Fuzzy Logic Control Based Adaptive Media Playout Design Approach for Video Streaming

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Abstract- Adaptive media playout (AMP) control, common receiver-based technique, is proposed to adjust the playout rate based on the bit-rate fluctuation of network channels to avoid playout interruptions. Most AMP techniques found in the literature adjust playout frame rate based on the buffer fullness or the buffer fullness variation. However, choosing an appropriate threshold to adjust a playout frame rate is challenging due to fluctuation in the channel's quality and its unpredictable video bitrate. In this research, a new AMP control, based on fuzzy logic control, is proposed as a solution to avoid video stream interruption and the challenge of choosing an appropriate threshold. The new Fuzzy Logic Adaptive Media Playout (FLAMP) control is designed based on buffer fullness and its variation. The FLAMP is expected to constrict the buffer outage probability and improve the video playback smoothness.

Keywords—adaptive media player, frame playout rate, buffer fullness, channel quality, fuzzy AMP inference engine

I. INTRODUCTION

Multimedia streaming is extensively applied in an online Internet video, Internet Protocol Television (IPTV), and mobile TV services [1], [2]. A video stream is sent in a continuous manner of data packets to the participants. As a result, the video stream could be watched immediately and would not need to be downloaded. However, network delay, delay jitter and packet loss due to network quality degradation seriously affect the quality of service (QoS) of video streaming [3].

Consequently, lots of techniques have been proposed to handle the fluctuation of network quality that causes interruption for video streaming. In [4], the researchers proposed that the sender adapted the video stream rate based on the current channel condition. The frame transfer, including the decision of discarding some frames, could be scheduled based on the network fluctuation. However, in certain scenarios same video content are multicast to multiple clients. Meanwhile, the server has to distribute the video stream to multiple devices and may be unable to adapt easily to the stream rate of the server because each may experience different channel quality [5].

In other conditions, client-side data buffering technique is commonly employed to handle network bandwidth variations. Typically the buffer is used to protect the video stream rate from short-term variations. Although the effects of dynamic network channel, packet loss and delay jitter, is reduced, the playout delay is increased and additional memory is needed [6]–[8].

Adaptive Media Playout (AMP) gives the receiver ability to reduce the buffered data. Therefore, playout delay is reduced to achieve a playout reliability [9]. Essentially, the rate is adjusted at which the video stream is played back according to the buffer fullness condition. In general, when the level of buffer fullness is less than the desired level, the video frame rate is dropped to reduce data consumption. In contrast, the playout frame rate is speeded up when the buffer fullness level exceeds the desired level. Adjusting the playout frame rate using AMP technique decreases initial buffering delay without sacrificing playout reliability [9]. Unfortunately, there are drawbacks with the existing techniques, the hence motivation for this research. These weaknesses will be mentioned in next sections.

In this paper, a new Fuzzy Logic Adaptive Media Playout (FLAMP) control is designed for video streaming. The FLAMP is used to eliminate buffer outage (underflow/ overflow), and playout speed degradation by adopting the appropriateness of Fuzzy logic control concepts to the dynamic behavior of network traffic environment without a need for a precise mathematical model of the network channel congestion. The proposed FLAMP is designed to control buffer usage condition based on two crucial network parameters, namely network channel quality, and playout frame rate.

The rest of this paper is organised as follows: section II delineates the background of AMP techniques; section III gives background about fuzzy logic control; section IV clarifies the design approach of FLAMP; section V presents the FLAMP technique objectives and section VI draws conclusions are made in.

II. AMP TECHNIQUE BACKGROUND

Adaptive Media Playout (AMP) permits the receiver to pre-roll fewer data and, hence, the playout delay is reduced for achieving a playout reliability [9]. It regulates the playout rate to compensate the fluctuation of network bandwidth. Based on the literature, AMP control is triggered based on buffer fullness, buffer fullness variation, and hybrid, buffer fullness variation related to buffer fullness.

AMP buffer fullness control techniques are adjusted the playout frame rate based on the buffer occupancy which reflects the network channel status [9]–[12]. Fundamentally, two thresholds, High and Low, are set to control the playout frame rate. The playout controller adjusts the frame rate consumption based on the number of buffered frames. When the buffer fullness exceeds high threshold value, the playout frame rate is increased. In contrast, when the buffer fullness is less than low threshold value, the playout frame rate is reduced.

The challenge of the AMP buffer fullness control techniques is to select an appropriate threshold value for adjusting playout frame rate. Selecting the buffer fullness threshold value is a challenge due to the unpredictability of network quality and video bitrate. Setting buffer fullness threshold value very high causes unnecessary adjustment for playout frame rate even the buffer fullness is far from the outage. The visual quality will be easily degraded and cause playout rate fluctuation. On the contrary, if the threshold value is too low, the playout frame rate control has a very short time to react in avoiding buffer outage.

On the other hand, the AMP buffer fullness variation control techniques adjust the playout frame rate based on the variance of buffer fullness which reflects the difference between the playout frame rate and the expected receiving rate [13]–[15]. The receiving buffer is monitored and the playout rate control is activated when the buffer fullness variation is larger than a given threshold value. Even though the playout smoothness and playout speed adjustment degradation are considered, the probability of buffer underflow is higher especially when the buffer level was not precisely considered. Furthermore, its playout rate adaptation is not satisfied or optimum due to the difficulty of the channel quality prediction, especially for wireless networks.

Apart from that, Hybrid AMP control techniques use buffer fullness and its variation to trigger playout rate adjustments [16], [17]. By observing the buffer fullness and its variation, an AMP technique based on underflow probability estimation is conceived in [16]. The probability of buffer underflow is estimated based on buffer fullness variation and achievable buffer fullness. When the average queue length reduction is greater than the achievable average reduction, the probability of buffer underflow is high after N time slots. In [17] a statistical model is proposed to estimate the time of buffer underflow. The technique's concept is based on the ability of buffered data to compensate the network channel fluctuation and variation of video bitrate. Actually, two thresholds, H_1 and H_2 where ($H_1 > H_2$), are selected empirically at the beginning. The estimated underflow time is compared with thresholds, if it is larger than H_1; the probability of buffer underflow is very small. Conversely, the probability of buffer underflow is high if it is less than H_2. Otherwise, the buffer fluctuates and the playout rate is adjusted according to the motion of video. Even though the buffer outage and playout smoothness are considered in these AMP techniques, the likelihood of buffer outage is high exactly when the buffer fullness is not safe enough.

III. FUZZY LOGIC CONTROL BACKGROUND

Fuzzy Logic technique is a subset of computational intelligence [18]. The concept of fuzzy logic is based on emulating the human thinking and the natural language in a way much appropriate than traditional logical systems. Furthermore, approximate values' ambiguous data are accepted to give the fuzzy logic control more flexibility than the other tradition logical control. It is more flexible than the traditional logic which allows generalization of conventional logic and provides for terms between [T, F], like (nearly true) or (incompletely false).

An intelligent system (IS) is a system that simulates some features of intelligence exhibited by nature. These include robustness across problem domains, enhancing efficiency, flexibility, extrapolated reasoning, learning, information compression [19].

Fuzzy control affords an official methodology to represent, manipulate, and implement a human's heuristic knowledge about how to control a system. One of the important application fields of fuzzy logic is the design of the fuzzy logic controller.

Mamdani method is the popular fuzzy inference technique [20]. A set of fuzzy rules is applied and supplied by experienced human operators. The main components of the fuzzy logic controller are a fuzzification process, a rule base, a database, a decision-making unit, and lastly a defuzzification process, as demonstrated in Figure (1). The function of each block is as follows: Knowledge base which contains two units; a *rule base unit* containing a number of fuzzy IF–THEN rules, and a *database unit* which defines the membership functions of the fuzzy sets used in the fuzzy rules.

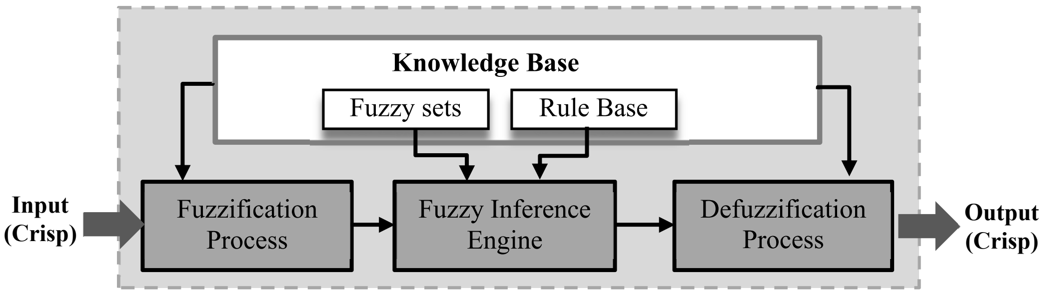

Fig. 1. Fuzzy inference system

In order to permit machines to handle ambiguous language input such as 'very high', the crisp input and output must be changed to linguistic variables with fuzzy components. For example, to control buffer fullness, the buffer fullness and the playout frame rate variables have to be changed to the related linguistic variables such as [V.High, High, Medium, Low, and V.Low].

The first step is the Fuzzification. The control rules are combined with the Membership Functions to derive the control output, and organise those outputs into a table called the lookup table. The control rules, which are related to a human being's intuition and feeling, represent the essence of the fuzzy inference process. For instance, if the buffer fullness is very low, the playout frame rate should be reduced, which is a human being's intuition.

The second step is the rules evaluation. Actually, the input variables obtained in the previous step are assessed by applying them to the system rules. After each step is processed, the consequential part of each rule is assessed by obtaining the membership degree of the output variables. When the system rules are discovered, all the system rule parts are calculated using the fuzzy set operations [21], [22]. Based on the results of the preceding rules, the membership degree for every output linguistic rule is carried out.

The third step is to aggregate the output of all system rules into a single output. The combination of the system rules' result into a single output result, which is called the single fuzzy set, is achieved in this step. The list of membership values for the output consequent system rules will be combined to get a fuzzy set for every output variable.

The fourth step is called defuzzification. A control output should be selected from the last step based on the current inputs. Further, the control output should be changed from the linguistic variable to the crisp variable, and then to the control operator. The Center Of Gravity (COG) method is the common defuzification technique, which objects to figure out the point located in the middle of the fuzzy set for each output linguistic [22]. Formally, the COG is defined according to next equation:

$$COG = \frac{\sum_a^b F_S(S) \times S}{\sum_a^b F_S\,(S)} \qquad (1)$$

IV. RESEARCH DESIGN APPROACH

This paper proposes a new AMP technique; namely, Fuzzy Logic Adaptive Media Playout (FLAMP), as illustrated in Figure 2 below. Unlike existing methods, the technique does not rely on certain parameter settings. Rather, it employs a Fuzzy Inference Process (FIP) as buffer outage adaptor. The playout frame rate is adjusted by the output of FIP for two input linguistic variables (buffer fullness B_{LVL}, buffer fullness reduction B_{var}), which reflects the network channel status.

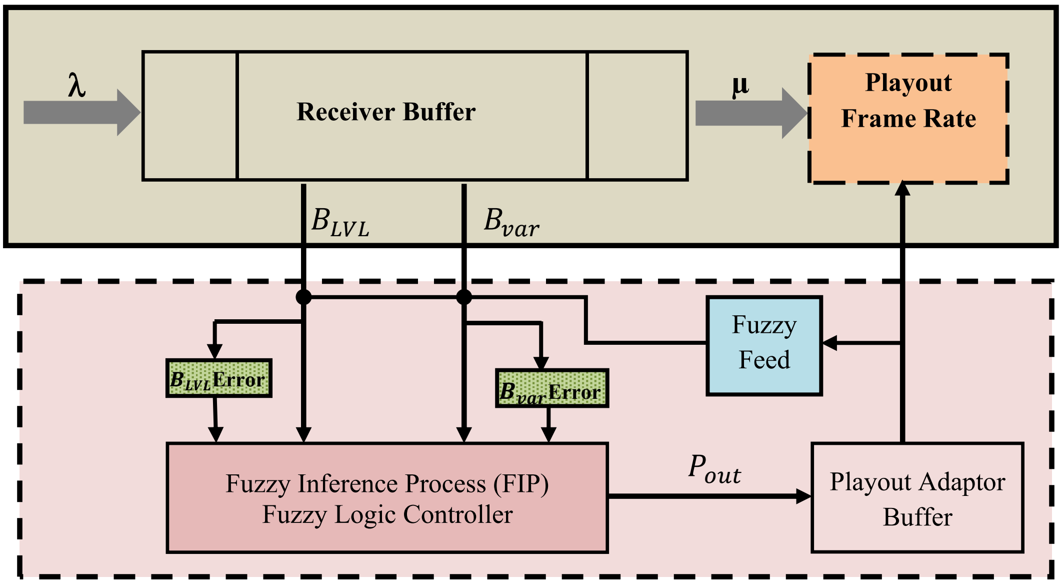

Fig. 2. The proposed FLAMP Technique

The proposed technique, FLAMP, integrates fuzzy logic control with AMP technique to tuning the buffer fullness into target level and avoids buffer outage. Unlike existing techniques of adaptation rate control, the use of thresholds in its underlying buffer is eliminated by using fuzzy logic control. The FIP, which is the core component in the FLAMP technique, gets two input variables (B_{LVL}, B_{var}) to give a single output variable (Playout variation P_{out}) at any time of playout packet from the receiving buffer in FLAMP technique.

The proposed FLAMP method, as illustrated in Figure 3, is implemented in five steps. The first step is initialization.

The parameters setting are initialized as the receiver buffer receives the first packet of the video stream and pre-rolling period starts.

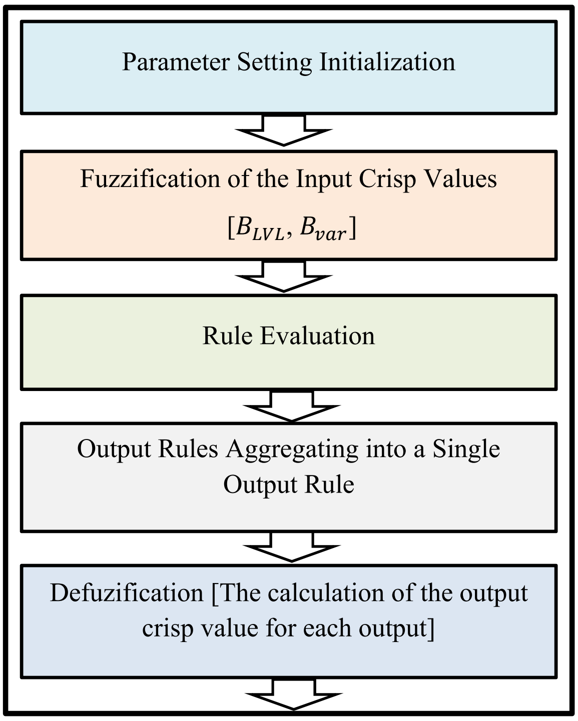

Fig. 3. The implementation steps of the proposed FLAMP method

The second Step is the Fuzzification of the Input Crisp Values. The crisp inputs (B_{LVL} and B_{var}) are taken to determine the degree of these inputs using their appropriate fuzzy sets. Figure 4 illustrates input and the output linguistic variables for the following fuzzy sets in FLAMP:

B_{LVL} = {V.Low, Low, Normal, High, V.High}

B_{Var} = {Negative, Normal, Positive}

P_{out} = {V.Slow, Slow, Normal, High, V.High}

Fig. 4. Input and output linguistic variables fuzzy set for FL-AMP

Each linguistic variable is chosen based on the variable behavior. For example, if B_{LVL} input linguistic variable is Low, this means buffer fullness level is low and buffer outage will occur faster. In the case B_{avg} input linguistic variable is Negative; it means the playout frame rate is faster than the frame arrival rate.

The third step is the evaluation of the proposed FLAMP rules. The fuzzified inputs (B_{LVL} and B_{avg}) are applied to the antecedents of the fuzzy rules. The fuzzy operator (AND or OR) is used to obtain a single number of the input values which represents the result of the antecedent evaluation.

The fourth step aggregates all the output rules into a single output rule. The membership functions of all previous consequent rules are scaled and combined into a single fuzzy set. Thus, the list of scaled consequent membership functions are aggregated to obtain the fuzzy set for each output variable.

The fifth step of the proposed FLAMP method is the defuzification of the aggregate output fuzzy set. As mentioned before, the Center Of Gravity (COG) method is used for defuzification. Thus, the result of defuzzification process is the crisp output (P_{out}) which is applied to the proposed FLAMP to make a decision for adaptation a new frame rate.

V. FLAMP TECHNIQUE OBJECTIVE

Generally, the first aim of FLAMP is to avoid the receiver buffer from being in buffer outage status, (underflow or overflow), which causes distortion and interruption for video streaming playback. Another aim of the proposed FLAMP is to improve the performance of video streaming in terms of the smoothness. The main objective of FLAMP is to optimize the usage of the receiver buffer and prevent buffer in being outage status.

In addition, this research optimizes video streaming in terms of continuity of playback smoothness, distortion of the video playout and video playback interruption. The FLAMP will yield better performance compared to existing AMP techniques considering the aforementioned issues.

VI. CONCLUSIONS

In this paper, a new fuzzy logic control methodology that is fused with AMP technique is presented as FLAMP. A linguistic interpretation of the system behavior is used to keep the fuzzy knowledge base design more simple. The expected outcomes are represented by a successful result for intra-media synchronization by estimation buffer outage and playout speed degradation using Fuzzy Logic control. Our research for tuning Fuzzy Logic control seeks to achieve many desirable properties, like the smoothness of adjusting playout rate, reduction of buffer outage occurrence, reducing of interruption time and fast system response.

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