A Case Study on Merging Strategies for Authoring QoE-based Adaptive Hypermedia

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Abstract. This paper describes recent work on *strategy merger* development in the authoring process of adaptive hypermedia. The goal of a merging strategy is to break a complex adaptation decision into a number of simpler ones which may be reused more easily and applied in different orders. To demonstrate the proposed method we present an example case study and sample strategies written in the LAG language. The case study is based on a recently proposed model for Quality of Experience in e-learning. This model exposes the complex interaction between a number of factors affecting QoE and hence presents a good candidate for the application of a strategy merger. Finally some evaluation points are identified, a conclusion is drawn and next steps are outlined.

Keywords: LAG; Quality of Experience; Quality of Service; Multimedia Learning; Educational Adaptive Hypermedia; Adaptation; Strategy merger.

1 Introduction

Where does the need of adaptive strategy merger and meta-strategies appear in adaptive hypermedia systems, especially in relation with the term 'Quality of Experience'? We will briefly answer this question here and provide more detailed answers in the following sections.

Learner satisfaction and learning outcome can be summarized as the *Quality of Experience (QoE)* of the learner. The Quality of Experience of the learner will influence strongly any future learning decisions [5]: Will the student continue to enthusiastically interact with this system; will they continue, but with an increasing sense of frustration; or will they give up entirely in their learning effort? It has long been established, that it is particularly difficult to maintain student engagement with e-learning systems [1] and thus it is essential to maximise learner QoE wherever possible. Improvement of the QoE can be achieved in many ways, one of which is through an adaptation of material to maintain student interest, and maximise the quality of the material presented to them. We will consider two aspects of adaptation that may be used to improve the student QoE: *Quality of Service (QoS)* and *Media Mix*. Quality of Service is a term used in computer networking, and refers to the network parameters in data transfer, such as bit rate, delay, jitter, and their impact on quality of data delivery. [14] A simplistic assumption would be that an increase of QoS immediately results in an increase of QoE [7]. However, many other factors also

impact on QoE [13], and research on the optimal balance is ongoing. By Media Mix we refer to the learning process supported by multimedia content: instead of presenting all the learning material in a single format, a number of formats (text, image, video, interactive) are used. Such learning has been shown to lead to better outcomes than one-media learning [10].

The trade-off between multimedia mix and QoS optimisation requires a complex adaptation which can lead to an equally complex adaptation strategy. This complexity limits the reusability of such a strategy. One way to enable the reuse of adaptive strategies is to break down large and complex strategies into *smaller modular strategies* which can be reused in different orders or in different combinations with other strategies to produce intelligent adaptation.

This paper outlines how to break down complex adaptation settings or a complex adaptation strategy into reusable parts triggered by a meta-strategy, and demonstrates this using the example of the QoE adaptation strategy.

The overall objectives of this paper are thus to:

1. *demonstrate a method to break down large strategies into reusable modular strategies.*
2. *demonstrate how these modular strategies can be combined efficiently via meta-strategies.*
3. *demonstrate how this would benefit authoring situations as outlined in the scenario.*

The case study in Section 2 outlines a motivation scenario, gives a short overview of work related to Quality of Experience (QoE), and describes the authoring process for complex adaptation, concluding with a QoE strategy overview. Section 3 gives the technical description, presents adaptation strategies for QoS and a media mix, discusses reuse and combination of adaptation strategies. The section closes with an example how to create reusable modular strategies using the case study. Section 4 discusses the methods presented and outlines how they can be evaluated. Finally we present conclusions and future work in Section 5.

2 Case Study

In this section we describe a course scenario, the theoretical background for the QoE model, the authoring process for such a course and an adaptation strategy.

2.1 Motivating Scenario

The following scenario demonstrates the need for QoS and media mix-based adaptive e-learning from the perspective of the learner, and the challenges it causes for the authoring process.

The learner perspective. Father Ted lives on the remote Craggy Island off the west coast of Ireland. He has decided he needs to learn German to keep up with current events in Rome, but access to face-to-face classes in higher education or professional training is very difficult if not impossible. So he signs up for an on-line

class. Although he does not have the most stable and powerful Internet connection, he still enjoys the course. The course provides a mix of different materials and activities and a variety of videos, audio clips or illustrated text. Materials are easy to access at all times and he enjoys the course so much, he often finds himself spending more time than originally planned.

On a trip to a meeting he runs into a colleague who lives in Dublin, who has an excellent broadband connection, and who also signed up for the course. They are very surprised when they compare their experiences and realize that they both learned the same, found the course equally enjoyable, but were not necessarily presented with identical material. Ted cannot remember all of the videos his colleague mentions, but he on the other hand recalls some very interesting audio clips his colleague seemed to have missed. Nevertheless they both enjoyed the course a lot, because:

- they both reached their learning goals.
- they did not run into problems with excessively long download times of material.

Discussion: The *QoS* aspect is present in the different types of media presented to the two learners, supporting the same set of learning goals. The *media mix* aspect is present in the variety of media the content is presented in.

The author perspective. Professor X prepares a new online German course for international students. She received a lot of feedback from previous students, mainly regarding two aspects that strongly affected their learning experience:

- Due to bad internet connections, for some students the course was not always accessible or only with considerable delay.
- Students were asking for more variety in the presentation of material, to avoid monotony.

She decides to write two new adaptation strategies, one taking network conditions into account and the other one considering a mix of different media formats.

She starts authoring the course in MOT [2] and when she makes a test run, she soon notices that the strategies do not run together very well. She sits down again and spends a lot of time writing a strategy that combines the two aspects. Finally she has the course running, but she is not able to use the strategies individually in the future.

Discussion: In this kind of setting we discuss how meta-strategies can support the combination of different strategies, using the example of Quality of Experience (QoE) adaptation [13].

2.2 Related Work

Quality of Experience model. QoE in a technical environment has been defined as the "overall acceptability of an application or service, as perceived subjectively by the end-user" [11]. It seeks to capture the end-user satisfaction with Quality of Service (QoS). Arguably, this definition, falls short of covering all relevant aspects user experience of learning systems, where learner experience is necessarily influenced by learning-related factors. Initial research on QoE in a learning context investigated QoE improvements in courses with illustrated text [6]. A recently proposed QoE model (see Figure 1) for adaptive e-learning systems describes QoE as determined by

learning experience, flow experience [12], which are both affected by QoS parameters, and usability [13].

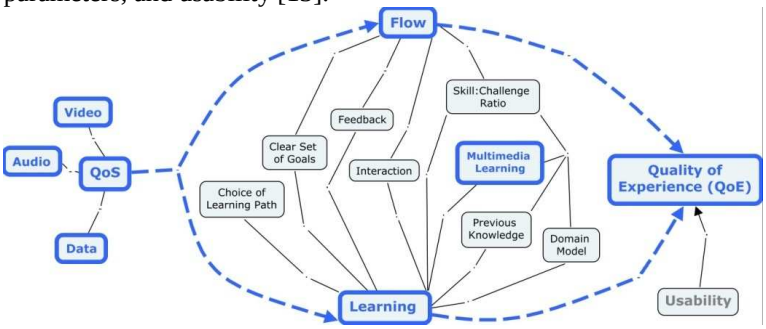

Figure 1: QoE Model for Adaptive E-Learning Systems [13]

This paper examines how QoS and learning aspects of this model can be translated into adaptation strategies as part of the authoring process of adaptive e-learning.

Quality of Service. Quality of Service describes the network parameters in data transfer, such as bit rate, delay, jitter, and their impact on quality of data delivery. Tolerance towards those QoS parameters depends on the application (see [14]). These network performance parameters loss, delay and bandwidth will be used to characterise the quality of network delivery conditions. This characterisation will then be used as input for adaptation decisions. Bandwidth can be considered the parameter most relevant for all multimedia e-learning applications, while the importance of loss, delay and jitter depends on the type of application. Adaptation to the QoS parameters is achieved by sending materials most suitable to the network conditions.

Media mix. The media mix aspect combines basic elements of Multimedia Learning theory [15] and motivational techniques [10].

Research on motivational techniques for e-learning shows the positive motivational impact [10] of alternating delivery and format into the media mix strategy. The change of media format also adds an element of variability, which has been identified as another motivational technique [15]. A media mix that varies the media format, presenting one media type at a time, prevents overwhelming the learner and leaves room for visual rests [1].

QoE-Authoring for Adaptive Systems. Authoring tools to author adaptive online courses [2] in combination with sets of adaptation rules, expressed as LAG strategies [3] provide the starting point for multi-strategy adaptation.

2.3 QoE Strategy Overview

The decision of what material to present to the learner is based on a combination of constraints from the technical environment of the learner and multimedia theory. This is really a two step process: first the assessment of network conditions and then mapping those conditions onto a media suggestion.

An initial assessment of the network conditions considers the QoS parameters available bandwidth, loss, delay and jitter (see Table 1) and maps them into profiles bad, medium, good and excellent (see Table 1), depending on the parameter values.

Table 1: QoE Strategy, Part I

Profile	Bandwidth	Delay	Loss	Jitter*	Suggestion
BAD	Dial-up (38, 56 kbps)	>>10s	>>3% (RTSP), >>1% (HTTP)	>>1ms	Text+images (low)
MEDIUM	DSL1 (256, 340 kbps)	~10s	~3% (RTSP), ~1% (HTTP)	~1ms	Audio at 96-128 kbps OR Text+images (high resolution)
GOOD	DSL2 (700kbps, 1Mbps)	<<10s	~0% (HTTP/RTSP)	<<1ms	Audio at 192-256 kbps OR Text+images (high resolution) OR Video at ~700 kbps
EXCELLENT	DSL3 (2Mbps, 4Mbps)	<<10s	~0% (HTTP/RTSP)	<<1ms	Audio at 192-256 kbps OR Text+images (high resolution) OR video at ~1 Mbps

Bandwidth is considered the most important parameter, because it not only affects all media formats, it also has a significant impact on loss and delay. If all other parameters are in a higher profile, the bandwidth determines the profile. Loss and delay are of high importance as well, since they affect all formats, jitter has a strong impact only on audio files and is considered least important.

These profiles allow for the selection of suitable media formats that can be expected to be delivered to the learner in good quality (see Table 1).

The decision which media format is ultimately selected depends on the user's history of the *media mix*. According to media mix theory, the media format used one step earlier is always excluded. We choose to use a predetermined ordering for the media with audio is followed by illustrated text, illustrated text is followed by a video and video is followed by audio.

Table 2: QoE Strategy, Part II

Profile	Suggestion	Previous media	Recommendation
BAD	Text+images (low res.)	Any	Text+images (_low)
MEDIUM	Audio at 96-128 kbps OR Text+images (high resolution)	Video	Audio at 96-128 kbps (audio_low)
		Audio	Text+images (_high)
		Text+images	Audio at 96-128 kbps (audio_low)
GOOD	Audio at 192-256 kbps OR Text+images (high resolution) OR Video at ~700 kbps	Video	Audio at 192-256 kbps (audio_high)
		Audio	Text+images (_high)
		Text+images	Video at ~700 kbps (video_low)
EXCELLENT	Audio at 192-256 kbps OR Text+images OR Video at ~1 Mbps	Video	Audio at 192-256 kbps (audio_high)
		Audio	Text+images (_high)
		Text+image	Video at ~1 Mbps (video_high)

Now, however, some formats may have to be ruled out because of delivery conditions. In this case, the format is varied as and how possible. If network profile is BAD, only text+images can be sent no matter what. This policy is summarised in Table 2.

It should be noted that several assumptions have been made as to the application order and exceptions to the adaptation rules in order to arrive at a coherent policy. The policy presented in Table 2 combines two separate policies, and ideally, the initial QoS and media mix policies would be available for reuse in different settings. To enable this adaptation strategy a few points in the authoring process as outlined in the following subsection are necessary.

2.3 Authoring process for QoE adaptive e-learning

The authoring process essentially follows the usual authoring process in MOT [4]. This part of the paper simply points out a few things to keep in mind.

The sample course has a basic structure for each part; title, introduction, main content, conclusion. Title, introduction and conclusion are always text-based. The adaptation affects the main content area only.

In this particular case of a multimedia course, adapting not only to network conditions or QoS parameters, but also providing a mix of different media, it is necessary to provide all learning resources in three different types of media. We consider videos in H.264 / MPEG-4 format, audio files in MP3 format and illustrated text.

The QoS adaptation requires adding additional attributes in the domain model, clearly named according to the different formats and possibly the different quality levels of the same content. An example for the authoring of these additional attributes is given in Figure 2, additional attributes are marked with an ”x”.

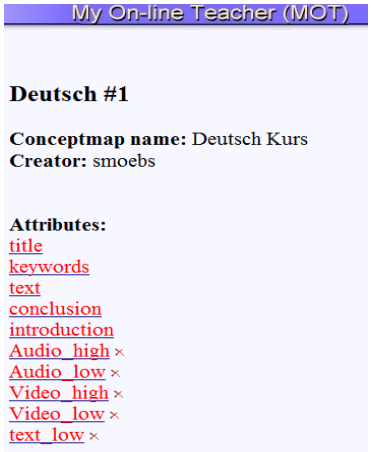

Figure 2: QoS and Media-mix based Attributes in MOT

The media mix adaptation can be enabled by adding labels in the goal and constraints (pedagogic) model, again named according to the different formats.

Adaptation strategies for the QoE adaptation have to be written [3]. This is described in more detail in the following section. In the processing order it makes more sense to write the strategies first, before setting up the course. Once the strategies are written, different content and courses can be used with these strategies. This requires that naming of attributes and labeling content follow the details in the strategies. Any other authoring activities are following the commonly known steps sufficiently outlined elsewhere [8]**.**

3 Technical Description

The case study highlights the necessity for two different strategies to improve the Quality of Experience of the Learner, considering media-mix and QoS changes. These strategies are introduced in the first subsection. The case study also points out the necessity for reuse and the possibility to combine strategies; this aspect is explored further in the second subsection. As sketched in the scenario, combination of strategies can become very complex. Next, the strategies are described, as well as the main problems with reuse and combinations of strategies are identified. The final subsection proposes a method to create reusable modular strategies, using the case study as an example.

3.1 LAG Strategies for QoS and Media-mix

The adaptation strategies aim at two different goals, adapting the content shown to changes in QoS conditions and providing a mix of the content media type.
The media mix strategy aims at providing a mix of different media in the main content area of the course, one type of media at a time. In this example we only consider video, audio and illustrated text, which could be diversified further into different quality levels for each media type.

The QoS strategy aims at adapting a course, depending on the changes in network conditions. Again the adaptation considers the main content area.

Example of a LAG strategy to provide a mix of media:

Each concept has a textual introduction and textual conclusions. This code should make them readable for all:

```
initialization(
  while true (
     if(GM.Concept.label=="introduction" OR
     GM.Concept.label=="conclusion") then (
    PM.GM.Concept.show = True )))
```

The following code shows how the mix of the media is selected depending on the history of the user, the media s/he has previously used or seen. Media information is stored in the user model; depending on the previously seen media, a pre-defined media type will be shown next. If the media type seen previously is “video” then the next media type will be audio, if the media type seen previously is “audio”, it will be followed by illustrated text and finally the media type “text” will be followed by video content accordingly. This guarantees a constant rotation of different media

types shown. On the other hand, because rotation does not vary, it might become easily predictable. In case of the QoE adaptation the adaptation to QoS parameters provides a varied sequence of media types.

```
implementation(
  if (UM.history == video) then ( if (GM.Concept.label LIKE[1]
 *audio*)  then ( PM.GM.Concept.show = True    ))
else if (UM.history == audio) then (if (GM.Concept.label LIKE
 *text*)   then ( PM.GM.Concept.show = True    ))
```

Example of a LAG strategy to provide adaptation to changing QoS conditions:

Again each concept has a textual introduction and conclusions, which should be readable for all (code omitted as it's thus identical with previous initialization).

Next, the QoS profile is estimated, based on current QoS information. It checks whether the bandwidth profile is lower than all other three profiles. If not, the bandwidth determines the QoS profile; otherwise the QoS profile is the sum of the weighted QoS parameters bandwidth, loss, delay and jitter.

```
implementation(
 if(enough(PM.bandwidth_profile<=PM.loss_profile
           PM.bandwidth_profile<=PM.delay_profile
           PM.bandwidth_profile<=PM.jitter_profile,3)
 then (PM.QOS = 0)
else (PM.QOS = (0.5 * PM.bandwidth_profile) +
(0.5*((0.4*(PM.loss_profile + PM.delay_profile)) +
(0.2 * PM.jitter_profile))))
```

The following code initializes the visibility of concepts based on above QoS profiles.

```
  if (PM.QOS <= 0.2) then (
  if (GM.Concept.label LIKE *text*) then (
      PM.GM.Concept.show = True    )
  ) else if (PM.QOS <= 0.5) then (
    if (GM.Concept.label LIKE *audio*) then (
      PM.GM.Concept.show = True    )
  ) else if (PM.QOS <= 0.8) then (
    if (GM.Concept.label LIKE *video-low*) then (
      PM.GM.Concept.show = True    )
  ) else (
    if (GM.Concept.label LIKE *video-high*) then (
      PM.GM.Concept.show = True    )))
```

This code shows how content is selected depending on QoS conditions. Text is selected for the lowest QoS level, while audio, video in low quality and video in high quality are selected for medium, good and excellent conditions respectively.

3.2 Reuse and Combination of Adaptation Strategies

The scenario illustrates both a solution to our case study, as well as a common problem in Adaptive Hypermedia: often, a course will need to use or reuse multiple adaptation strategies to achieve the desired behaviour.

[1] The 'LIKE' construct requires an extension of the LAG language, which will be available with the next update.

Although it is possible to manually combine the various strategies into one overall strategy, this does not aid a strategy author who requires reusing a particular behaviour from a previous course and combining it with a new one.

It would be more useful if the required adaptations could be described by modular adaptation strategies which could then be reused and combined in various permutations. This would reduce redundancy and aid the strategy authoring process for adaptive hypermedia systems.

3.3 Problems with reuse and combination of adaptation strategies

There are problems with reusing some adaptation strategies on different content domains as they can be specialised to particular content which cannot be easily reused without editing the course content. A method for solving this problem using the LAG strategy language has been described elsewhere [9].

However there are other problems with reusing adaptation strategies which arise when multiple strategies are used at the same time. Although problems with multiple strategies can occur when an author has written them specifically for the same course, they most commonly occur when strategies from different courses are reused. While adaptation strategies may produce the desired behaviour if they are executed individually in isolation, when they are run together they can produce unforeseen behaviours which are not intended by the course author.

Some potential problems which occur when using multiple strategies are:

- **Execution Order**: Some strategies will work fine when they are run in one particular order but not if the order of execution is reversed or changed.
- **Variable Clashes**: Unforeseen behaviour can be produced if multiple strategies access, and more importantly, update the same variable. For example if two strategies both have the following line (example 1) in the strategy file then the system may report that the user has accessed the concept six times when the user has actually visited the concept only three times.

Example 1

```
UM.GM.Concept.beenthere += 1
```

- **Type Conflicts**: Multiple strategies use the same variable to store different types of value. For example one strategy (example 2) may store a Boolean while another (example 3) will expect an Integer when it accesses the same variable.

Example 2: Strategy 1

```
UM.GM.Concept.accessed = True
```

Example 3:Strategy 2

```
if (UM.GM.Concept.accessed > 2) (...
```

3.4 Creating reusable modular strategies using the case study

It would be useful to use both the QoS and the Media mix strategies in an attempt to get the adaptation behaviour of the QoE strategy, which is to adapt the course contents to both the quality of the connection and the multimedia learning theory showing only one media type at a time.

For example we could try running the QoS strategy first and then the Media mix strategy. However, this would cause a problem, because a user who had a medium quality connection and had just viewed a piece of text as part of the course would be shown next an audio file from the QoS strategy and both videos from the media mix strategy. This is not acceptable, especially as all three content parts would contain the same information.

This problem occurs because the two strategies both selectively display parts of the lesson contents as per the adaptation behaviour they envision. The strategies do this without any knowledge of what other parts of the lesson being displayed are shown or hidden. As this is a restriction of most current adaptation engines we will consider how to solve this problem without the adaptation strategies needing to know what other lesson content parts are visible.

The strategies both initialize and display lesson contents. As the individual strategies do not know what is visible at any single point as generated by another strategy, the overall strategy to achieve the behaviour would be to show one content part for video, audio and text, switch the quality of that content, as per the QoS theory, and then hide any content which doesn't fit the media type that needs to be shown by the multimedia theory.

We need to do this in a way that the strategies can then be reused to achieve the QoS or media-mix behaviour in other contexts. In general, this can be done by identifying the main tasks that are needed for the overall strategy and write the new strategies to perform these tasks. However, for some behaviour, it may not always be possible to do this as the tasks themselves may clash. For example a “Show All” task would clash with a “Hide All” task. In this case we would need to create an additional task to arbitrate this situation. After these strategies are written, a meta-strategy would be created to combine them in a way that would produce the desired adaptation behaviours.

The proposed method, as described above, could be used as a generic method for creating reusable strategies using a task based approach and is summarised as follows:

1. Divide the overall behaviour into tasks that are needed to be performed;
2. List the areas where the tasks might clash and what assumptions are needed for the task to be carried out;
3. Write an adaptation strategy for each task; and
4. Write a meta-strategy to control when and how the strategies should be executed.

The main tasks that are needed for the QoE strategy are:

- Initialising the course content;
- Creating a default state for the lesson to be viewed;
- Switching the content quality to be shown as per the QoS; and
- Showing and hiding content as per the Media Mix theory.

The areas where these tasks could clash are in showing and hiding content. We do not want to show content without ever removing it. A simple solution is as follows. For every condition resulting in addition of content such as:

```
if (condition) then ( PM.GM.Concept.show = true )
```

we would hide the content that we do not want displayed like:

```
if (condition) then ( PM.GM.Concept.show = true ) else ( PM.GM.Concept.show = false )
```

The initialization task is performed in the course initialization stage and the default setup task is performed in the course implementation stages. Hence they can both be contained in the same LAG file as follows:

Strategy – Initialization and Default Setup

```
initialization(
  while true (
    if(GM.Concept.label==introduction OR
GM.Concept.label==conclusion) then (PM.GM.Concept.show = True))
)
implementation(
  if (GM.Concept.label LIKE *video-high*) then (
    PM.GM.Concept.show = True
  ) else if (GM.Concept.label LIKE *text*) then (
    PM.GM.Concept.show = True
  ) else if (GM.Concept.label LIKE *audio*) then (
    PM.GM.Concept.show = True
  ) else if (GM.Concept.label==introduction OR
GM.Concept.label==conclusion) then (
    PM.GM.Concept.show = True
  ) else (   PM.GM.Concept.show = False
  ))
```

The code above initialises the course content to show the introduction and conclusion for each lesson as per the initialization task. The implementation loop for the Default Content task sets the highest quality content to be displayed as the default; for the purposes of this paper we assume that text and audio have no quality differences. Everything else is hidden; this includes content labelled video-low which would be a low quality version of the video-high.

An example of the QoS code that deals with showing the correct video content quality is shown next:

```
// SWITCHING CONTENT QUALITY
if (GM.Concept.label LIKE *video-low*) then (
  PM.GM.Concept.show = True
) else if (GM.Concept.label LIKE *video-high*) then (
  PM.GM.Concept.show = False)
```

This code would hide video-high content and show video-low content, switching the quality for that particular type. Variations on this would be run for different QoS values.

The code for the Media Mix task is composed of conditions similar to the following code.

```
  if (UM.history == video) then (
    if (GM.Concept.label LIKE *video* OR GM.Concept.label LIKE
*text*) then (
      PM.GM.Concept.show = False
    ) else (
      PM.GM.Concept.show = True
    )
```

The code above hides the content that shouldn't be displayed according to the Media Mix theory and shows other content. There would be variations on this code for the other possible UM.history values.

The full strategy code listings for the QoS and Media Mix tasks are:

Strategy – QoS

```
initialization()
implementation(
  // QoS profile:
  if (enough(PM.bandwidth_profile<=PM.loss_profile
             PM.bandwidth_profile<=PM.delay_profile
             PM.bandwidth_profile<=PM.jitter_profile, 3) then (
    PM.QOS = 0
  ) else (
    PM.QOS = (0.5 * PM.bandwidth_profile) +
             (0.5 * ((0.4 * (PM.loss_profile +
PM.delay_profile)) + (0.2 * PM.jitter_profile)))
  )
  // initialize visibility of concepts based on above QoS
profile
  if (PM.QOS <= 0.2) then (
    if (GM.Concept.label LIKE *text*) then (
      PM.GM.Concept.show = True
    )
  ) else if (PM.QOS <= 0.5) then (
    if (GM.Concept.label LIKE *audio*) then (
      PM.GM.Concept.show = True
    )
  ) else if (PM.QOS <= 0.8) then (
    if (GM.Concept.label LIKE *video-low*) then (
      PM.GM.Concept.show = True
    ) else if (GM.Concept.label LIKE *video-high*) then (
      PM.GM.Concept.show = False
    )
  ) else (
    if (GM.Concept.label LIKE *video-high*) then (
      PM.GM.Concept.show = True
    ) else if (GM.Concept.label LIKE *video-low*) then (
      PM.GM.Concept.show = False    )))
```

Strategy - Media Mix

```
initialization()
implementation(
  if (UM.history == video) then (
    if (GM.Concept.label LIKE *video* OR GM.Concept.label LIKE
*text*) then (
      PM.GM.Concept.show = False
    ) else (
      PM.GM.Concept.show = True
    )
  ) else if (UM.history == audio) then (
    if (GM.Concept.label LIKE *audio* OR GM.Concept.label LIKE
*video*) then (
      PM.GM.Concept.show = False
    ) else (
```

```
      PM.GM.Concept.show = True
    )
  ) else if (UM.history == text) then (
    if (GM.Concept.label LIKE *text* OR GM.Concept.label LIKE
*audio*) then (
      PM.GM.Concept.show = False
    ) else (
      PM.GM.Concept.show = True    )))
```

These strategies can now be run together or in different combinations to achieve the desired adaptation behaviours. The meta-strategy which would combine the above strategies to achieve the QoE behaviour is shown below. The exact LAG syntax for meta-strategies is yet to be finalised so we show here an example of a possible syntax.

```
initialization(
  Strategy-Setup.initialization
)
implementation(
  Strategy-Setup.implementation
  Strategy-QoS.implementation
  Strategy-MediaMix.implementation
)
```

Automate the method. One drawback of the proposed method is that it is a manual process. To make it more useful, as much as possible of the method needs to be automated when input strategies are available. It may be possible to automate the first two steps by doing the following:

Step 1: Automate the identification of behaviour

- Analyze the variables used in the input strategies.
- Identify the different types of adaptation existing in the original strategies.
- Analyze the interaction between different layers of adaptation
- Map the adaptation behaviours to the variables that they depend on

Step 2: Verification of strategies

- Check if any single variable is responsible for multiple adaptation behaviours.
- Identify the dependencies of variables which are responsible for the adaptation behaviours.
- Analyze how and when variables cause an adaptation.
- Identify problematic patterns that could cause clashes.

A more detailed view on these topics is in the centre of ongoing research.

4 Evaluation

An evaluation of the method described has to be approached from different perspectives: the system, the author and the learner.

The evaluation from the system's perspective includes:

- *Does the strategy merger result in the same outcome as a strategy created from scratch?*

- *If the method is automated, what is the time it takes to process, and what is it's precision (in comparison with a strategy created from scratch)?*

The evaluation from the author's perspective will have to address the following questions:

- *Does the proposed method improve the authoring of complex strategies?*
- *Does the method provide a less error prone way to author complex combined strategies?*
- *Can the method be expanded to include tools supporting the authoring of strategies?*
- *Is the method limited to the combination of two strategies or does it enable the combination of a larger number of strategies?*
- *Does the method support combination with existing strategies?*

Strategy authors currently working with MOT and used to writing LAG strategies without the outlined method can get information on how to apply the method and can provide answers to the set of questions. These answers can then feed into ongoing research on improvements to the method and strategy authoring in general.

Evaluation can be broken down into the categories about authoring of new complex strategies and combining existing strategies.

The learner perspective needs to address the following questions:

- *Does the method provide strategies or strategy combinations which enable the desired adaptation?*
- *Does the QoE overall strategy improve the learning experience of the learners?*

5 Conclusion and Future Research

The scenario outlined in the case study describes a typical problem situation in the authoring process of adaptive hypermedia. The paper proposes a method to improve the authoring process by breaking down the authoring of complex strategies into smaller steps.

Combining strategies can cause clashes in the ways different strategies handle domain and program variables. This can result in strategy combinations which make important parts of an adaptive hypermedia course inaccessible to the user. For example, choosing media type before adapting to network conditions could cause no content to be displayed to the user. Further research is needed to find ways to avoid these situations, warn strategy authors about possible problems and detect and avoid those situations as they arise in an adaptation delivery engine.

Research is needed to develop standards for writing modular strategies that can be reused in multiple environments and how to automate this process. Moreover, the authoring of meta-level strategies that dynamically manage the combination of simpler sub-strategies needs to be addressed.

So far the case study has been implemented, including a successful combination of the two strategies. Next steps will include the testing of the method with a group of

strategy authors to identify problem areas, deficiencies and to get general feedback. The ongoing research on Quality of Experience will include testing of the method, considering the authoring, learner and system perspective.

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