AES: A Generic Framework for Adapting Information in Multidimensional Contexts

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Abstract

Access and management of current information systems involve important challenges. Users may receive huge amounts of information that are not always relevant for their needs and characteristics. This problem worsens in mobile environments due to their access devices. Under these conditions, it is very difficult to provide adapted information according to the users' context. In order to adapt the information delivered to a user, it is necessary to identify: *i)* the most appropriate sources that will answer a query and *ii)* information to enrich the services invoked for obtaining the desired results. This paper focuses on the second aspect. The enrichment information can be obtained from the context in which the interaction between the user and the system takes place. However, it is difficult to find a generic environment to adapt information in any kind of scenario, because of the varying users' needs and the conditions of their interaction with the system. This paper presents the ***A***gents for ***E***nrichment ***S***ervices (*AES*) model, a generic framework to adapt information. Applications can use *AES* to enrich services and retrieve information that best suits the user's needs, context and characteristics.

Keywords: Adaptation, Agents, Profile, Context.

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1. Introduction

Adaptation is the process of enriching a service to provide information according to the needs of a user in a specific context. Enrichment is achieved through the addition of characteristics that are selected from a group of features that might influence the user interaction with the system. Characteristics are obtained from different high-abstraction processes, such as inference, deduction, information processing, among others. As a consequence, the application that uses the service obtains more information for refining the service invocation.

Adaptation focuses in solving the problem of cognitive overload that users suffer when receiving huge volumes of data from existing information systems. Many of these systems do not consider the preferences of the user, what they like or just what they are searching. They just send the same information to all of their users. Additionally, these systems do not address user mobility (user location and device) to provide information. Adaptation provides customizable information to minimize those huge volumes of information, through the selection of the appropriate information to the user, considering his/her location and access device.

Existing tools for information adaptation are strongly dependent of specific scenarios or applications, which limits the application of those tools in other domains [1] [7] and do not address users nomadic characteristics (mobility and display problems) [12]. Overall, the main problem that motivates this research is that there are no generic computational tools to adapt the information in any kind of scenario, considering the mobility aspects of the user.

To address the above problems, this paper proposes the ***A***gents for ***E***nrichment ***S***ervices (*AES*) approach, a generic framework for adapting information in multidimensional contexts that addresses the mobility of the user. *AES* can be used by any application that needs to enrich services to provide information to users that is adjusted to their needs and context; in other words, an adaptation process. The main idea is that an external application sends an initial query request to *AES*.

Fig. 1 describes the overall approach. An *External Application* is utilized by the user to perform a query to a service. *AES* obtains relevant characteristics of the query (user, context, device profiles) and calls some filters to get high-abstraction information to generate an *Enriched query* that will be sent back to the *External Application*. Later on, *AES* receives feedback from the *External Application* in order to know if the enrichment was satisfactory and to update the profile information.

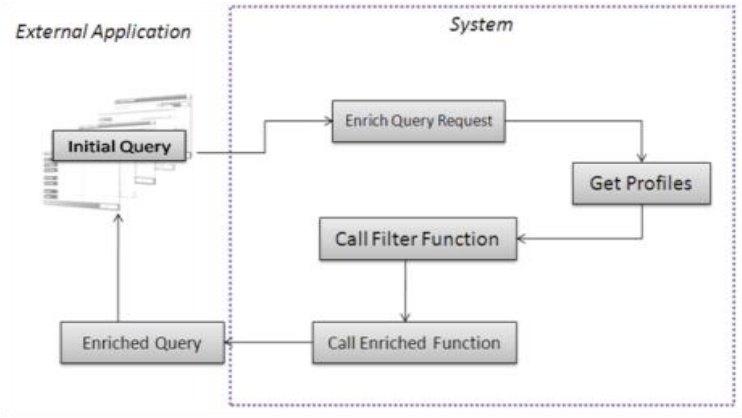

Fig 1. *AES* general operation

The remainder of the paper details the proposed approach. Section 2 presents *AES* and describes its architecture and a scenario of application. Section 3 presents the *AES* implementation. Section 4 presents a case study used to test *AES* functionality. Section 5 discusses related works on generic adaptation systems and contrasts them with *AES*. Section 6 concludes and describes future work in this research area.

2. Agents for Enriched Services - *AES*

The requirement of providing the user with information tailored to their features and needs, as well as its context[g], is the main motivation of creating the *AES* framework. *AES* addresses different features of the user, access devices, and context to provide relevant information in the right moment, place and device (mobile or not). *AES* was created by the Pontificia Universidad Javeriana [19]. *AES* is a generic agent-based adaptation system that can be used by other projects that need services enrichment to provide information according the user needs and context.

AES is part of a project called *ASMA*[h], an agent-based platform for application development built on *BESA* [11] that includes: *i)* an agent internal architecture which allows concurrent behavior, *ii)* asynchronous event-based communication between agents, *iii)* cooperation and social structure between agents. *ASMA* and *BESA* facilitate the development of complex applications, because they divide the problem in independent modules. Interactions between modules are clearly structured and specified. Also, *BESA* allows a distributed deploy of the system.

[g]For this paper, context refers to the set of features that can influence the user's interaction with the system [9].
[h]*ASMA*, acronym in Spanish of Architecture for MultiAgent Systems

Programmers that built *AES based applications* must define the adaptation mechanisms and filters to be utilized by AES to generate a new *Enriched query*. This approach guarantees that *AES* can respond adequately, according to the business rules (independently of the external application that uses the framework), allowing *AES* to be used by different systems and scenarios that require service enrichment.

2.1. Architecture

Figure 2 depicts the *AES* architecture with its inputs, outputs, components and relations. The components that are represented with circles are active components, while the components that are represented with rectangles are passive components.

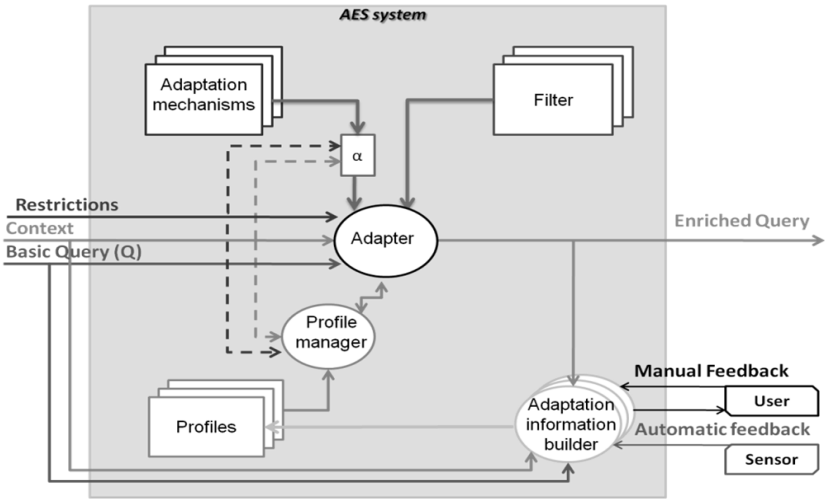

Fig. 2. *AES* model

Inputs:

The *Basic Query* (*Q*) that the user (*e.g.*, application, person) makes to the adaptation module is the first input to the system. Additionally, external information can be act as an input (*Context*), such as the access device used, the environment characteristics or location in which the interaction of the user takes place, among other characteristics.

Due to the interaction of the user with the system, context variables may be affected by some boundaries or constraints. Those elements, called *Restrictions*, can also be an input to *AES*. Finally, there are two kinds of feedback given to *AES*: a *Manual Feedback* given by the user through evaluation GUI and *Automatic Feedback* obtained from observations made by an external system related to the quality and the expectations on the output.

Outputs:

AES outputs an *Enriched Query*. If the original query cannot be enriched, the *Enriched query* will be the same as the input query. The enrichment can include the modification of the original query and/or the addition of useful information derived from the adaptation process.

Passive Components:

Passive components are not autonomous and they must be invoked as methods. These components are:

a) *Adaptation mechanism*: adaptation libraries to enrich the query *Q* that comprises an enrichment function and a list of filters that can be handled by the enrichment function. b) *Adaptation mechanism Selector* (α): component responsible for selecting the enrichment function. c) *Filters*: function(s) that generate highly-abstracted information to enrich the query *Q*. Its parameters correspond to a profile list of the same category and determines, through subcategories, which field of the profile is used to filter information. d) *Profiles*: corresponds to a set of relevant features that represent concepts. A profile has a category (for example: user, location, device, group) and fields (for example: name, description) that are represented as subcategories, and an *ID*.

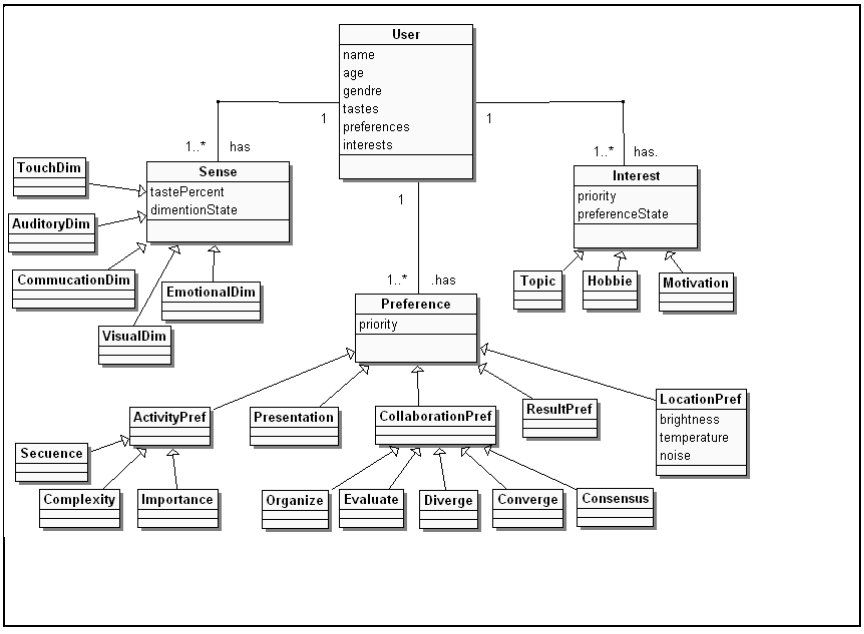

Fig. 3. User Profile Example

Figures 3 and 4 are examples of *Profiles*. Figure 3 is a profile that contains relevant features of a user, such as his/her basic data, preferences (information on how the user

wants something or multiplayer options, for example, outcome preferences, collaboration, presentation, localization and activity), tastes (sensations perceived by the senses), and interests (activities that prompt the user some sort of concern as: motivations, hobbies and topics). Figure 4a is a profile that contains environmental features according to the interaction between the user and the system, such as user location, infrastructure (physical description of the place), available resources (supplies that may be personal, computer and / or communication type), social (beliefs and customs of the user environment), and political (conditions, restrictions and sanctions). Figure 4b is a profile that contains relevant features of the user device, such as connection type, hardware (screen resolution, memory, processor and autonomy), software (browser, applications and operating system).

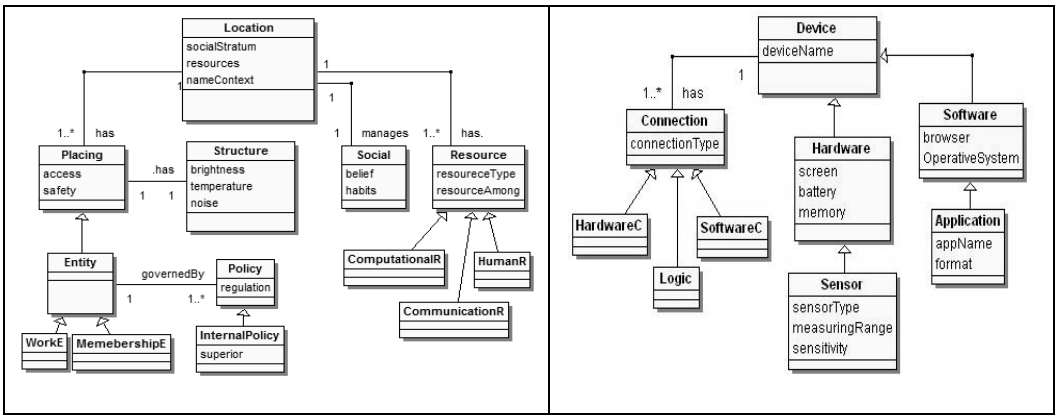

Fig. 4 (a) Location Profile Example; (b) Device Profile Example

Profile definition depends on the system that will use the framework *AES*. *AES* generic profiles can be refined considering the specific information needs that will be used by the specific application to enrich its queries. Each *Filter* has a category that corresponds to a profile type; *Filters* are applied only if the filter type matches the profile type. Internally, each profile characteristic is represented as a tuple (*attribute*, *value*, *number*), where the *attribute* represents an aspect to be evaluated (*e.g.*, color). An attribute can assume different *values* associated to the context in which the user interacts with the system (*e.g.*, red). *Number* corresponds to the quantification of the priority value of that attribute. A *number can be obtained* from user beliefs (*e.g.*, the user says he likes red 75% of the time) or can be deduced from the interactions between user and system (*e.g.*, the system can deduce that as the user has chosen to change the background color to red 40% of the time, his/her favorite color is red with a probability of 40%).

Active Components:

Active components are autonomous proactive components that communicate among themselves and have the ability to invoke the passive components. These are:

a) *Profile Manager*: considers adaptation information needs of the *Adapter*, this component looks for the *profiles* to extract information and return it to the *Adapter*. b) *Adaptation Information Builder*: element whose purpose is to provide feedback and update the *profiles* through *Manual Feedback* and / or *Automatic Feedback*. These updates may correspond to a base value or a set of deductions and they are implemented by the method "*update*". The parameter of this method is the information from the *Manual Feedback* and / or *Automatic Feedback* (whose source may be from the user, a sensor or extra resources), the category of a profile, the instance identifier and the feature(s) of the profile to modify. c) *Adapter*: this is the main component of the system, responsible for using all of the components to enhance the request (*i.e.,* to generate the *Q enriched* from the *Q* and Adaptation Information.) This component provides the parameters (*profiles*) to the filter. This *Adapter* gets the *profiles* with a request to the *Profiles Manager*.

2.2. Test Scenario

In order to build a test scenario of the system functionality and to prove the models interactions, the test case of a query of a student on a particular subject was analyzed.

Let's suppose the student John wishes to make a query regarding macroeconomics (*Q*). John is in the Building 1 and he accesses the system through his cell phone (*Context*). This time he only requires *PDF* electronic books or articles on the subject (*Restriction*). The profiles that the system stores are: student, location (structural and environmental in classrooms, auditoriums, laboratories, *etc.*), and device (cellphone, computers, laptops, *etc.*). From these profiles the system will select those that will be used to enrich the basic query (*Q*) through the *Profile Manager*. In this specific case, the selected profiles are John's user profile, the Location profile of Building 1 and the device profile that corresponds to the cellphone John is using to access the system.

The first filter receives John's profile and deduces that John is an expert on the subject and that he learns better when the information comes in a visual way. The second filter receives the Building 1 profile and returns that the building has a low signal affecting connectivity to the internet. The third filter receives the device profile and returns information saying that the device has a low screen resolution: CGA (*Filters*).

Considering that the student is an expert on the subject, he learns through visual stimulus, there is low connectivity and the access device has a low resolution screen, the system deduces that it should specify that books must be in advanced macroeconomics and the size of those books in KB must be small (Enriching Function). As a response from the enriching function and taking into account the Filters (user experience, cellphone connectivity), the system executes the Filters in a specific order: first the Location Filter then the Device Filter and finally the User Filter. The Location Filter shows the user has a low connectivity, low resolution device (320 x 200 pixels) and the user prefers PDF documents (established in the *Restriction*).

Since visual information is the kind of information that best fits John's learning method, the system deduces the *PDF* documents must contain graphics. John's location in building 1 says that his connectivity is not strong and the device resolution is low, the system deduces that the graphics and the PDF documents presented must be in low resolution and have a low size in KB (*Adapter*). The *Adapter* then produces an *Enriched query*: Books on macroeconomics with low resolution graphics in PDF format.

This test scenario can be seen in Fig. 5:

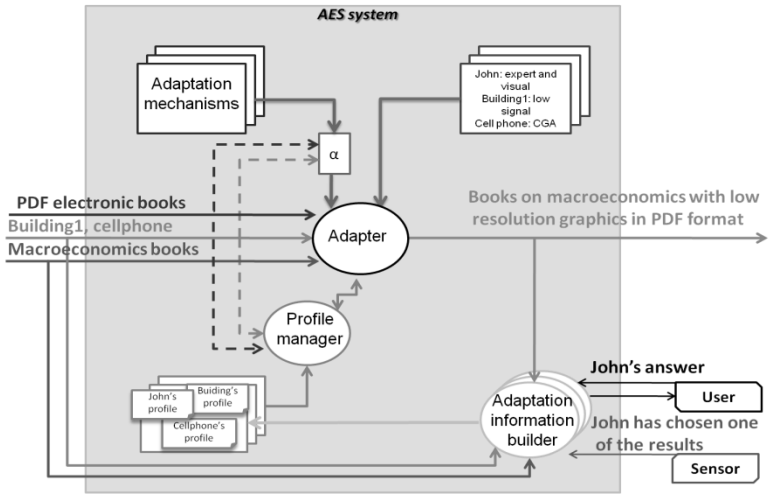

Fig. 5. Query of a student on a particular subject

In order to give feedback to the system and improve its adaptation process, it is necessary to validate and evaluate the level of expertise of the user (*Adaptation Information Builder*). To achieve this task the system checks if John has chosen one of the results provided by the *Enriched Query* (*Automatic feedback*). Additionally, it can evaluate through a test answered by John himself to determine how useful was the information for him (*Manual Feedback*).

3. Development

This framework was developed using the *BESA* platform [11], a platform made in the Systems Engineering department in the Pontificia Universidad Javeriana as a framework for multi agent systems development.

AES active components re-implemented by software agents, due to their artificial-intelligence capacity and proactivity that aids them in their goal achievement process. Passive components are resources that are not autonomous, resources that are used by software agents.

Two main agents were designed: *i)* the *Adapter Agent* that handles the creation of high abstraction information taken from filtering each profile with its respective filter and *ii)* the *AIS Manager Agent* that handles the storage and updates of every *profile*. The *Adapter Agent's* resources are *Filters* and *Adaptation Mechanisms* and the *AIS Manager Agent's* resources are the *AIS (Adaptation Information Source, a synonymous of profile)*. Furthermore, the *AIS Manager Agent* includes the functionality described above as the *Adaptation Information Builder*, taking into account the manual and automatic feedback.

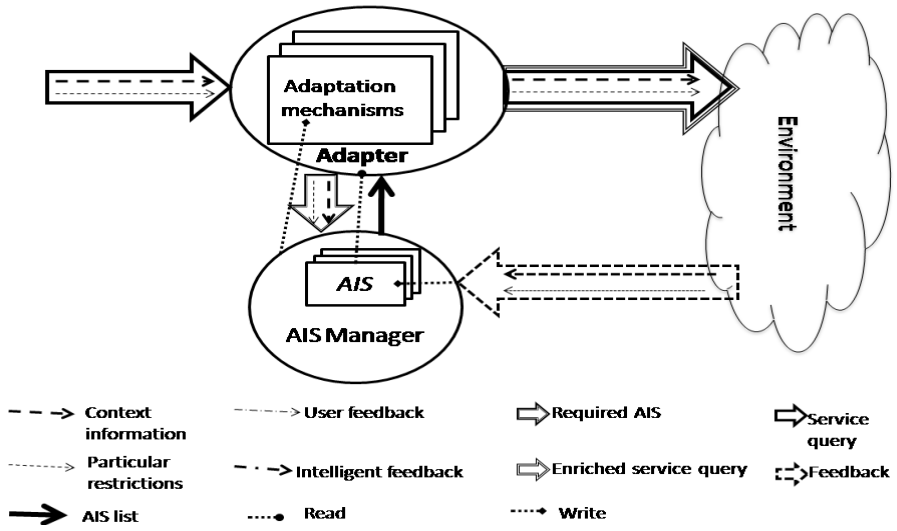

Fig. 6. Agent Model

The agents, depicted as ovals in Fig. 6, contain rectangles that represent pasive components. Passive components match the information they manage to fulfill their task (resources). The environment represented as a cloud corresponds to all of the external sources that use the enriched query and provide feedback to the *AES* framework.

The framework's components are *Filters*, *Adaptation Mechanisms* and *AIS (profiles)*. The logic of these components includes a basic functionality that can be used in any context. Besides, their logic can be extended to address the specific application needs where adaptation is required, taking into account their own business rules.

The framework receives as first input the *Query* (Q), the *Particular Restrictions* and *Context information*. These parameters are managed by the *Adapter Agent* through the execution of each *Filter* contained in the most adequate *Adaptation Mechanism*. The *Adapter Agent(s)* asks the *AIS Manager Agent* for the profiles needed in the filters, taking into account the *Context information* and the *Particular Restrictions*. After the execution of each *Filter* using the *AIS* returned by the *AIS Manager Agent,* the *Adapter Agent* collects all the different high-abstraction information produced by each *Filter* and combines them producing an *Enriched service query*. Once feedback is given to the system, the *AIS Manager Agent* acts as an *Adaptation Information Builder*, and using deduction it updates the affected *AIS* with the feedback in order to give a better adaptation service in the future. An *AES* implementation can be found in detail in [19].

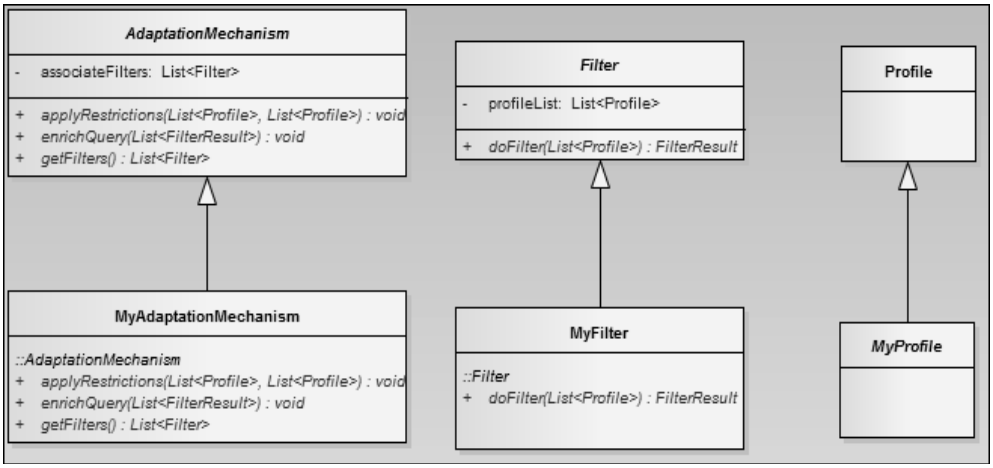

Fig. 7. Object Inheritance

The flexibility of the framework is based on Object inheritance, which allows the user to extend new classes from basic classes already provided overriding the key methods and attributes that the framework uses to enrich a service. Fig. 7 is an example of the way basic elements, *Filters*, *Profile* and *Adaptation Mechanisms*, can modify the basic attributes and operations of their parent classes in order to use the most suitable methodologies or technologies available in order to solve a particular adaptation need of an *AES framework* user.

4. *AES* Test Scenario

In order to prove the adaptation functionality of *AES*, this section presents the improvement of the information obtained using *AES* applied to the test scenario presented in Section 2.2. In this case, *AES* will enrich a Google query with relevant parameters according the user characteristics, with the purpose to reduce information overload on the user search.

4.1. Test Scenario without Adaptation

When a user enters a query into an information source, the results are not measured, *i.e.* based on their preferences, senses and interests. If John needs to consult macroeconomics books, he receives a lot of books no matter how expert John is, the best way that he learns, among other John's characteristics that could guide his search to what he really needs. For this reason, the information that John received from Google when he requests the query "macroeconomics books" is about the range of millions (exactly 8.130.000 results, see Fig. 8) and from Google Scholar, specialized on education, is about the range of thousand (exactly 70.500 results, see Fig. 9). These results are general and presented to any user who requests the same query, whether the user is on a mobile device or not.

Fig. 8. "Macroeconomics books" query in Google Academic

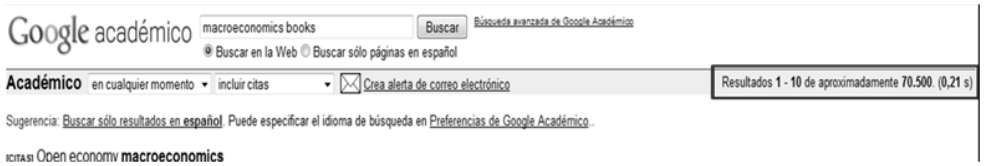

Fig. 9. "Macroeconomics books" query in Google

4.2. Test Scenario with Adaptation

Using the *AES* framework integrated with an information source (see Fig. 10), in this case Google and Google scholar, the number of results decreases drastically, so the cognitive overload decreases too. The results are more specific, since the

Enriched Query has information about the book format (.pdf), the expertise level of John (advanced) and device restriction (low resolution). John received from Google 6.410 results (see Fig. 11) and from Google Scholar 93 results (see Fig. 12).

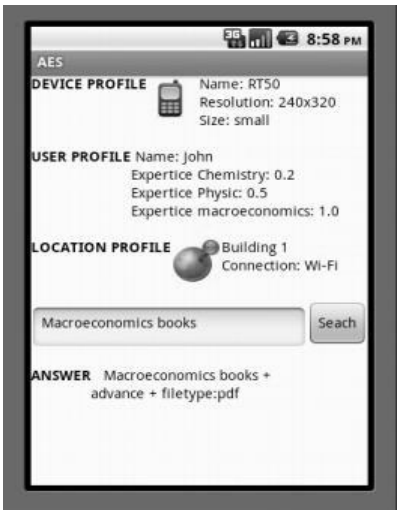

Fig. 10. *AES* mobile interface

In a mobile context it is possible to take into account the location in a more precise way by using the mobile devices as the *GPS* when it is available. For example building 1 may have low connectivity on the inside but in the immediate surroundings of building 1 the signal strength greatly increases. If a student uses the framework with a GPS it may help the framework to enrich a service with more precise information.

Fig. 11. *AES* mobile interface

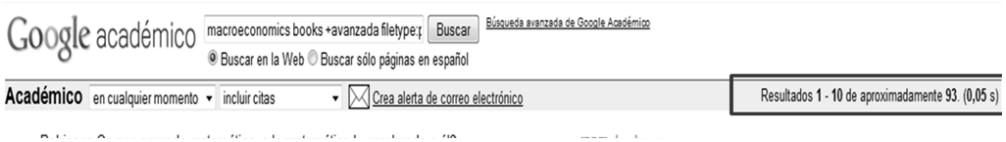

Fig. 12. *AES* mobile interface

It is important to note that: *i) AES* was tested in a mobile environment but the application that uses *AES* is the responsible to have the mobile interface and *ii)* the results can change depending on the device characteristics.

5. Related Work

Adaptation information is a process that considers different variables in order to generate changes in a particular entity for the purpose of enriching the required information. To do that, adaptation requires awareness of external conditions and the ability to change a behavior proactively in order to adjust to changing conditions. This section presents some related works about systems that adapt the information considering user context and mobility.

There are many frameworks that realize the adaptation process, such as the framework for Complex Manufacturing Systems in [17], the adaptive agents for auctions like [16], which use adaptation with agents applied on a specific problem [8].ATRACO [14] uses a more general approach based on ontology alignment, a process in which the equivalences in the knowledge between different entities is used to enrich a service. This approach is based exclusively on the use of ontologies, discarding other possible knowledge representation options and it's based on SOA architecture, which limits other possible architectural structures.

A different approach is the use of a large number of cooperative distributed agents [15] that make the enrichment of a service through sharing acquired knowledge in every agent, enabling agents to recognize user's needs and communicating them to other agents in order to improve the quality of the services according to the user needs. However, by having a large quantity of interacting agents, they must be well organized in order to achieve the goal efficiently. This is the objective of [4] who proposes to organize the agent's behavior using a quadratic or logistic map, adapting their interactions and the information stream according to their environment, so they can effectively share knowledge. Other authors such as [10] turn user preferences into instructions for agents and compiling them into neural networks so agents can learn from the user and enrich a service. Other frameworks such as *PUMAS* [3] enrich services based on user's preferences, historical information and technical constraints; through agents in a mobile environment.

Some frameworks called mobile applications are location–oriented and use this information to enrich a service. That is the case of WAZE [21], a social service that takes into account the location of every user in order to enrich a routing/mapping service. Another tool is MyCity [20] a tool that shows, using both location and information available in the user community, the enrichment of a tourist guide service. FriendZone [2] also takes into account the community information and the location information in order to determine if a friend is nearby, enhancing communication within entities. WAY [18] uses shared information to enrich the user

location service. However, this information is available to all of the users of the application.

Table 1 shows a comparison between different mobile apps and it shows a ++ notation where fields are heavily used to enrich a service, a + notation where fields are moderately used and a - notation in fields where no information is taken into account. The comparison criteria are as follows: i) Generic system: the application can be used in different scenarios, ii) Contextual information: the application considers context aspects such as location, infrastructure, socio-cultural characteristics, etc., iii) User information: the application considers user aspects such as preferences, senses and interests to adapt the information, iv) Access device information: the application considers access device aspects such as physical characteristics, hardware and software features, connections type, etc., v) Information representation: the application uses different representations to manage the information and can be integrated with other systems.

Table 1.Comparison between related works and *AES*

	WAZE	FriendZone	WAY	My City	*AES*
Generic system	-	-	-	-	++
Contextual information	++	++	++	+	++
User Information	+	++	+	++	++
Access device information	+	-	-	-	++
Information representation	Unknown	Generic.	Agents	Unknown	Generic

Even though many applications enrich services through shared information and using location as an input, their adaptation mechanisms are passive and do not provide the possibility of adding new parameters to the service enrichment based on custom information. *AES* considers these limitations and covers the need of creating an adaptation framework that can be applied in different scenarios corresponding to different domains, taking into account the user's characteristics, location and device at the same time.

6. Conclusions and Future Work

AES is a framework that can be used to adapt information in different kind of environments due to its ability of using generic filters and adaptation mechanisms. All of these components can be extended for the particular requirements of the service

that should be enriched. This characteristic makes the *AES* Framework a generic framework for adapting services using basic inputs and providing the user a transparent and customized experience. Its profiles can be refined considering the specific information needs of the application which will use *AES* to enrich its queries.

Future work includes integrating *AES* with different projects and make performance tests over the adaptation process in other scenarios (*e.g.*, health, enterprises and crisis managements). This work also includes using this framework in an agent based CSCW (Computer Supported Cooperative Work) framework focused on educational collaboration called *AYLLU* as a method to enrich different services that enhance cooperation between students and identify their learning style in order to present them the learning object that best fits their profile.

7. Acknowledgements

This paper is developed within the projects "*AYLLU: Plataforma de Cooperación mediada por Agentes aplicada en un Contexto de E-learning Colaborativo*" (COLCIENCIAS register No: 1203-489-25592 and contract CT 599- 2009). This project is supported by the Pontificia Universidad Javeriana (Bogotá, Colombia). We would like to thank Jaime A. Pavlich-Mariscal for his comments to this paper.

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