Context-aware recommendations in ubiquitous devices

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Abstract. Thanks to great technological advances occurred in the latest years, particularly in ubiquitous computing, users are able to perform almost any kind of application in small mobile devices. The diversity and heterogeneity in culture, educational background, age, characterize these users. In many cases, online recommendation is not only about the services offered, but also related to actions to take in a certain situation. This would be an added value for mobile device users. However, context-aware recommendation is still an open issue. In this paper we focus on this problem, particularly on the challenge of providing dynamic recommendations, that are calculated locally in the device, using only the data produced by the user in each situation (location, time, action). We present a component based model in which the role of the controller component is underlined. The controller has to deal with the generation of models dynamically in a resource-aware environment. We also present a modular architecture in which the ubiquitous data mining components are integrated.

1 Introduction

Since data mining research first appeared the number of references one can find in the literature related to solving the problem of recommendation are very numerous: recommendation of product in marketing problems, recommendations in e-commerce [14][5][15], recommender systems [6][2]. All the works related to this research is characterized by: i) recommendations made using global information ii) the process of data mining is performed in a centralized way. However, in mobile environments, one can find many situations in different domains where recommendations calculated locally and making use only of local data would certainly bring an added value. Let's think on a user in a vehicle where for some reason no connectivity is available and a recommendation is needed about the best road to follow, or a visual impaired user asking for information about a location with no GPS signal. However, context-aware recommendation in mobile devices is a challenging area mainly due to the impact of ubiquity in the broad sense (data, users, process, devices) on the process of data mining

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[12][13][20][16]. Ubiquity has made researchers on data mining review the whole process of knowledge discovery to analyze how to adapt processes to the new environment of ubiquitous users, process and data.

Data Mining processes are not the only ones affected by ubiquity, the growing number of web services on mobile and portable devices that have appeared in the last years is just another example of the increasing importance of moving services to mobile devices. Standardization to provide device independence adaptable services to heterogeneous users is one of the main problems that web service community is facing [18]. Recently, this challenge has been extended to allow web users to dynamically select the most appropriate mode of interaction for their current needs, including any disabilities, as long as enabling developers to provide an effective user interface for whichever modes the user selects [17]. Depending upon the device, users will be able to provide input via speech, handwriting, and keystrokes, with output presented via displays, pre-recorded and synthetic speech, audio, and tactile mechanisms such as mobile phone vibrators and Braille strips. Personalization services are then the next step of knowledge discovery processes in ubiquitous environments.

Location Based Services (LBS) are yet another example that are adapting to mobile environments. Beyond location data itself, usually georeference coordinates, and information related to the semantics of the coordinates themselves are needed in order to provide users with the information they demand when invoking a LBS application. Therefore, this kind of scenario once again demands standards in order to guarantee the service's interoperability and usability.

For the case of knowledge discovery processes, there are a lot of examples where autonomous and adaptable Data Mining components are needed to build recommendation context aware services in ubiquitous environments. In the aerospace domain robots to be fitted with a autonomous data mining component able to decide actions to be taken depending on the situation: location, resources available and actions to be taken would be desirable [16]. For the case of intelligent vehicles as in [22][4][9], there are many situations where there is no internet working connectivity. In such cases the vehicle should be equipped with some component able to take decision of the best road to take. Domotic houses [19] are only another example of such situation where information related to the actions taken by the user in particular situations could be taken as basis for future recommendations. Technology to assist users is one of the domains where one can find an increasing demand for personalized intelligent components able to help taking decisions to the user. For example technology has removed the barriers for visual impaired users that can now read email or browse the internet. PDA and other mobile devices and phones fitted with capabilities to deal with users incapacities [8][7][11]. However it would be desirable for the PDA or the mobile phone to assist and recommend the user in actions to be taken depending on the situation.

Ubiquitous Data Mining provides a chance for providing true personalization for the individual user in each particular combination of location moment and actions. Despite the lack of standard guidelines to build data mining components for resource-aware mobile devices some results have been already obtained [3][16]. The challenge has at least three dimensions: i) on the one hand data mining capabilities are locally needed so the components have to be able to compute in resource aware devices. Ideally the components should be device independent ii) models of data mining should be calculated even on those situation where only local data is available iii) the models should reflect the changing environment, this is to say models have to be dynamically calculated so to adapt to the user changing behavior.

Consequently, in this paper we further analyze the challenge of adding recommender capabilities to mobile like devices and propose a component based module in which the role of a controller is specially underlined.

We use the visual impaired scenario to explain the lacks of the traditional mining process in resource-aware devices on ubiquitous environments and analyze the challenges of adapting the process. By analyzing a very simple case of user action recommendation taking into account what we call situation (the triplet composed by location, timestamp and user actions), we develop a set of components in which capabilities has been added to deal with the constraints that computing recommendations have in this scenario. In order to integrate the ubiquitous mining module in the global scenario of the device we also propose a possible architecture in which these components will interact. The main aim presenting the architecture is to underline how the new components interact with the rest of components emphasizing the role of the controller. The architecture is similar to that presented in [21], but we emphasize the role of a new set of components that we call Ubiquitous Data Mining Module (UDMM). This module is composed by all the components responsible of the data mining process in ubiquitous environments. The architecture is also based on the one presented in [10], to deal with data mining with streams data in which as in our case special attention is due to resource-constrains. The rest of the paper has been organized as follows. In section 2 the process of computing recommendation in mobile devices is revised to highlight the challenges to be faced. In section 3 the process of recommendation in context aware ubiquitous devices is reviwed in order to obtain a set of standard components that will interact in autonomous way to produce recommendations. The role of a special component "'the controller"' is highlighted is the section. In section 4 an architecture to integrate a set of components is introduced. In this section the special role of the UDMM module is underlined. To conclude, section 5 presents the main conclusion and the future research lines.

2 Challenges for the mining process

We address in this section the main challenges to perform context-aware recommendations in a mobile device. We assume for simplicity a scenario in which the device receives data from sensors and other networks but does not send any data it collects. In such an environment and in order to illustrate the problem we concentrate on the problem of recommending actions to visual impaired users.

We assume a user equipped with PDA, mobile phone or laptop computer that receives information of wireless cards or GPS and records information of the actions the user makes in each moment trough the device. We want to define a service that will increase the functionality of the device, so that it will give aid the user giving her/him information related to actions to be performed: objects to be avoided, place to go in order to leverage a certain service, connect to battery (even related to PDA). In particular, we assume a blind user equipped with a Mobile phone with visual impaired modules[1]:

- voice output of visual display information concerning all menu options, caller-ID, indicators such as battery level, signal strength, roaming status, active/inactive call status, mute on/off, ringer profile and access to text messaging;
- Audio alerts for message indicators, power on/off, change in roaming status, and battery low warnings;
- Accessible input and controls. Keys that are easy to identify by touch with a tactile nib and voice echo of key entry.

We assume that the owner of the mobile uses the mobile to: make phone calls, browse the internet with the help of the voice output, and the most important part as location service, the mobile is equipped with GPS and location services. It would be interesting though, that the mobile apart from providing the user with these services would help him recommending actions to be taken depending on the context, location and past history of the user behavior. Consequently, we propose here to add these capabilities by a association rule recommender module that would calculate associations among the actions performed by the user. Two important aspects here to take into account as the device is mobile are location and time. Possible recommendations of the recommender module would be: suggesting to stop browsing the web, asking to plug in even when the level of battery is not very low but the situation suggests to run it out, or telling the user to take or leave the bus in a certain location.

Thus we define the user situation as the triplet: $\{Timestamp, Location, Action\}$, and we want to perform recommendations based on associations of situations. Note that we use associations as basis of the recommendation although we could have used classification. Nevertheless the results obtained so far are also valid for the case of classification.

We assume the following:

- Location: is a pair of values identifying a point in a known map, it can be enriched by a semantic: the device and implicitly the user is in a certain shop, at home or at doctor's office. Literature offers a wide range techniques for location [1], GPS and indoor wireless networks are an example. The various techniques have different accuracy, normal GPS systems have an error in the

[1] www.afb.org

range of three meters, indoor wireless can reduce this error. Depending on the accuracy we could define a semantic ontology for the localization. In fact, having the exact position we could enrich the semantic with a more detailed information (i.e. the user is near the door of the meeting room at University). For our example we assume the application has a map of a building with some information related, in such area the user moves and interacts. The related information completes the map by adding the available services in each room (i.e. in the meeting room there are wireless and internet services, but no GPS), and it is important to enrich later the recommendation. Furthermore, the device is continuously receiving location, analyzing it in a period we obtain movements and paths of the user.
– Timestamp: we assume that day time periods (morning, afternoon, evening and night) have been derived and more information such as the day of the week and working day.
– Action: a set of fixed action: Call, Internet surfing, bank movements, music listening, plug in the device, text editing, route planning, activity scheduling.

For simplicity reasons in this paper we are no dealing with privacy issues, as we are concentrating on designing resource aware platform independent components, and we are not focusing on the process itself.

The innovative capability of the recommender service will take into account:

– resources. The data mining process has to be resource-aware;
– priorities. The device has to take into account priorities of actions to perform depending on each particular situation. For example location services are the priority when the user is out of known location;
– processes to be developed: not only the data mining processes but also the main operational process for which the mobile device was thought of: phone calls, location services, ...

3 The process of recommendation in components

The challenge is to define the process of knowledge discovery for recommendation with the change of paradigm we are facing. The traditional process has to be reviewed due to two main factors: i) it is acting in an ubiquitous environment ii) it has to be locally computed in the device.

We propose to analyze the process in order to identify atomic pieces that we call *components*. Our goal is to define resource aware platform independent components for ubiquitous environments. The ubiquitous mining framework from a functional point of view can be divided into two pieces: i)model generator and ii)model applicator, nevertheless in the new scenario (see figure 1), a new component that we call controller appears. Although in the figure the process is divided into two main components, they should not be seen as inseparable components, but as an aggregation of atomic modules which completes a functionality. In fact, it is important to underline the need to divide into atomic components stressed by the resource aware constraints.

The controller main function is to interact with monitoring services of the device and depending on the resources launching the appropriate subset of atomic components in each situation. The controller can also decide to execute some atomic components, instead of launching the whole model generator.

It is important to see that we are assuming the whole process to be executed locally, so to give the mobile device the possibility of developing the whole process if needed. Nevertheless, this fact does not mean that we assume the mobile device to have complete autonomy and no need to communicate with a server so to calculate models based on global information or to get computing power for complex calculations. There would be cases in which this communication is needed and other cases where it will not be required, in either case, we are not dealing with that problem but with the problem of delivering data mining components able to execute, collaborate and produce results in a resource-aware device in the presence of other processes.

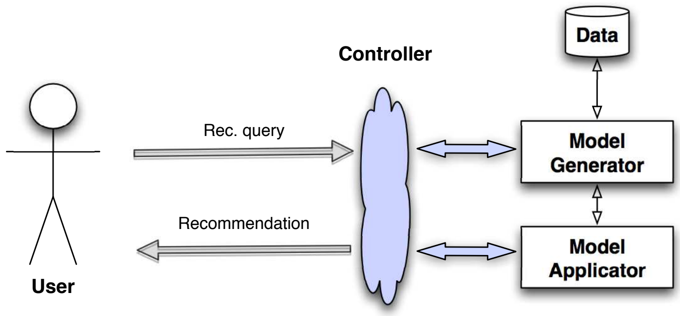

Fig. 1. The mining process

The challenge is then to be able to design an implement components with the following features:

- resource aware. Components have to be aware of: battery level, CPU, memory;
- context aware. They should recognize different features of the context;
- adaptable. Components should adapt to different platform;
- autonomy. The set of components all together will provide an autonomous data mining service if needed.

The controller component will coordinate and manage components of this kind to fulfill our goals. Due to the crucial role of the controller, after describing the model generator and the model applicator we will underline the main characteristics of this new component.

3.1 Model generator

In traditional data mining experts deals with the various phases[2] of: 1) Data preparation 3) Modeling 4) Evaluating 5) Deployment. The experts understand and prepare the data to extract one or more models, then they evaluate the model and finally decide how to deploy it. In the ubiquitous data mining framework such process should be carried out in the device in an autonomous way. In the figure 2 we can see the model generator in atomic components. Although the components in the figure are shown as sequentially executed, in fact they need to be coordinated and launched by the controller.

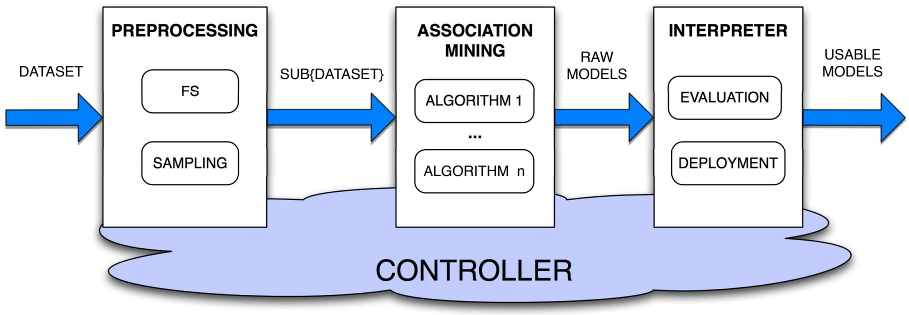

Fig. 2. The model generator in atomic pieces

Preprocessing module. The Preprocessing consists of preparing the data to apply the association rules algorithm. One of the main components required in this case will be to reduce both data and attributes for efficiency reasons. On the other hand these two processes have to be automatized as we are assuming autonomous data mining components. We concentrate here in two components that will be required in almost data mining process and that their standardization is consequently required. We are talking of the Feature Selection component which reduces the dataset vertically with the number of attributes and of the sampling which operates horizontally on the number of instances.

Feature Selection component (FS). Feature selection in practice is the task of generating a consistent subset of variables for the mining algorithm, where consistent include the concepts of relevance and non-redundancy. In Ubiquitous Knowledge Discovery the feature selection problem is stressed by the resource aware constraints, to compute more variables means to consume more energy and keep the device longer busy. For those strong constraints the traditional feature selection approach can be reviewed in order to obtain a smaller dataset:

[2] www.crisp-dm.org

by rethinking the task or just defining more constraining parameters. We can notice that the intention of FS in ubiquitous environments should be to give more importance to the resource consumption that are required for the attribute derivation. In fact we are not in a traditional data mining problem where relatively we don't care about resources, the ubiquitous should be outlined as a trade off between resource consumption and result accuracy.

Sampling component. Sampling is that part of statistical practice concerned with the selection of individual observations intended to yield some knowledge about a population of concern. A good sampling should not affect an inference result, and in the case it affects partially, the error should be less important than the advantages of sampling (i.e. time or resource consuming). Thus the importance of sampling can be motivated by nature of devices. The device is continuously receiving information and it is relevant the storage and reorganization of such information. From this point of view the sampling is fundamental when we have limited resources.

Association mining module. Association rules can be calculated using one or different resource aware algorithms, the controller will be the one deciding which algorithm to launch in each particular situation. Observe also that the input data in a dynamic environment can also change: location is not available or any other attribute is missed. For flexibility shake model with different input data should be performed, yielding different sets of association rules that will finally be used for the recommendation step. Consequently all these components will be part of this module.

Interpreter module. At least this module is composed by two components: i) evaluator in charge of deciding sets of rules that have the required quality in charge of translating ii) interpreter in charge to translate association rules into recommendations. Not also the importance of these components as part of the autonomy of the process relies on the function.

3.2 Model applicator

The model applicator is in charge of selecting the model and consequently the set of recommendations, and choosing the best one for the particular situation. The recommendation can be asked from the user or by the system. Two components: model selector and results personalization have been identified (see figure 3), that are next further explained.

Model selector module. The model generator has provided several models, the role of the model selector is to find the proper model which better fits each situation. The controller has once again a crucial role, as one of its aims is to decide when a recommendation is needed.

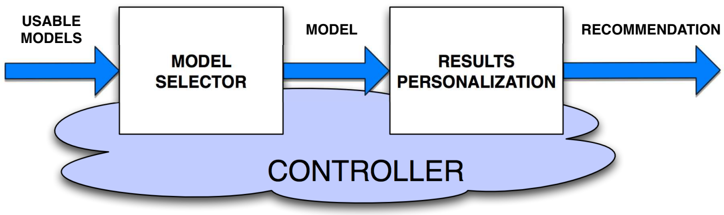

Fig. 3. The model applicator in atomic pieces

Result personalization module. One of the dimension of ubiquity we have to deal with is heterogeneity of user which has to do with: different cultures, languages, disabilities etc. Consequently components have to be developed in order to deal with this heterogeneity: magnify fonts for the visually impaired, speech recognition, braille capabilities.

3.3 Controller

As previously noted the controller component is one of the keys underling the new paradigm. Three are the main challenges this component has to manage:

- *Context aware.* The Ubiquitous KD process has to be aware of the context, where the context is represented in terms of sources the device is receiving and information the device offers. The controller should be able to set priorities or even stop certain processes depending on the context. In figure 2 the controller communicates with the modules and with the atomic components. Before running the FS for example, the controller collects information about the context, and it should be able to decide whether is the case to launch the task or not.
- *Resource aware.* The controller is in charge of the problems related to limited resources: battery, memory, CPU, communication. A controller which is not taking care of the battery level could terminate last energies to compute a non important recommendation instead of preserving the possibility to make an emergency call. Supposing a case where the controller is informed about a low battery and the input attributes are many. It could decide to run the FS module, but with more constrain parameters in order to obtain a smaller number of attributes. It could bring to a worse result, but a result, which can save more battery than a precise one.
- *Priorities.* In ubiquitous environments the time and the context make the tasks more sensitive. The controller should be aware of which moment is the right one. Supposing the visually impaired is in his/her house with the device connected to an outlet, the user is not using the device and does not need a recommendation. This could be a right moment to execute the sampling task whose results will be used for future recommendations. In fact the CPU is not being busy by any process and the energy used is recoverable, the

higher priority is given to the sampling module. The priorities are strongly correlated to the recommendation. The awareness that the user is going to ask a certain recommendation will see that the controller will give higher priorities to the that prior recommendation.

4 Architecture

4.1 Design Principles

Once we have analyzed the process and identify a set of components we present an architecture in which the components are integrated.

We propose a service-based architecture that is inspired in that presented in [21] and optimized to execute simple, but local services. The main goals are support the strong requirements of ubiquitous devices regarding small resources, e.g. low memory consumption, supporting mobility, and robustness. Additionally, components-based design supports the reusability of existing components or parts of components. The main design principles are:

- adjusting to multitude of changing environment variables;
- mining is performed locally on a resource constrained capabilities environment.

4.2 Architecture Description

Figure 4 represents the components organized in two layers: i) the layer of Ubiquitous Data Mining Module (UDMM) and ii) the middleware services that interacts with the operating system and resource abstract layer.

UDMM is the differentiating module as it provides the services described in the section 3. The main feature of this module is the controller component which is in charge of managing the data mining process on the basis of the middleware monitoring services and the context. The middleware layer contains the infrastructure services such as location, scheduling, storage and registration hiding the device heterogeneity.

The scheduler manages, connects, and runs services. Therefore, the resulting middleware layer provides an interface to services which is significantly simpler and at lower cost because it is based on WWW standards. Context Management and Monitoring Services components are responsible of detecting changes of context and resource availability.

5 Conclusions

In this paper he have address the problem of context aware recommendation in mobile devices. Taking as example, the case of recommendation for visual impaired users, we have deeply analyzed the whole process. The first goal has been the identification of atomic components that will be the basis for designing a

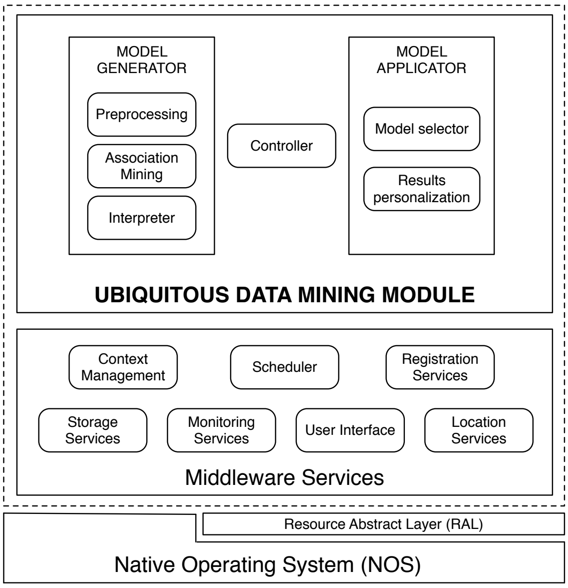

Fig. 4. Layer's Structure of Ubiquitous Mining Architecture

platform of independent data mining components for ubiquitous environments. The analysis of the process using these components has raised the need for a special component that we have called the controller. The controller main function is to interact with monitoring services of the device and depending on the resources launching the appropriate subset of atomic components in each situation. We have also presented in this paper an architecture that includes the Ubiquitous Data Mining Module that joins together all the components previously identified. The identification of atomic components, could be the basis for future data mining services or software components. We are currently working on the design of the model for the standard component of interaction and the standard API, all taking into account the functionality of the model.

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