others[4]. However, because of the repetitive training of authoring tools, these rarely exist [5]. The efficient use of traffic for streaming multimedia needs to be considered in designing multimedia presentations and algorithms in optimizing real-time multimedia performance are needed in the process of creating multimedia documents [6, 7].

2. **Kernel Mechanism.** A multimedia document is a multimedia information repository containing multimedia objects and multimedia application models [8]. The multimedia document has the definition as "a computer product that contains communication and information by combining several media such as text, images, animation, sound, video, and interactive reality" [9]. Multimedia object models consist of the structure and behavior of multimedia objects. Initially, there are four kinds of conceptual models for interactive multimedia namely the Graphical Model, Object-Oriented Model, Language Base Model, and Temporal Abstraction Model. Several main issues about structured multimedia documents should be considered by the author for the development. The first issue is the development of conceptual models that can represent semantic multimedia objects and express a multimedia presentation. The second issue is the creation of a multimedia query language that is capable of manipulating various functions for multimedia objects but is simple in interacting with the author. The third issue is the ability of indexes and organizational techniques for multimedia data. The fourth is the development of efficient storage for managing real-time multimedia data. In Multimedia Authoring there is a term known as Kernel Mechanisms which is a process framework for authoring. The authoring environment is divided into four parts as shown in Figure 1.

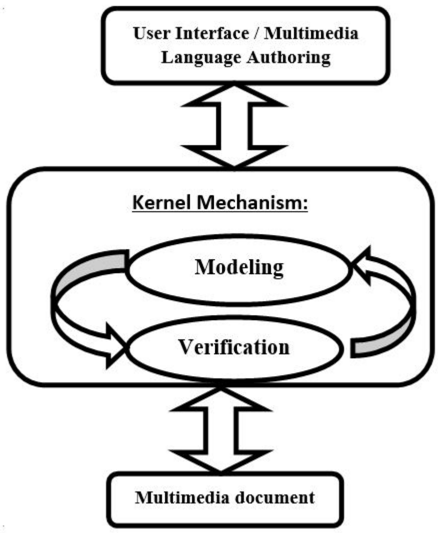

FIGURE 1. Kernel Mechanism

User Interface or Multimedia Language Authoring is a module that functions to interact with the author. An author can create a multimedia presentation through the interface provided. The input provided by an author can be in various forms such as temporal and spatial views. The input from the processor is processed by a system called Kernel Mechanism which consists of two parts namely Modeling and Verification. Models for Multimedia documents have many types, including Petri Nets and Hoare logic. In the Kernel Mechanism, there is also a verification process that functions to check if an error occurs. Modeling and Verification are not always in the form of two separate modules, some types of models are already contained intrinsically verification in the modeling algorithm. The result of the Kernel Mechanism process is a new multimedia document that is error-free [10].

The kernel mechanism has three main parts namely importing an existing presentation, Real-Time Synchronization Model (RTSM), and user interface. The user interface consists of spatial editing following the playback duration for each media object [11]. Authoring

Multimedia Modeling mostly uses Petri Net Model, Hoare Logic Model, and LOTOS. The advantages and disadvantages of theses models is defined in next section.

3. **Petri Net.** Petri Nets was developed by Carl Adam Petri in 1962. The Petri Nets is applied in various fields such as in Programming Languages, hardware, embedded systems, internet, telecommunications, computer networks, manufacturing, and e-commerce. Petri Nets deals with graphical aspects, not algebraic calculations. A Petri net is a group of directed arcs that connects places and transitions. Places stores tokens. Marking a Petri Net is assigning tokens to places as shown in Figure 2.

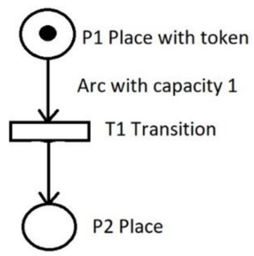

FIGURE 2. Petri Net

Arc by default has a capacity of 1, if the capacity of an arc is not 1 then the capacity will be written on the arc. Places by default have infinite capacity. Transitions have no capacity and do not store tokens at all. The rule is that the arc can only connect places to transitions and connect transitions to places. In 2005, Dick C.A. Bulterman wrote an article entitled Structured Multimedia Authoring, which discussed Graph-Based Paradigm in the form of flowchart models and directed graph models. In this article, it was discussed that Petri Net became the dominant paradigm that was widely used for multimedia authoring [12]. Original Petri Net can be modified for certain purposes. There are several additions and functions to the Petri Net graph that are performed for various purposes. The modification still uses three basic notations namely Place, Transition, and Arc.

3.1. **Real-Time Synchronization Model (RTSM).** In 1996, Chun-Chuan Yang and Jau-Hsiung Huang began to model for synchronized multimedia using a Petri net base called the Real-Time Synchronization Model (RTSM) [13]. Figure 3 is an example of RSTM for temporal layout.

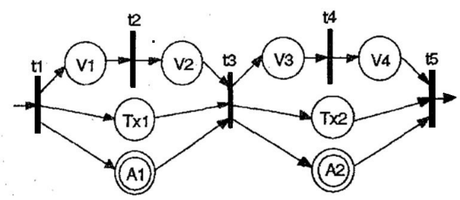

FIGURE 3. Example of Real-Time Synchronization Model

Definition for Figure 3:
Real-Time Synchronization Model is a seven-tuple (T,P,E,A,D,R,M)
Where:
T = { t1 , t2 , ... , tn } = Transitions

P = { pl , p2 , ..., pn } = Regular places
E = { el , e2 , ... , en } = Enforced places
S = P $\rightarrow$ E =Places
A: {T x S } $\rightarrow$ ST = Direction of Arc
D:S $\rightarrow$ Real number Time duration(places)
R: S $\rightarrow$ { r1 , r2 , ... , rk } = Media type
M: s $\rightarrow$ { 0 , 1 , 2 } = State of places
The place has the following possibilities:
0: no token
1: blocked token
2: unblocked token

The elements in RTSM are places, tokens, and transitions. Places used to represent media units (visual: video, image or picture, animation, text; non-visual: text) and media actions. Token has a value of 1 or 0 that represents the state of a place. A place has two states according to its token value. An active place will contain a token value of 1 while an inactive place will contain a token value of 0. An active token can be in two conditions, blocked token or not blocked token. Synchronization relationships on related places using transitions between places. At this time, RTSM is used for multimedia data transmission needs. In 2003, Chun Chuan Yang re-used the RTSM model inspired by the Petri Nets model to develop an Authoring System for SMIL Based Multimedia [6].

3.2. **Petri Nets model with non-deterministic event.** In 2008, Chun Chuan Yang developed a previous study into an Extension of Information base editing for Non- deterministic temporal behavior in Multimedia Authoring. This article uses the concept of a Dividable Dynamic Timeline. By using Dividable Dynamic Timeline (DDTL), the author can create interactive multimedia presentations with a convenient timeline display [14]. Based on these needs, the RSTM that was once developed by Chun Chuan Yang was modified into Object Composition Petri Net (OCPN) to anticipate real-time synchronization problems. In the Real-Time Synchronization model, there is a non-deterministic temporal behavior in the SMIL code that is marked by double circles that have a question mark "?". In this model, there are two types of non-deterministic events: splitting event and non-splitting event. An event is called a split event when the resulting event is removed into two separate parts of the model. Players must wait for the split event before they can continue playing the next presentation. For example in "Btn1.Click" and "Btn2.Click" models are non-splitting events and "Btn3.Click" are splitting events.

3.3. **Hierarchy SMIL Petri Net (H-SMIL Net).** In 2007, Abdelkader Belkhir conducted a study entitled "Formal Design of SMIL Document". The study examined the creation of a new formal based on the extended time Petri Nets named SMIL Net Modeling. In this study document verification was also carried out for temporal and hyper-temporal consistency [15]. In 2008, A. Belkhir and S. Bouyakoub conducted a study entitled "A Hierarchical Petri Net Model for SMIL Document". The study modeled SMIL with a hierarchical temporal extension in Petri Nets. The solution is named H-SMIL-Net for incremental authoring from SMIL Authoring [16].

H-SMIL Net was re-used by Samia Bouyakoub and Abdelkader Belkhir in 2011 in a study titled "SMIL Builder: An Incremental Authoring Tool for SMIL Document". In this study, the H-SMIL Net model is used in the kernel mechanism. H-SMIL Net model has advantages in abstraction that can provide many levels of abstraction. The ability of many levels of abstraction makes it easy for authors to create complex systems [17].

In 2012, Samia Bouyakoub and Abdelkader Belkhir conducted a study entitled "A Spatio Temporal Authoring Tools for Multimedia Document" that used the H-SMIL model, a temporal extension based on Petri Nets [10]. In this study, the Petri net is still being used, with the addition of SMIL document verification for spatial layouts. Spatial layout is verified if an error occurs, for example, a spatial conflict. Spatial conflicts often occur and reduce the quality of multimedia streaming or presentations. In Multimedia authoring, spatial conflict can occur when two or more visual media overlap with one another, especially when playing at the same time.

3.4. **Timed Petri Net.** S. Yovine, A. Olivero, and D. Monteverde (2010) conducted a study entitled "An approach for verification of the temporal consistency of NCL applications" base on the Petri Nets model. In this study, Petri Nets used are called Time Petri Nets (TPN) [18]. In the Time Petri Net (TPN) model, a slight modification was made to the original Petri Net. On the TPN the shape of the transition was changed to a box shape. The shape of the box has other functions besides being a transition that is as an event [19, 20].

3.5. **Petri Net with Fuzzy Logic.** Fuzzy logic can be used for processing multimedia components such as for various kinds of image processing. [21] T. Hrkac and S. Ribaric and conducted a study entitled "A model of fuzzy Spatio-temporal knowledge representation and reasoning based on high-level Petri nets" in 2012, in that study carried out modifications to Petri Net using Fuzzy Logic. Fuzzy logic is used in Spatio-temporal knowledge using Petri nets as the basis. FuSpaT which is a temporal and Spatio-temporal relation is a representation of knowledge in the fuzzy logic used. [22]. A token in a fuzzy Spatio-temporal Petri Net graph is converted into a Spatio-temporal token which has two functions. The main function is a state marker of the modeled system and additional functions as a carrier of Spatio-temporal information. The token is named PeNeFuST (Petri Net with fuzzy Spatio-temporal tokens). Spatio-temporal information on tokens is based on the p-space-timed model. Space-time network model information is the duration of an action or state and information on changes in spatial position in each place.

4. **Hoare Logic.** Hoare Logic (also called Hoare rules or Floyd-Hoare Logic) was introduced by Tony Hoare in 1969 a British computer scientist. Hoare Logic can be used as a model of Multimedia Presentation. Hoare rules are the basic parts of a program before it becomes a complex program. Hoare logic is a formal system that can verify the correctness of a computer program using a set of logical rules. Hoare Logic has the main function called Triple Hoare which displays the execution of programming code that changes the computational state. The form of a triple Hoare is:

$$\{P\}C\{Q\} \tag{1}$$

Where:
Q and P are assertions.
C is the command

Assertions are formulas in predicate logic. P is called precondition and Q is called post-condition. When precondition is fulfilled, an execution will occur to calculate the post-condition. In Hoare logic, there are axioms and inference rules that function to form imperative programming languages. Axioms and inference rules in Hoare logic include:

- Axio of Assignment

$$P[x/E] := E \tag{2}$$

The notation explains that in P, the existence of x can be replaced by the expression E. Post condition of this rule is that P with the state x has been replaced by E.

• Rule of Consequences

$$\frac{P' \to P, \{P\}S\{Q\}, Q' \to Q}{\{P1\}S\{Q'\}} \tag{3}$$

This rule shows that precondition P can be strengthened as indicated by the notation P' → P and postcondition Q can be weakened which is indicated by the notation Q → Q'. The notation shows that the left side of the operator → is stronger than the right side. This rule is commonly used for identical post-conditions for the then and the else parts.

• Rule of Composition

$$\frac{\{P\}S\{Q\}, \{Q\}T\{R\}}{\{P\}S;T\{R\}} \tag{4}$$

This rule applies to sequential S and T programs. In the notation, it is seen that if precondition P is executed then S produces post-condition Q. Q is preconditioned for T, and after execution will produce post-condition R. Briefly that precondition P will be executed by S and T sequentially producing post-condition R.

• Rule of Conditional

$$\frac{\{B \wedge P\}S\{Q\}, \{\neg B \wedge P\}T\{Q\}}{\{P\}S;T\{R\}} \tag{5}$$

This rule applies to programs that are executed if certain conditions are met. In this example, B states the condition and P as the precondition. If condition B is met then S will be executed and if condition B is not met then T will be executed to produce post-condition Q.

• Rule of Iteration

$$\frac{\{P \wedge B\}S\{P\}}{\{P\}\ while\ B\ do\ S\ done\ \{\neg B \wedge P\}} \tag{6}$$

This rule applies to programs that contain iteration or repetition for certain conditions. In the notation, B states the condition as a benchmark for iteration and P as a precondition. If condition B is fulfilled then S will be executed repeatedly to produce post-condition P until condition B is no longer met.

4.1. **Rule Validation.** Hoare logic can be implemented as a model for multimedia presentation documents. P and Q are assertion languages used to express the precondition and post-condition of the temporal aspects of a media [23]. Table 1 and Table 2 are functions and abbreviations used in assertions [24].

TABLE 1. Functions of assertion language P and Q

Function	**Condition**	**Description**
Tcr: I → R	Precondition	Returns instant time value of an element
dur: I → R	Precondition	Returns value of a media playing duration
Times:(ε×(I∪{⊥}))→R*	Precondition	Returns sequence of all instant times when an event occurs
begin: I → R	Post-condition	Returns value of the instant time of the media started
end: I → R	Post-condition	Returns instant time value of the media ended

Table 2. Abbreviation for assertion language

Abbreviation	**Description**
Begin B(c)	means t if{begin(c) = t } ⊆ B
End B(c)	means t if{end(c) = t } ⊆ B
media	continuous or static
Continuous	Video or audio or animation
Static	Text or image or brush
Indefinite(time)	Holds if time is indefinite
Cmd	Media or seq or par or excl
Finite(time)	Holds if time is real

4.2. **Hoare Logic Rules Enrichment.** The rules in Hoare logic can be added according to the needs and objectives of making models using Hoare logic. F. Mekahlia, A. Ghomari, S. Yazid, and D. Djenouri enriched the Hoare logic rules to verify temporal inconsistencies in the Multimedia document [25].

5. **LOTOS.** LOTOS stands for Language of Temporal Ordering Specifications and it is a formal description technique [26]. ISO standardized LOTOS which is an extension of a multiway synchronization mechanism [27, 28]. Timed Lotos (T-LOTOS) and Enhanced Time Lotos (ET-LOTOS) were developed by the University of Liege, Belgium. RT-LOTOS is similar to ET-LOTOS with a slight difference. RT-LOTOS is an improved technique from LOTOS with the addition of operators such as delay, time restriction, and latency.

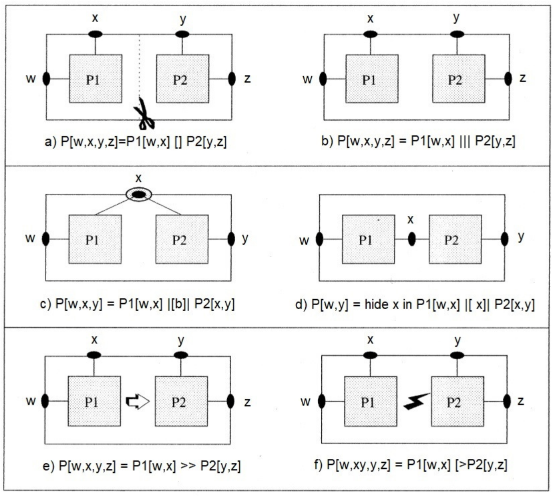

Figure 4. Basis LOTOS Operators [27]

LOTOS is a system that can specify relations between objects. LOTOS is a process that can consist of several sub-processes. LOTOS uses the black box paradigm to specify a complex system. There are 6 basic operators of LOTOS as shown in Figure 4 [27].

5.1. **Enhanced Time Lotos (ET-LOTOS).** Enhanced Time LOTOS (ET-LOTOS) is a LOTOS that allows the modeling of time-sensitive systems. The time value in ET-LOTOS is a set of value data denoted by D. D is a sequential set of data for example [4, 6, 12]. The value of the time domain must be discrete [29].

5.2. **Real Time Lotos (RT-LOTOS).** RT-LOTOS (Real-Time Lotos) is an analysis of two subtypes of LOTOS: LOTOS-T and Timed Lotos. RT-LOTOS is also a development of ET-LOTOS. ET-LOTOS and RT-LOTOS have similarities in the non-urgency assumptions of action. The difference between the two LOTOS subtypes: ET-LOTOS and RT-LOTOS are related to the time latency. A non-deterministic delay can be represented differently by RT-LOTOS. The solution to a new latency operator is better represented by RT-LOTOS than ET-LOTOS [27, 30]. Models of multimedia are an important part of the interconnect layer in the delivery of streaming data [31]. Real-time streaming data is very dependent on the bandwidth, latency and availability of the network, and it is influenced by the multimedia model used [32].

6. **Summary.** Designing multimedia presentations can be created using a tool called Multimedia Authoring Tool. Most of Multimedia Authoring tools use the Petri Nets Model, the Hoare Logic Model, and the LOTOS Model. Petri Nets is a model of Multimedia Authoring that is widely used. Petri Nets uses a model developed since 1962. The Petri Net model uses graph calculations consisting of places, transitions, tokens, and arcs. Tokens will be fired from one place to another place that is separated by a transition. Petri Net has several modifications, including Real-Time Synchronization Model (RTSM), Petri Nets model with non-deterministic events, Hierarchy SMIL Petri Net (H-SMIL Net), Timed Petri Nets (TPN), and Petri Net with Fuzzy Logic.

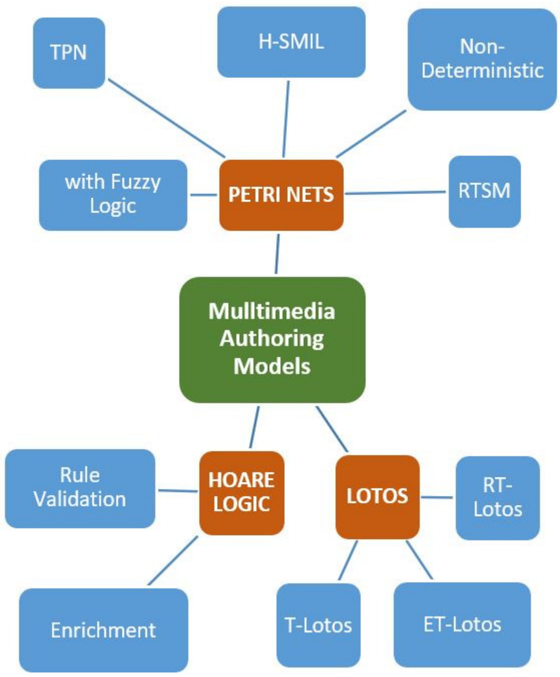

Figure 5. Multimedia Authoring Models

Hoare Logic uses a model that was developed since 1969. Hoare Logic uses mathematical logic to model Multimedia Authoring. The basis of Hoare logic is Triple Hoare which consists of P (assertion), C (Command), and Q (assertion). Hoare logic has several modifications, including Rule Validation, Hoare Logic Rules Enrichment. Language of Temporal Ordering Specification is a model of multimedia authoring in the form of a formal specification language. LOTOS is based on the temporal ordering of events. LOTOS is used as a communication protocol in the International Organization for Standardization Open System Interconnection Model (ISO – OSI). LOTOS became the ISO 8807 standard in 1989. LOTOS is a system capable of specifying the relation between objects. LOTOS has several modifications including Timed Lotos (T-LOTOS), Enhanced Time Lotos (ET-LOTOS), and Real-Time Lotos (RT-LOTOS). Figure 5 shows the models of Multimedia authoring which are summarized from various existing studies. Table 3 shows the authors and existing studies related to each model.

Table 3. Functions of assertion language P and Q

Multimedia Authoring Model	**Modification**	**Author(s)**
Petri Net	-	[12]
	RTSM	[11, 13]
	Non-deterministic	[14]
	H-SMIL	[10, 15, 16, 17]
	TPN	[18, 19, 20]
	With Fuzzy	[22]
Hoare Logic	Rule Validation	[23, 24]
	Enrichment	[25]
LOTOS	ET-LOTOS	[29]
	RT-LOTOS	[27, 30]

Each model of the Multimedia Authoring Model can be modified for specific purposes, such as in the studies discussed in this literature study. The development of modifications of these models can be further developed in the future.

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REFERENCES

[1] J. A. F. Dos Santos, D. C. Muchaluat-Saade, XTemplate 3.0: Spatio-temporal semantics and structure reuse for hypermedia compositions, *Multimedia Tools and Applications*, vol. 61, no. 3, pp. 645-673, 2012.

[2] D. Picinin, J. M. Farines, C. A. S. Santos, C. A. Koliver, Design-oriented method to build correct hypermedia documents, *Multimedia Tools and Applications*, vol. 77, no. 16 , pp. 21003-21032, 2018.

[3] I. Kazanidis, G. Palaigeorgiou, A. Papadopoulou, A. Tsinakos, Augmented interactive video: Enhancing video interactivity for the school classroom, *Journal of Engineering Science and Technology Review*, vol. 11, no. 2, pp. 174-181, 2018.

[4] S. Goumas, G. Terzopoulos, D. Tsompanoudi, A. Iliopoulou, Wordsearch, An Educational Game in Language Learning, *Journal of Engineering Science and Technology Review*,vol. 13, no. 1, pp. 50-56, 2020.

[5] B. Meixner, H. Kosch, Interactive non-linear video: Definition and XML structure, *In DocEng 2012 - Proceedings of the 2012 ACM Symposium on Document Engineering*,pp. 49-58, 2012.

[6] R. Vijayarani, L. Nithyanandan, Dynamic slot-based carrier scheduling scheme for downlink multimedia traffic over LTE advanced networks with carrier aggregation, *Turkish Journal of Electrical Engineering and Computer Sciences*, vol. 25, no. 4, pp. 2796-2808. 2017.

[7] H. A. M. Ramli, Z. I. Rizman, Novel scheduling algorithm for optimizing real-time multimedia performance in Long Term Evolution-Advanced, *Turkish Journal of Electrical Engineering and Computer Sciences*, vol. 25, no 1, pp. 247-253. 2017.

[8] M. C. Wijaya, Z. Maksom, M. H. L. Abdullah, Brief of Review: Multimedia Authoring Tool Attributes, *Ingénierie des Systèmes d'Information*,vol. 26, no. 1, pp. 1-11, 2021.

[9] Y. Belhadad, A. Refoufi, P. Roose, Spatial reasoning about multimedia document for a profile based adaptation: Combining distances, directions and topologies, *Multimedia Tools and Applications*, vol. 77 no. 23, pp. 30437-30474. 2018.

[10] S. Bouyakoub, A. Belkhir, A Spatio-Temporal Authoring Tool for Multimedia SMIL Documents, *International Journal of Multimedia Technologies*, vol. 2, no. 3, pp. 83-88, 2012.

[11] C. C. Yang, Y. Z. Yang, SMILAuthor: An Authoring System for SMIL-Based Multimedia Presentations, *Multimedia Tools and Applications*, vol. 21, no. 3, pp. 243-260, 2003.

[12] D. C. A. Bulterman, L. Hardman, Structured Multimedia Authoring, *CM Transactions on Multimedia Computing, Communications and Applications*, vol 1, no 1, pp. 89-109, 2005.

[13] C, Yang, J. Huang, A Multimedia Synchronization Its Implementation in Transport, *IEEE Journal on Selected Areas in Communication*, vol. 14, no. 1, pp. 212-225, 1996.

[14] C. Yang, C. K. Chu, Y. C. Wang, Extension of Timeline-based Editing for Non-deterministic, *Journal Of Information Science and Engineering*, vol. 24, no. 5, pp. 1377-1395, 2008.

[15] A. Belkhir, S. Bouyakoub, Formal design of SMIL documents, *In Webist 2007 - 3rd International Conference on Web Information Systems and Technologies Proceedings*, pp. 396-399, 2007.

[16] S. Bouyakoub, S., A. Belkhir, H-SMIL-Net: A hierarchical Petri Net model for SMIL documents, *In Proceedings - UKSim 10th International Conference on Computer Modelling and Simulation*, pp. 106-111, 2008.

[17] S. Bouyakoub, A. Belkhir, SMIL builder: An incremental authoring tool for SMIL documents, *ACM Transactions on Multimedia Computing, Communications and Applications*, vol. 7, no. 1, pp. 1-30, 2011.

[18] S. Yovine, A. Olivero, L. Córdoba, An approach for the verification of the temporal consistency of NCL applications, *In Proceeding of Simposio Brasileiro de Sistemas Multimedia e Web (WEBMEDIA)*, pp. 179-184, 2010.

[19] G. Gardey, O. H. Roux, O. F. Roux, State space computation and analysis of Time Petri Nets, *Theory and Practice of Logic Programming*, vol. 6, no. 3, pp. 301-320, 2006.

[20] B. Berthomieu, F. Vernadat, State space abstractions for time petri nets, *Handbook of Real-Time and Embedded Systems*, pp. 30-31, 2007.

[21] T. N. Tu, A fuzzy approach of large size remote sensing image clustering, *Journal of Information Hiding and Multimedia Signal Processing*, Vol. 11, No. 4, pp. 187-198, 2020.

[22] S. Ribaric, T. Hrkac, A model of fuzzy spatio-temporal knowledge representation and reasoning based on high-level Petri nets, *Information Systems*, vol. 37, no. 3, pp. 238-256, 2012.

[23] O. Gaggi, A. Bossi, Analysis and verification of SMIL documents, *Multimedia Systems*, vol. 17, no. 6, pp. 487-506, 2011.

[24] A. Bossi, O. Gaggi, Enriching SMIL with assertions for temporal validation, *In Proceedings of the ACM International Multimedia Conference and Exhibition*, pp. 107-116, 2007.

[25] F. Z. Mekahlia, A. Ghomari, S. Yazid, D. Djenouri, Temporal and Spatial Coherence Verification in SMIL Documents with Hoare Logic and Disjunctive Constraints: A Hybrid Formal Method, *Journal of Integrated Design and Process Science*, vol. 20, no. 3, pp. 39-70, 2017.

[26] M. C. Wijaya, Z. Maksom, M. H. L. Abdullah, Two Verification Phases in Multimedia Authoring Modeling, *Journal of information and communication convergence engineering*, vol. 19, no. 1, pp. 42-47, 2021.

[27] J. P. Courtiat, C. A. S. Santos, C. Lohr, B. Outtaj, Experience with RT-LOTOS, a temporal extension of the LOTOS formal description technique, *Computer Communications*. vol.23, no. 12, pp. 1104-1123, 2000.

[28] L. Logrippo, M. Faci, M. Haj-Hussein, An introduction to LOTOS: learning by examples, *Computer Networks and ISDN Systems*, vol. 23, no. 5, 325-342, 1992.

[29] L. Léonard, G. Leduc, An introduction to ET-LOTOS itive systems for the description of time-sens, *Computer Networks*, vol. 29, no. 3, pp. 271-292, 1997.

[30] P. N. M. Sampaio, J. P. Courtiat, An approach for the automatic generation of RT-LOTOS specifications from SMIL 2.0 documents, *Journal of the Brazilian Computer Society*, vol. 9, no. 3, pp. 39-51, 2004.

[31] M. A. Belhamra, E. M. Souidi, An Information Hiding Scheme for Live P2P Streaming Based on the R2 Protocol, *Journal of Information Hiding and Multimedia Signal Processing*, vol. 12, no. 2, pp. 102-115, 2021.

[32] J. Zhai, H. G. Zhao, Q. Jie, X.D. Xie, Computational Resource Constrained Deep Learning Based Target Recognition from Visible Optical Images, *Journal of Information Hiding and Multimedia Signal Processing*, vol. 9, no. 3, pp. 558-566, 2018.