Anurup: An Adaptive Instruction Approach

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Abstract—Personalization in e-learning is an emerging research area today. Personalization has gained importance mainly because, it addresses the learner’s concern and attempts to make the learning experience more enjoyable to the individual. Personalization can apply to almost all learning entities like curriculum, syllabus, assessment, pace etc. Personalization can be based on various parameters viz., learner’s age, language of instruction, region, prior knowledge, mastery level etc. A lot of research is in progress to identify a comprehensive approach for personalization, which can provide effective and enjoyable learning to large base of real-life learners. The paper presents a brief overview of existing work in adaptive instruction, and details the approach for adaptation used in 'Anurup – A Framework for Adaptive Instruction'.

Keywords—personalization, e-learning, adaptive instruction

I. INTRODUCTION

E-learning has reached a large base of people and its contribution in imparting education in distance or in blended mode is well-established. More research is in progress to increase impact of learning anywhere anytime, by personalizing learning. Personalization attempts to address the problems commonly found in e-learning, viz., short attention span of the learner, low motivation and relative isolation, to some extent. Personalization includes tailoring the learning environment and customization of instruction based on learner's current interest, his/her knowledge level, social economical background, motivation, etc. Effective technological solutions for personalized learning are very rare in practice due to difficulty in applying, measuring and calibrating personalization parameters. This paper presents a personalization approach and its implementation in 'Anurup – A Framework for Adaptive Instruction'.

Instruction can be adapted for a learner on the basis of various parameters ranging from learner’s personal information like age, region, etc. to the technologically inferred information such as prior knowledge, mastery level, etc. These parameters can be grouped into different categories as shown below:

1. Learner's cognitive abilities[2] - The cognitive abilities are intellectual skills related to knowledge gathering and applying, like recall or recognition of specific facts, understand, analyze, synthesize, etc. Mastery/competency level is implicit part of cognitive abilities since it is a measure of learner's depth of knowledge in the area. For example, a learner who can analyze and apply has more mastery over the subject than a learner who can merely recall.

2. Learner's psycho-motor abilities[2] - Psycho-motor abilities include motor-skill areas like driving, swimming, and is measured in terms of speed, precision, distance, procedures, etc.

3. Learner's affective abilities[2] - Affective abilities include the learner's way of dealing with things emotionally like feelings, appreciation, values, motivation, attitude etc.

4. Learner's style of learning- Learner styles include learner's preferred way of learning. Different people naturally prefer a certain single different learning style. A number of learning style models exist today for modeling learner styles.

Information on cognitive abilities, competency/mastery levels and motivation is useful in identifying the topics in which learner needs to improve and thus helps in selecting and structuring content for the learner. Learning style theory proposes that different people learn in different ways; some may prefer reading to understand a concept whereas others might prefer a demonstration. Learner style information is useful in presenting the same lesson in different pedagogy types based on learner's learning style. Affective abilities are very difficult to measure or model and using this information in adapting content is a major challenge.

The paper first presents a brief overview of existing work in adaptive instruction, followed by a comprehensive approach for adaptation used in 'Anurup – A Framework for Adaptive Instruction'. A short discussion on issues faced during implementation of the approach and future enhancements in Anurup are presented at the end of the paper.

II. EXISTING WORK IN ADAPTIVE INSTRUCTION

Content adaptation can follow various approaches, with each one addressing different perspectives:

1. **Granularity of adaptation**: Learners can be given different content differing at various levels like sentence level(Micro adaptive), or chapter level(Macro adaptive). In Macro-adaptive[12] approach, adaptation is achieved by allowing different alternatives in selecting a few main components such as learning objectives, levels of detail, delivery system, etc. In Micro-adaptive[12] approach, adaptation is achieved by diagnosing the student’s specific learning needs during instruction and accordingly provide instructional prescriptions at a micro-level like sentence or pedagogy level.

2. **Sequencing(dependency)**: Sequencing includes content-level sequencing and link level
sequencing. Content level sequencing presents the content in different pedagogical order to the learners, while link level sequencing provides different learning paths to the learner. This is captured in an adaptive hypermedia approach which combines adaptive instructional systems and hypermedia-based systems, and provides both content-level as well as link-level sequencing.

3. Filtering: Different learners need different types of content according to their learning needs. This requires content filtering to identify and deliver content matching to the need of the learner. Filtering can be on the basis of pedagogical role or media type. Constructivist collaborative approach follows constructivist pedagogical approach combined with collaborative learning. It focuses on how knowledge is learned and filters content based on the context, learning activities and cognitive structure of the content. Aptitude treatment interaction[12] presents different types of instructions or even different media types for different students based on learner characteristic.

Attempts have been made by various researchers to bring about adaptivity and personalization in e-learning. The well-known among these, which focuses on adaptivity of content are the following:

- In Arthur[11], learner is shown different learning material based on learner style. Alternate content for different styles is pre-stored in the system and appropriate content is selected depending on the learner profile.
- Another system, ELM-ART[8], provides adaptive navigation support for browsing a course. The learner will follow different paths to learn the course depending on the learner profile and prior knowledge level.
- In AdeLE[12], the adaptivity in instruction is achieved by changing the delivery type and sequence of the content based on the user's eye tracking movements and other data like time spent, frequency of visits of the content etc.

It can be seen that each system addresses one or more specific chosen personalization perspective. Personalization can be made more effective if all the perspectives of personalization mentioned above are supported in one platform. We, therefore, propose a comprehensive architecture for adaptivity - but, focusing only on content adaptation. This architecture called Anurup, accommodates most of the personalization perspectives.

The subsequent sections of the paper outline the approach used in Anurup and present some actual content personalized using Anurup.

III. Adaptive Instruction Architecture in Anurup

Adaptive Instruction in Anurup is based on Micro-adaptive, Aptitude treatment interaction(ATI), and Constructivist collaborative approaches listed in the previous section. Learning objectives are selected based on learner profile. Content is selected and sequenced differently based on learner characteristics. The media type of the content delivered also varies based on learner characteristics. Broadly, the approach for adaptation is shown in Figure 1 and explained below.

![Figure 1: Adaptive Instruction Architecture in Anurup](image)

Content repository stores the content along with appropriate metadata like pedagogical role, age, language, region of the learner to which this content is suitable etc. Learner model consists of learner styles and information about the learner like age, language, region etc. The adaptive engine matches the content from repository to suit to a learner primarily based on learner styles and then considering the other parameters like age, language etc. Finally, the tailored content is shown to the user. Sections from A to D explain these blocks in more detail.

This approach is described in detail in the consequent sections.

A. Build a content repository

Content plays a very important role in any learning environment. Its organization and storage is critical for efficient retrieval and manipulation.

In Anurup, content is categorized into atomic units on the basis of its pedagogical role. The pedagogical roles identified, along with their explanation is given in table 1:

<table>
<thead>
<tr>
<th>Pedagogical role</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>The purpose of this content is to position the following material.</td>
</tr>
<tr>
<td>Definition</td>
<td>A definition is a formal specification of a concept, used to make it clear and precise.</td>
</tr>
<tr>
<td>Fact_list</td>
<td>A list of facts.</td>
</tr>
<tr>
<td>Example_list</td>
<td>A list of examples.</td>
</tr>
<tr>
<td>Non_example_list</td>
<td>A list of non-examples. A non-example is used to demonstrate what is NOT a concept.</td>
</tr>
<tr>
<td>Demonstration</td>
<td>It is used to show an activity, or illustrate a presentation</td>
</tr>
</tbody>
</table>
Various media types have associated content of objectives and objectives have associated content of learning context. There can be separate threads for each objective. A thread consists of a set of objective types to be accomplished in order to visit current goal or objective. Actual learning resources (content) are associated with specific objectives. The objective type and uses this to fill in content for a given objective type.

Thus, goal contains threads, threads contain objectives and objectives have associated content of various media types. See Figure 2.

Following example of content is from a book 'Course on Compute Concepts (According to DOEACC Syllabus)' for chapter 'What is a Web Browser'.

Definition: A Web browser is a software package supplied free by Microsoft Corporation and many other companies that is used to view Web pages as well as navigate the World Wide Web.

Fact_List: Browsers are also referred to as Web clients.

Example: Currently, most popular browsers for the World Wide Web are Netscape's Navigator, developed by Netscape Communications Corporation and Internet Explorer developed by Microsoft Corporation.

Apart from the pedagogical role, the content also stores additional information like media type, complexity, intended age range of the learner, interactivity level etc.

In Anurup, content organization is done in a hierarchical manner. 'Goal' is at the top of the hierarchy and contains a large number of objectives. Goals are broad, generalized statements about what is to be learned, roughly analogous to one chapter/lecture in a class. A course for given subject and standard /grade normally would have well-defined goals, which learner has to achieve at the end of course. Objectives are brief, clear statements that describe the desired learning outcomes of instruction and intend to measure specific behaviors. Objective differs from goal only in terms of the scope. Both goals and objectives have pre-requisites, which need to be accomplished in order to visit current goal or objective. Actual learning resources (content) are associated with specific objectives.

In theory, the learner may pursue the objectives in any order. There are large number of objectives within a goal, this freedom may break the learning context very often resulting in a haphazard sequence of content. In order to avoid this, one more hierarchical level is introduced in between goal and objective. As in classroom environment, we call it as learning context or thread. This level eliminates issue of mixing of many learning contexts when delivering content. It is also helpful in maintaining learning context during a course. A thread consists of a set of objectives with same learning context.

Thus, goal contains threads, threads contain objectives and objectives have associated content of various media types. See Figure 2.

Figure 2: Content organization in Anurup.

An objective can be achieved in a particular way, depending on the nature of the objective. Following are the objective types identified in Anurup:

- Fact - A fact represents specific and unique data or instance that is to be transferred to the learner.
- Process – A process represents a continuous action, operation, or series of changes taking place in a definite manner.
- Principle - A principle is a statement that expresses a relationship between concepts. The relationship can be a cause, or it can be a fundamental assumption or rule which has some theoretical proof or is derived from the observations, or it can be a premises.
- Concept – A concept represents an abstract or general idea inferred or derived from specific instances or an idea of something formed by mentally combining all its characteristics or particulars.
- Procedure - A procedure represents a series of clearly defined steps that result in achievement of a job task. Procedure could be a series of psychomotor steps or it could series of cognitive steps.

For each objective of a given type, one can visualize a sequence of pedagogical roles. For example, if an objective is of type concept, then it would be explained with introduction, fact_text_list, example, definition, non-example_list, demonstration, summary. Such a sequence is called Instruction Template for that objective type. Anurup identifies such an Instruction Template for each objective type and uses this to fill in content for a given user, as explained in section C.

B. Build Learner Model

Learner model captures the learner attributes and values, based on which the instruction can be personalized to suit the particular learner. In Anurup, learner model consists of learner styles, prior knowledge and personal information like age, region, preferable language of instruction, accessibility information for disabled learners. Due to the differences in learning styles, the instruction presented to the learners will vary in terms of what content should be given, and the order in which the content pieces should be delivered. Currently, Honey and Mumford's Learning Style Model[9] is used for representing learner styles, according to which learner can have one of the four distinct learning styles:
1. Activist - An activist learns by active experimentation or doing by self.
2. Reflector - A reflector learns by observation or watching demonstrations first.
3. Theorist - A theorist prefers understanding by conceptualization or analyzing things.
4. Pragmatist - A pragmatist prefers learning from experience or actually feeling.

In our approach, we also considered other attributes of content like age range (consider the age of intended user), accessibility level, difficulty level, locale (hindi/english), interactivity level, etc. Knowledge level is used to define the learning path for each learner. How these learner characteristics are used for personalization is explained in the next section.

C. Adaptive Engine

Adaptive Engine is the 'decision maker' in Anurup and decides what piece of information of what type/media is to be delivered to the current learner next. The overall process can be split into two stages – creating a customized template and fitting in the same with actual content. Thus the adaptive engine performs the following two major tasks:

a) Customize the instruction template associated with an objective for learner style.

b) Identify the content unit for each pedagogical role slot in the instruction template.

a) Customize the instruction template

As mentioned earlier, an instruction template models the way in which a specific objective type can be achieved. This can be customized to suit the learner style based on his/her learning style. This is done by removing the pedagogy types not suitable to a learner style, and re-sequencing the pieces in the instruction template[5]. Table 2 shows the pedagogy types for one dimension of learner styles - activist and reflector[5]:

<table>
<thead>
<tr>
<th>Objective type</th>
<th>Pedagogy types for activist</th>
<th>Pedagogy types for reflector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fact</td>
<td>Experiment, Fact_text_list, Summary</td>
<td>Introduction, Fact_text_list</td>
</tr>
<tr>
<td>Process</td>
<td>Simulation, Stage_list, Fact_text_list, Summary</td>
<td>Introduction, Fact_text_list, Stage_list</td>
</tr>
</tbody>
</table>

b) Identify the content unit

Once the pedagogy types for an objective are identified based on learner style in the form of an LSIT, actual content is populated for each pedagogy type in the template and delivered to the learner. This is done by first filtering the content for matching with the objective and then filtering it further to match the particular pedagogy role slot of the LSIT. If this results in multiple options, content selection is further refined based on learner preferences, which include age, locale, urban or rural area, region, difficulty level, interactivity level, accessibility level etc.

IV. USER INTERFACE FOR INSTRUCTION DELIVERY

The main aim of adaptive instruction is to provide the content to learner that can comply with individually different educational goals and learning abilities. In Anurup, there are three different views to deliver learning content to learner. These views are designed to accommodate different learning needs of a learner. These are explained below:

A. Objective Wise View

In this view learner can navigate the content according to the individual objective. Learner can select the specific objective according to his learning need and view its content. The content of a single objective is displayed at one instance. He can move around among various objectives using the navigation pane on the left. (See Figure 3).
B. Context Wise View

In this view, learner can complete the learning objective according to a learning context or thread. The objectives under the choice are displayed along with the entire content for all objectives under the thread. (See Figure 4).

C. Consolidated Content View

This view shows the full learning content for a particular goal, in one shot. In this view, learner will be able to see all objectives of a goal and their associated content. Sequencing of objectives is done according to the pre-requisites of objectives. (See Figure 5).
V. CASE STUDY: CONTENT OF DOEACC CCC COURSE ADAPTED USING ANURUP

A ‘Course on Computer Concepts(CCC)’ of DOEACC[13] has been populated in Anurup. The content is taken from the text book specified by DOEACC. Alternate content for adaptivity has been added in some places. The following snippets show the actual text book content for the objective 'Introduction to Operating System' and the content delivered through Anurup to learners with learner styles activist and reflector respectively. See Figure 6 and 7.

VI. THE ANURUP APPROACH IN PRACTICE

As we worked towards building the Anurup approach for adaptive instruction, a number of issues were noticed. Some of them and the way Anurup addresses them are mentioned below:

1. Granularity level of the content to be adapted - Content can be adapted at various levels like goal, objective, pedagogy type, section, sentence or word. Sentence and word are too deep, needs complex language processing. Therefore, this was not considered. Goals are too broad, and therefore, they were not considered for adaptivity. In Anurup, adaptivity is done at objective and pedagogy type level.

2. Wandering of the content - If all the pieces of content are completely independent of each other, they can be delivered, in any order. In practice, this assumption results in garbage content, having very less or no meaning most of the times. In Anurup, an attempt is made to minimize this problem by organizing content into objectives, thread and goals. Learning context is maintained by threads.

3. Distinguishing between scope of goal and objective - By looking at the structure of text book content, it was clear that there is some hierarchy in the organization of the content. This was modeled using goals and objectives. But it was very difficult to clearly define the boundaries between them. In Anurup, the approach was taken that goals and objectives differ only in terms of the scope. Goals are at very abstract high level, objectives are more precise and measurable.

4. Mapping content to pedagogy types - Defining pedagogy types, with clear distinction between each of them was difficult. The difficulty was noticed when we actually started tagging the content. Some of the content pieces appeared to belong to multiple pedagogy types. This meant a revision of the pedagogy types was required. This process continued many times until reasonably stable definition were obtained.

Figure 5: Consolidated content view in Anurup

Figure 6: Actual Text book content
VII. CONCLUSION

Adaptive instruction is emerging as a productive research area in e-learning, with lot of work yet to be done to make it more effective in providing right information the right way to the right student. In this paper we have outlined a comprehensive architecture for content adaptation. We have a prototype implementation of the Anurup - Framework for Adaptive Instruction, which is available for use at http://nrcfoss.cdacmumbai.in/fai. A National Workshop on Adaptive Instruction was organized by CDAC Mumbai on December 15-16, 2011 to create awareness about adaptive instruction. There were 41 participants in the workshop from the academia and corporate. The general feedback on the system was positive.

In future, we plan to include comprehensive assessment in Anurup to verify that the learner has actually gained knowledge that he claims to and thus obtain more reliable profile of current knowledge. Assessment data is also useful in verifying the approach of adaptive instruction is suitable to the target learners and modify it, if required, to make it more effective.

Also, there is a plan to add learner monitoring and progress tracking in Anurup to make the adaptive instruction approach more precise and more suitable to an individual learner.

As noticed during the workshop, learners generally belong to not just one learner style but a mix of learner styles. We plan to address this concern in future release of Anurup, to ensure that a large base of real life learners is addressed by Anurup.

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