ASHYI-EDU: Applying Dynamic Adaptive Planning in a Virtual Learning Environment

Jaime Pavlich-Mariscal[1], Yolima Uribe[1], Luisa Fernanda Barrera León[1], Nadia Alejandra Mejia-Molina[1], Angela Carrillo-Ramos[1], Alexandra Pomares Quimbaya[1], Monica Brijaldo[1], Martha Sabogal[1], Rosa Maria Vicari[2] and Hervé Martin[3]

[1]*Departamento de Ingeniería de Sistemas, Pontificia Universidad Javeriana, Bogotá, Colombia*

[2]*Departamento de Informática Teórica, Instituto de Informática, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil*

[3]*Laboratoire d' Informatique de Grenoble, Grenoble, France*

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Abstract: Activity planning is an essential element in the teaching-learning process, since it can ensure that adequate activities are utilized to convey the information to students. The common practice in course planning is that the teacher selects the same set of activities for every student in the classroom. However this does not address the students' heterogeneity in learning styles, knowledge, and personality. To address this problem, this paper proposes ASHYI-EDU, a Virtual Learning Environment (VLE) with dynamic adaptive planning. ASHYI-EDU is able to capture distinctive student characteristics and provide students with plans that are especially tailored for their particular characteristics. This paper also presents an ongoing case study that utilizes ASHYI-EDU in a university course.

1 INTRODUCTION

Formal educational processes require several elements to foster student competencies and abilities. One key element is the plan of activities that students need to perform in a course. This plan should satisfy two main requirements: its activities must be aligned with the course goals and they have to be aligned with the students characteristics, so that students can effectively learn the course contents (Sangineto et al., 2008).

To create a course plan, teachers usually develop a unique plan of activities that must be followed by every student in the classroom. Although this is a widely utilized practice, it may not guarantee that the courses' learning goals are satisfied by every student. The reason is that students are heterogeneous; they have different personalities and learning styles, which means that activities should be aligned with these characteristics to properly convey the information to students. In addition, students have different degrees of competencies, and abilities, which means that some students may require additional remedial activities to properly accomplish the course goals.

Overall the common way of planning a course may not be the optimal way to ensure effective learning in students. To address this issue this paper presents ASHYI-EDU, a Virtual Learning Environment that assists teachers to create especially-tailored plans for every student, taking into account their specific personalities (Yang and Chen, 2013), learning styles (Mohamad et al., 2013), competences (Rytikova and Boicu, 2014a), and abilities (Li et al., 2008a). The word "ASHYI" from ASHYI-EDU is a Quechua word that mean to search, to investigate. The combination with "EDU" conveys the idea of searching, investigating to provide education.

Although there are other approaches to create adapted plans in educational environments (Li et al., 2008b; Bahmani et al., 2011; Rytikova and Boicu, 2014b), their planning process takes into account either context, student personality, learning styles, learning context, but not all of them simultaneously. Some of them focus on coarse-grained learning elements, such as courses or learning units, but not fine grained activities. In addition, some approaches only rank learning activities but they do not elaborate an adapted plan for each student.

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The main contributions of ASHYI-EDU are: a more detailed analysis of of user and context information to perform dynamic adaptive planning and taking into account the student evolution during the course execution. Student evolution is relevant, since students may learn new abilities or competences during the course. As students changes their attributes, the plans currently assigned to them may not be the optimal. To address this situation, student plans in ASHYI-EDU are dynamic, which means that whenever students change their characteristics, ASHYI-EDU creates a new plan that is better suited to these new student conditions.

ASHYI-EDU also is able to determine whether a student requires a remedial activity or not, to compensate the lack of certain competences or abilities that the student requires to complete certain course activities. Moreover, ASHYI-EDU not only is able to select the best suitable activities for each student; it is also able to select the best resources available for a specific activity, based on context (e.g. access device, location).

The remainder of this paper describes ASHYI-EDU and an ongoing case study to validate the approach. Section 2 discusses similar approaches for activity planning. Section 3 briefly explains ASHYI, the high-level architecture that is the base for ASHYI-EDU. Section 4 explains ASHYI-EDU in detail. Section 5 describes the case study to validate the approach. Finally, section 6 concludes and discusses future work.

2 RELATED WORK

Automatic planning is a topic widely addressed in the literature. This section analyzes three main categories: generic planning, planning oriented to specific context, and approaches for planning in personalized education.

Table 1 summarizes the main features of related work. The '+' symbol means that the feature is supported by an approach; '-' means that it is not supported, while '?' means it is not clear whether the feature is supported or not.

Several works address the planning problem with a general-purpose approach. The work of (Coles et al., 2010) (1) propose a tool to create plans, based on partial order planning withing the framework of forward search to reduce the ordering constraints that may arise when creating a plan or sequence of activities. The plan can be modified over time. The work of (AnousouyaDevi et al., 2012) (2) presents an approach to address non-predicable actions using a temporal planning algorithm. The approach of (Plaku and Hager, 2010) plan collision-free trajectories for robots, based on the STRIPS algorithm (Fikes and Nilsson, 1972). The work of (Geib and Goldman, 2009) is PHATT, a tool creates a model that takes into account the negative experience of the user in the execution of a plan. The approach of (Geib and Goldman, 2009) (3) creates a stochastic model for the execution of a plan, based on AND/OR, negative experience and multi-goal agents.

In regard of automated planning to different domains, the work of (Oh et al., 2009) (4) addresses meeting planning, focusing on maximizing satisfaction of participants. This planner takes into account what happens before, during, and after the event. This approach also calculates the time required by each activity to minimize wait time between them. The work of (Guoqi et al., 2010) (5) focuses on task decomposition as the main concern to plan activities in a multi-agent environment. This decomposition takes into account time and order relations between tasks to identify and resolve conflicts between agents. The approach of (Johnson and Sieber, 2009) (6) addresses planning for tourists that travel through different places, to determine the impact of external processes and specific planning decisions. This approach takes into account socio-economical and contextual elements, such as weather, recycling, etc. The work of (Marki et al., 2012) (7) present a planning approach that takes into account the motivation of the user to execute upcoming activities based on their results in previous activities and the discomfort originated from their performance. The approach of (Nijland et al., 2012) (8) propose a planner for people's daily agenda. In this case, most activities are planned in advance, so planning, re-planning, and programming are performed in different times. The planner takes into account a person's data (gender, age, income, education, occupation, etc.) and creates a plan that also includes activities that are not explicit in the agenda, but that may be of importance to the user.

Several works address planning in the educational context. The work done by (Rytikova and Boicu, 2014b) (9) creates a course from resources provided by the teacher. The course is presented to each student depending on their course competences, which are obtained through an initial test. The approach of (Bahmani et al., 2011) (10) propose a tool to recommend courses to students, based on some student attributes and context. Several agents interact to find the best study plan for a given student.

Even though these approaches contribute in different contexts and with different methods to the problem of activity planning, when they are used to plan student activities they have some limitations. For instance, they do not facilitate the inclusion of new variables, such as student personality, learning styles or learning context, to increase the precision of the activity assignment. Besides, some proposals do not include mechanisms to dynamically change the plan according to the evolution of the individual. Finally, some of these approaches do not establish methods to increase the possibility of success using remedial activities. All of the above issues are directly addressed by ASHYI-EDU. ASHYI-EDU has comprehensive profile information about activities and students to better determine the most alike activities to students. ASHYI-EDU is able to dynamically adjust the plan, based on the student evolution and context changes, and it is able to include remedial activities, if the student needs them during the execution of the plan.

Table 1: Related Work.

Approach	Activ. Decmp.	Re-planning	Agents	User's satisf.	Context	User data
(1)	+	?	-	-	+	?
(2)	+	?	-	-	+	?
(3)	+	?	+	+	+	+
(4)	+	+	-	+	+	-
(5)	+	?	+	-	-	-
(6)	?	+	-	-	+	-
(7)	+	-	-	+	+	+
(8)	?	+	-	-	+	+
(9)	+	-	-	+	+	+
(10)	-	?	+	-	+	+

3 THE ASHYI ARCHITECTURE

This section briefly describes ASHYI, a high-level architecture to perform adaptive planning that is the base of ASHYI-EDU. For more details about ASHYI, the reader can refer to (Jaime Pavlich-Mariscal, 2015). The main elements of ASHYI are: roles, activities, resources, context, users, and a generic planning process.

The main roles in ASHYI are: the Administrator, who characterizes the application domain, defines the main activities that can be performed and the user characteristics; the Planner, who guides the planning process and solves conflicts that the system may not be able to solve; and, the Executor, who performs the activities in a plan that the system creates according to his/her specific characteristics and context.

Activities are the main actions that can be performed in a plan. They form a hierarchical structure of composite activities (contain sub-activities) and atomic activities (have no sub-activities). Activities may have pre and post conditions that determine the requisites to execute them and the effects they produce in the environment, respectively.

Resources are physical or logical elements that are employed to perform certain activities. Among other attributes, resources have keywords to identify them and a specification of the way to locate them (e.g. URLs for logical resources).

Context includes all the external elements that may affect the interaction between users and the system. The main identified elements are: location, time (e.g. season, time of the day), location infrastructure (e.g. computer availability, Internet connection, etc.), communities (i.e. groups of persons to which the user belongs), environment (e.g. weather, luminosity, ambient noise, etc.), regulations (i.e. rules, laws, standards that affect the individual), access devices (e.g. hardware, software, etc).

The user profile characterizes the people who utilize the system. The main information in a profile are: demographic data, preferences (for different activities, information display, etc.), interests (things the user wants to do), predilections (perceptions that the user likes), and habits (actions the user performs following a pattern).

The planning process in ASHYI,comprises three main stages: (1) environment configuration, (2) activities planning, and (3) activities execution. Stage (1) defines the specific domain characteristics to perform the planning process. In particular this stage defines the specific resources, activities and their pre and post conditions that will be utilized in the adapted plans.

Stage (2) utilizes user, and context profiles to determines the sequence, dependencies, and conflict resolution between activities in a meta-plan, i.e., a structure that describes all of the possible plans that could be assigned to users. According to the specific user and context information, the system must select a subset of the meta-plan that is the best suitable plan for each user, i.e., the adapted plan.

Stage (3) is the process in which the user executes, step by step, his/her adapted plan. The user executes each activity in turn. The results are evaluated by the system to determine the user's performance. The system may determine that the user has changed and because of that, the user may need a better adapted plan. In that scenario, the system should automatically create a new adapted plan for that user.

4 ASHYI-EDU

To validate ASHYI, the framework was instantiated into a specific domain (education). The result is ASHYI-EDU, a dynamic adaptive planning system for virtual learning environments. ASHYI-EDU is a Java-based application that enhances Sakai (Apereo-Foundation, 2014), a virtual learning environment software, to provide personalized education to students.

ASHYI-EDU addresses several issues in the teaching-learning process. First, teachers need to develop plans that convey knowledge, abilities, and competencies to students. Those plans comprise several learning activities that students must perform to reach specific learning goals in a course. Since students are heterogeneous, they may benefit more from some type of activities and less from others.

For instance, some students prefer to learn by executing practical activities, while others would learn better by doing theory-intensive activities. Some students may prefer to learn by visual means (e.g. diagrams, images, etc.), while others may prefer to obtain the information in textual means.

Consequently, to provide the best learning path to each student requires that the teacher creates different plans, each of them providing the best activities for each student, depending on their specific characteristics and preferences.

In practice, this is a complex task. A teacher would have to: (1) Understand the specific characteristics and preferences of each student, (2) determine the best activities for each student depending on the information of (1) to create a custom plan for each student, and (3) monitor the execution of each custom plan. Without the help of technologies, the above task would be very time consuming for teachers.

The above issues are the motivation to develop ASHYI-EDU. ASHYI-EDU provides a set of tests to assess student characteristics and preferences. It characterizes activities, based on their suitability for different student attributes and automatically creates plans with activities that are the most suitable for the students' learning processes.

ASHYI-EDU is able to recognize changes in the student attributes, usually yielded by the successful learning of specific abilities or competences. Using this information, ASHYI-EDU can automatically create a new plan that is more suitable to the student. Moreover, the system is also able to provide remedial activities to the student if he/she needs them to successfully complete the rest of the activities in the plan.

Figure 1 summarizes ASHYI-EDU planning and execution. The first activity is to (1) configure the virtual learning environment, in which the teacher specifies the course structure and all the possible activities and resources that can be utilized to fulfill those goals (2). The second activity is the course planning itself (3), in which the system automatically selects activities and creates a meta-plan (4), i.e., a structured description of all the possible adapted plans that could be assigned to students. When students are going to interact with the course, they have to complete personality and learning style tests (5), which provide the information for their profiles (6). The system automatically assigns (7) students a custom plan (8) that is best suited for their characteristics. The last activity is the execution (9), in which the student performs the assigned activities, the teacher evaluates the results of the activities (10) and updates the student profile (11). If the student profile (12) changes, the system automatically creates a new plan (7).

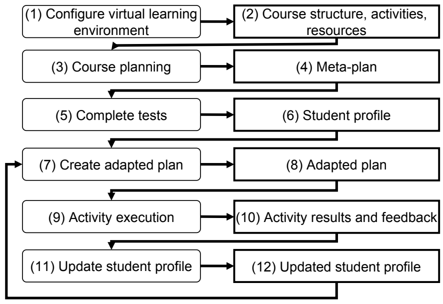

Figure 1: ASHYI-EDU planning and execution.

The rest of this section describes each of the above elements in detail.

4.1 Configure Virtual Learning Environment

This activity is performed before beginning any course in the system, and focuses on creating all of the essential course elements: learning units, learning goals, activities, and resources.

ASHYI-EDU assists teachers in creating the above elements by providing the basic data structures to specify learning units and learning goals, and providing a searchable repository of activities that the teachers must fill before initiating any course.

4.2 Course Planning

After the basic course structure is created and a sufficiently large pool of activities has been created, the teacher must perform two main activities: preselecting activities and resources and creating a meta-plan

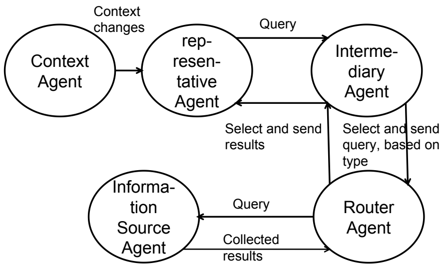

Figure 2: Overview of PUMAS-LITE.

that describes all of the possible plans that could be executed by students. Both activities are described as follows.

4.2.1 Activity and Resources Selection

One of the key elements in course planning is the selection of all of the activities and resources that are aligned with the course goals and learning units. ASHYI-EDU provides a repository of activities and resources that teachers can fill to utilize in one or more courses. Since the repository can be shared by multiple users, other teachers may contribute with activities and resources that can be aligned with the learning goals of the current course. To properly preselect the available activities and resources, ASHYI-EDU provides PUMAS-LITE, a java-based subsystem that utilizes agents to search the repository according to different criteria: keywords, learning goals, among others.

PUMAS-LITE is a lightweight version of PUMAS (Carrillo-Ramos et al., 2007), a multi-agent system for knowledge management and adapted information retrieval with a focus on ubiquitous environments. PUMAS provides four multi-agent systems that support the location of resources in an ubiquitous system: a multi-agent system in the client device, another one on the server-side that performs adaptation and search, a third one that acts as a middleware between the two, and the last one that performs adaptation.

PUMAS was instantiated into the educational domain as PUMAS-LITE, focusing only on the server-side multi-agent system. Figure 2 is an overview of PUMAS-LITE. There are five agents:

Context Agent, which is aware of the user execution environment and reacts to its changes. There is one Context Agent per user.

Representative Agent, which represents the student within PUMAS-LITE and manages the student profile. There is one Representative Agent per user.

Intermediary Agent that is in charge of receiving and collecting queries from different representative agents, selects those queries and pass them to a Router Agent. There can be several Intermediary Agents in the same platform.

Router Agent that is in charge of receiving queries from the Intermediary Agent and searching for an information source that could totally or partially satisfy the query. Once the source is found, the router agent communicates with the Information Source Agent to retrieve the answer to the query.

Information Source Agent, which contains the information required to answer a given query. This agent explicitly searches among the activities and resources of the information source, manages their location, and provide the required answers to the Router Agent.

Agent interaction occurs under two main processes.

Query, in which the Representative Agent receives the query from the user. The latter enriches the query date with the user profile (provided by the Representative Agent) and the context data (provided by the Context Agent). The Intermediary Agent receives the enriched query, which categorizes the query according to its type (SQL, keyword search, etc.). The Router Agent receives the categorized query and finds the relevant information sources and sends the query to the corresponding Information Source Agent.

Results Retrieval, in which the Information Source Agent executes the query and sends the results back to the Router Agent, then to the Intermediary Agent and to the Representative Agent. The latter asks the Context Agent to determine if there were any context changes. If there are no context changes, the results are returned to the user, otherwise the query is run again with the new context information.

4.2.2 Meta-Planning

PUMAS Lite selects a set of candidate activities for the given course goals. The next step is create a *meta-plan*, a compact structure that contains all of the activities and is organized in such a way that all of the adapted plans can be extracted from that structure.

In many cases, activity planning through algorithms, such as GraphPlan, requires each activity to have pre and post conditions, which are the conditions required to perform the activity and the assertions that must be true after successfully executing the activity, respectively (Blum and Furst, 1997). In these kinds of algorithms, the activity precedence is not known before the planning algorithm is executed.

However, in the educational context, to define pre and post conditions can be a tricky task. Teachers must define several activities and ensure that they can

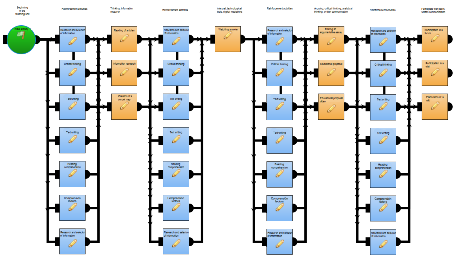

Figure 3: Meta-plan example.

be chained in many different ways to have a sufficiently broad set of different plans for the various students in their courses. Moreover, in the educational context pre and post conditions are often not strict. In many situations course activities can be performed by students even though they may have not fully meet the activities' requirements. In other cases, when course activities require more strict pre-conditions, the student may perform remedial activities before executing the course activity

Taking all of the above into account, ASHYI-EDU's meta-plan uses a non-strict approach for pre and post conditions and a slightly more structured way to organize activities in the meta-plan. The essential premise is that course goals are accomplished in a specific sequence during the course. Therefore, the precedence of course activities is given by the goals to which they are aligned.

It is important to note that each activity may have different alternative resources (e.g. files, URLs) that the student may utilize in case the main resources are not available. To represent this information in the meta-plan, each node in the graph corresponds to a combination of a given activity with one of the main or alternative resource. In other words, the graph may contain one or more nodes that correspond to the same activity, but utilizing different resources.

To better illustrate the approach Figure 3 shows an example of a meta-plan in ASHYI-EDU. Activities and resources are organized in a multi-partite graph, in which each partition is denoted as a column. Orange-colored nodes correspond to course activities, while blue-colored ones correspond to remedial activities. A *course activity partition* is a column in the graph containing orange-colored activities that focus on the same course goal. A *remedial activity partition* is a column of blue-colored activities that is placed in between course activity partitions. The green node at the left side of the graph is not an activity, but the start node in the graph, the node from which all of the adapted plans will begin.

Each partition is fully connected with the next partition. In other words a course activity partition is fully connected to the next remedial activity partition and each remedial activity partition is fully connected to the next course activity partition.

In addition, each course activity partition is also fully connected to the next course activity partition. In other words, a course activity partition that corresponds to a given course goal is fully connected to the course activity partition of the next goal. For simplicity, these connections are not shown in the figure.

4.3 Creating Adapted Plans

The meta-plan holds all of the possible adapted plans for the course. After creating the meta-plan, the next step is to obtain an adapted plan for each student. An essential piece of information in this stage is the student profile.

To obtain this information, ASHYI-EDU measures personality traits and learning styles of the students. To measure personality, ASHYI-EDU utilizes the Myers Briggs personality test (MentiScore-Solutions-Limited, 2014), which profiles students according to 16 personality traits. A student may express these personality traits in different degrees. To measure learning styles, ASHYI-EDU utilizes the Honey-Alonso Learning Styles Questionnaire (Alonso et al., 2009).

After the student answers the above tests, the student profile is complete and ASHYI-EDU is able to create the adapted plan for the student.

Recall that an adapted plan corresponds to a path from the start node on the left side of the meta-plan graph to any node in the last column of the right (see Section 4.2.2). Figure 4 depicts an adapted plan obtained from the meta-plan and a student profile. The best plan for a given student corresponds to the shortest path in the meta-plan graph, represented as the non-gray nodes and the green connections. For illustrative purposes, the nodes in the optimal route are zoomed in, but in the real application they have the same size of the other nodes. The function that determines the weights depends on student and activity information. Therefore, edge weights will be different from one student to another and the optimal path might differ from one student to another. This ensures that each student will obtain a personalized learning plan.

The learning plan determines the order in which activities should be performed by the student, starting from the activities on the left side and ending on the activities on the right side. Sometimes, activities may require the student to previously develop some abilities or competencies to properly execute those activities. ASHYI-EDU is able to detect when a student

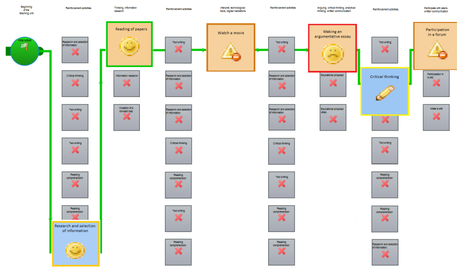

Figure 4: Adapted Plan Example.

does not meet those requirements, and plans accordingly. In those cases, ASHYI-EDU will include remedial activities in the plan, so that the students can develop those missing abilities and competencies before performing the activity that requires them.

Another important feature is that ASHYI-EDU takes into account the changes in the student during the execution of the plan. For instance, a student may learn new abilities or competencies after successfully executing a given activity. The adapted plan created by ASHYI-EDU assumes that the student successfully executes every activity. Changes in his/her profile after each activity are taken into account to determine the affinity with the remaining activities in the meta-plan.

If, for some reason, the student does not successfully executes an activity, ASHYI-EDU is able to create a new plan that takes into account this situation (see Section 4.6).

4.4 Matching Students to Activities

To determine the best learning plan for a given student, ASHYI-EDU must select the most suitable activity for the student to accomplish each learning goal. This selection is based on the affinity between the student and each activity. This affinity if obtained from the edge weights in the meta-plan graph. The weight of an edge between two nodes in the graph represents the affinity between the student and the activity to which the edge is pointing (i.e., the activity on the right side of that edge).

To calculate the edge weights, ASHYI-EDU utilizes a *distance function* that yields a value that is inversely proportional to the degree of affinity between a student and an activity. Consequently, the shortest path in the meta-plan will yield the set of activities that have the most affinity to a given student.

The distance function takes as input a student vector and an activity preconditions vector. Both vectors have the same structure, summarized in Figure 5. Each vector has 55 components, each one representing a specific attribute. The values range from 0,

Learning styles	Personality traits	Skills	Competencies
[1,4]	[1,16]	[1,19]	[1,16]

Figure 5: Student and Activity Vector.

which means the total absence of a given attribute, to 1, which means a strong presence of the attribute. The first 4 components correspond to learning styles, the next 16 components are personality traits, the next 19 are abilities, and the last 16 are competencies.

For students, the vector components represent the degree of a certain learning style, personality trait, ability, or competency is present in each student. For instance, a value close to 1 in a learning style means that the student has a strong preference to learn using that style. Similarly, a value close to 1 in a personality trait means that the student strongly manifests that trait. A value close to 1 in an ability or competency means that the student has significantly developed that activity or competency.

In an activity, the vector represents a non-strong set of preconditions. To be more precise, the activity vector represents the degree of suitability of the activity for students who have a certain set of attributes. For instance, a value of 1 in a learning style or personality trait means that the activity is highly suitable for students who have a high preference for that learning style or strongly manifest that personality trait. A high value in an ability or competency means that it is highly recommendable that the student develops that ability or competency to successfully execute the activity.

Some vector components have continuous values between 0 and 1 (learning styles), while others may assume only the values 0 or 1, but no values in between (personality traits, abilities, and competencies). Because of these differences, the distance function d is a weighed average of different distance functions:

$$\begin{aligned} d(S,A) &= w_l d_l(S,A) + w_p d_p(S,A) + \\ &\quad w_a d_a(S,A) + w_c d_c(S,A) \end{aligned}$$

Where S is the student vector, A is the activity vector, d_l is the euclidean distance between learning style components of S and A, d_p is the euclidean distance between personality trait components of S and A, d_a is the Jaccard (Candillier et al., 2008) distance between ability components of S and A, d_c is the Jaccard distance between competency components of S and A, and each w_i corresponds to the weight of each distance metric in the final result.

Figure 6: Adapted Plan as a List.

4.5 Adapted Plan Execution

Figure 4 is an example of the way ASHYI-EDU displays an adapted plan for a student. The adapted plan corresponds to the optimal route in the meta-plan graph and represents the set of activities that are more alike to a student.

The student can also visualize his/her own adapted plan as a list, as shown in Figure 6 (the figure is cropped for space reasons). Different icons denote the various states of each task. Pending activities have an hourglass icon. Available activities are marked with a pen icon. Activities that have been finished have either a happy face or a sad face icon, depending on the teacher's feedback.

The student can execute this plan following these steps:

1. Access the activity form in Figure 7 and download the resources to execute the activity, which can be files or URLs.
2. Follow the instructions and execute the activity.
3. Access the activity form (see Figure 7) and complete two fields: the file to upload with the answer to the activity and the feedback to send to the teacher.
4. The teacher evaluates the activity thereafter and provides feedback to the student through the same form. The teacher can indicate the skills and competences achieved by the student, the grade, and the feedback to the student.
5. The student then receives the teacher's feedback and can execute the activities that become available after the teacher's evaluation.
6. The above steps are repeated until the student has executed the entire adapted plan.

4.6 Context and User Changes and Re-Planning

In some cases, things may not occur according to plan. For instance, the student may not successfully execute an activity, which means that he/she does not learn the expected abilities or competencies. In other cases, context changes may limit the access to certain resources. For instance, the student may be trying to access the activity resources from outside the university and may not have access to services protected behind the university's firewall. These situations may require to provide alternative activities or resources so that the student can execute the plan successfully.

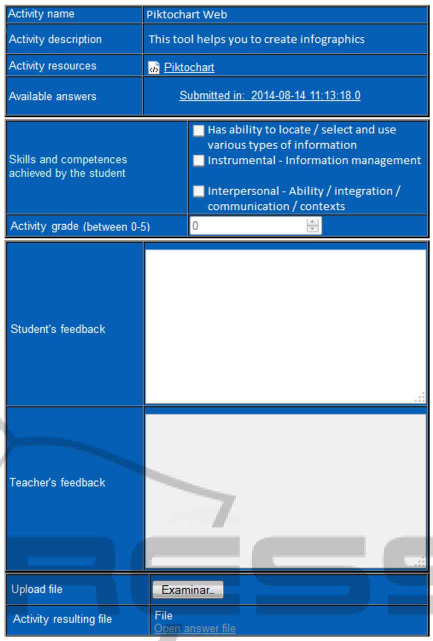

Figure 7: Activity Form.

To address the above issues, ASHYI-EDU is able to automatically detect changes in the student profile or in the context and create a new plan. To perform re-planning, ASHYI-EDU updates the user profile and the meta-plan with the corresponding changes and executes the planning algorithm with this new data. The result is a plan that is best adapted to the new scenario.

Currently, ASHYI-EDU is able to perform re-planning based on the following scenarios:

1. The student did not learn the expected abilities or competencies after the execution of a given activity. In this case, ASHYI-EDU updates the student profile accordingly and creates a new plan that includes activities more alike to the student in this new scenario. This new plan may also include additional remedial activities.
2. The student is not able to access a given resource. For instance, if the student is outside the university and he/she needs to access an internal service of the university that is protected by a firewall from the outside. To address this case, ASHYI-EDU disables the nodes that contain the inaccessible resources and executes the planning algo-

rithm again. Recall that multiple nodes in the meta-plan graph may contain the same activity, but with different resources (see Section 4.2.2). Therefore, some activities can still be included in an adapted plan if they are associated with available resources.

3. The teacher decides to cancel a specific activity or make it unavailable to students. In this case, ASHYI-EDU removes all of the corresponding nodes from the meta-plan graph and executes the planning algorithm again. Recall that several nodes in the meta-plan graph may have the same activity, but different resources (see Section 4.2.2). Therefore, all of the nodes containing that activity must be removed from the graph.

5 CASE STUDY

To validate ASHYI-EDU, we are currently developing a case study in a university course for students of the career of Primary School Teacher. The course is called "Learning to Learn in the Web". This course utilizes blended learning and its goal is to give the students tools to learn in the web.

This course is being taught each semester to different groups of students.The case study spans through three semesters. The first semester (Spring 2014) included an offline course that did not use ASHYI-EDU and relied only on manual procedures to create adapted plans and interact with students. The second semester (Fall 2014) includes an online course that utilizes ASHYI-EDU to manage the entire course planning and student-teacher interaction. The third semester (Spring 2015) will include a course utilizing ASHYI-EDU in the same way as the second semester.

5.1 Course Structure

Figure 8 denotes the structure of the course in all of the three semesters. The course has several goals that students should satisfy after finishing the course. To satisfy those goals, the course comprises three learning units. Each learning unit has a set of goals that must be satisfied and a meta-plan with the activities to satisfy those goals. The first learning unit has 4 goals, the second has 3 and the third one has 4. Each activity in the meta-plan is either a course activity aimed to satisfy one of those objectives or a remedial activity.

5.2 Offline Course

This course is called *offline* because it was taught face-to-face to students without the help of a virtual learning environment. The teachers evaluated students and created adapted plans manually.

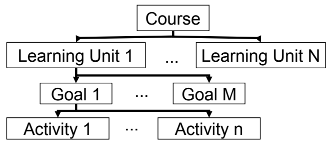

Figure 8: Course Structure.

Table 2: Student Characteristics in the Offline Course.

Student	Active	Pragmatic	Reflexive	Theoretical	Personality
E1	7	8	12	8	ENTJ
E2	10	17	17	18	ENFJ
E3	17	16	18	17	ESFJ
E4	7	18	19	16	ENFJ
E5	12	12	10	6	ENFJ
E6	7	14	18	14	ENFJ
E7	14	15	16	17	ENTJ
E8	10	13	13	13	ENTJ

The course had 32 students, from which only 8 filled the tests to define their profiles. They were from different careers: Middle School Spanish Teaching Licentiate, Accounting, Psicology, and Information Sciences.

Table 2 shows the characteristics of the students who took that course. Columns 2 to 5 correspond to learning styles scores, where the maximum value is 20. The last column correspond to personality traits, where E means Extroverted, N means Intuitive, S means Sensing, T means Thinker, F means Feeling, and J means Judging.

As shown in that table, there are students who have different learning styles and personality traits. Most students have high preferences for Reflexive and Theoretical styles, while fewer ones prefer Pragmatic and Active styles.

Table 3 summarizes the results of the execution of the first learning unit. Grades are in a scale of 0 to 5. The teachers determined that the low performance of some of them was because of lack of reading comprehension and writing skills. Therefore, they proposed a set of remedial activities to address these issues.

5.3 Online Course

The online course was performed the following semester after the offline course (Fall 2014). Most of the online course is based on the offline course. The online version adds more activities, so that each learning goal can have several alternative activities to achieve it.

Table 3: Results of the first learning unit.

Student	Grade	Grade Analysis
E1	3	Did not execute all activities
E2	3.2	Incomplete work. The student didn't do what was asked for
E3	1	Incomplete work. The student didn't do what was asked for, writing errores
E4	5	
E5	5	
E6	4.6	Does not clearly express ideas
E7	4.4	Does not clearly express ideas
E8	2.5	Incomplete work. The student didn't do what was asked for. Does not clearly express ideas

The study of that semester involved all of the course 29 participants: 6 men and 23 women. The students were from different backgrounds: Education, Accounting, Information Sciences, Psychology, Software Engineering, Business Administration, and Microbiology.

A prototype of ASHYI-EDU was created, which utilizes Sakai (Apereo-Foundation, 2014), a Java-based virtual learning environment software. The implementation of ASHYI-EDU relies on a modified version of Sakai's Lesson Builder component that includes dynamic activity planning to build learning units and its lessons and a simple interaction facility for students and teachers.

The development of the online course focuses on automatically performing several tasks that were slow or cumbersome in the offline course: i) providing adapted plans according to the necessities of each student, ii) automatically re-planning according to context changes, and iii) register the interaction between users and the system.

The ASHYI-EDU prototype provides several features to facilitate the creation of dynamic adaptive plans and monitor their execution. Recall Figure 3 that shows the meta-plan of a learning unit that is built by the teacher. The teacher can create, modify or remove activities from the meta-plan and the system will automatically organize them according to learning goals and activity type (course or remedial).

A student that begins a course must complete the Myers Briggs personality test and also the Honey-Alonso Learning Styles Questionnaire tests. ASHYI-EDU uses this information to fill the student profiles and to automatically create adapted plans for each student.

ASHYI-EDU is able to provide different plans for different students, according to their specific characteristics.

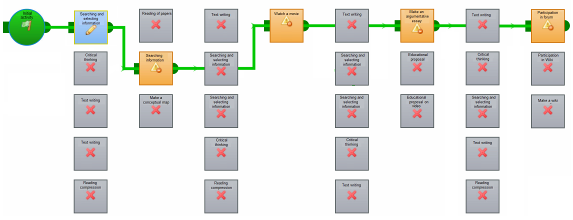

Figure 9: Adapted Plan for Student A.

Figures 9 and 10 correspond to adapted plans for Student A and B, respectively. For space reasons the chosen examples are not radically dissimilar but in practice two students may have very different plans. In this example they have two important differences:

Remedial activities: ASHYI-EDU did not plan remedial activities for the Student A, while it planned a remedial activity, called Information Search and Selection (shown in blue) for Student B. This activity aims to develop analysis and synthesis abilities in the student. ASHYI-EDU assigned the remedial activity, because the student lacked these abilities for the first course activity.

Course activities: To accomplish the first learning goal (second column in both graphs), to analyze, reflect and understand the information search process, ASHYI-EDU assigned Student A a paper reading activity to develop reading comprehension abilities, while the Student B must perform information search to learn critical thinking and analysis and synthesis abilities. These activities were assigned according to the student learning styles and personalities:

Student A: Learning Style: Active - level: 6, Pragmatic - level: 7, Reflexive - level: 15, Theoretical- level: 12; Personality: INFJ; Skills: understanding, relate their reality with the environment, interpret and analyze information, observation, generates own answers from their knowledge and experience.

Student B: Learning Style: Active - level: 15, Pragmatic - level: 19, Reflexive - level: 19, Theoretical- level: 19; Personality: ENFJ; Skills: understanding, observation, generates own answers from their knowledge and experience, shows interest and initiative to continue learning, agility and adaptability, empathy, and global vision, interpersonal relationships and managing emotions and feelings.

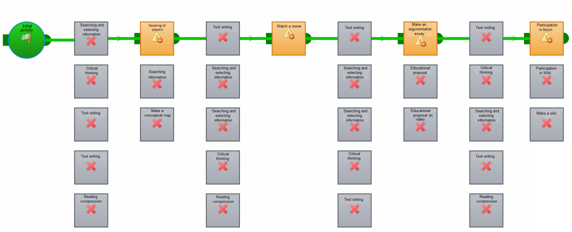

Figure 10: Adapted Plan for Student B.

5.4 Current Results

Students were interviewed to determine their satisfaction with the online course. The overall responses were positive. The students expressed that the course helped them to understand the way they approach to learning in the course, which learning styles are the most important in their learning process, and the most adequate activities for them. The students felt more identified and comfortable with the activities that they performed. Similarly, they felt that the inclusion of remedial activities helped them to improve their performance.

The online course has only been applied to one group of students. The case study will yield more detailed results after finishing the Spring 2015 course, which will yield results that could be compared with Fall 2014.

From the point of view of the teachers, one important change is the amount of effort to create the course content. While a traditional course may need only one type of activity per learning goal, ASHYI-EDU, requires several activities per learning goal. Another important change is that teachers require to characterize each activity to determine how alike are them to specific types of students. The above requires a high initial effort to create the course. However, the repository provided by ASHYI-EDU has the potential of reducing this effort by facilitating reuse of existing material.

6 CONCLUSIONS AND FUTURE WORK

This paper presented ASHYI-EDU, a system to perform dynamic adaptive planning in virtual learning environments. ASHYI-EDU captures the essential student characteristics through a series of tests and is able to create adapted plans that are the most aligned with those characteristics. ASHYI-EDU is also aware of changes in context and is able to dynamically modify existing plans to make better plans for new constraints.

The feedback obtained from the students suggest that ASHYI-EDU is effectively assigning the most alike activities to each student, based on their specific abilities, competencies, personality traits, and learning styles. The feedback of the students about remedial activities suggests that the automatic assignment of remedial activities effectively addresses learning needs of the students. Overall, it means that ASHYI-EDU has the potential of improving the teaching-learning process.

It is important to note that the student-activity matching process is as good as the information in the student and activity profiles. Further validation of the proposed approach requires: to ensure that the tests utilized to build the student profile are the most effective ones to capture the student characteristics, and that the activity profiles are effectively the most adequate for certain types of students.

Overall, the proposed system is able to provide a fine-grained personalized learning plan to heterogeneous students, which takes into account more information than existing approaches. Another advantage over related work is the ability to re-plan based on context and user information, while ensuring that each student has the best learning plan possible at all times. Lastly, the ability to select remedial activities for students facilitate even more the learning process, to ensure that student have the required abilities and competences to complete all activities in a learning unit.

Future work is to complete the first and second semesters of the online course, analyze their results and finish the validation of the proposed approach.

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