BABEŞ-BOLYAI UNIVERSITY

FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

Domain: Cybernetics and Statistics

CONTRIBUTIONS TO THE DEVELOPMENT OF PORTALS THROUGH CONTENT RECOMMENDATION SYSTEMS

- Summary -

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Abstract

We can all agree that there has been an exponential growth in the amount of information we must manage on a daily basis. Portals are regarded as a solution to the information overload because they gather information from multiple sources so that it is easily accessible to users. Even if portals offer only one access point towards the information gathered from multiple sources, users may encounter difficulties in identifying and locating valuable resources. Without proper guidance, they will lose interest and leave the portal. Recommender systems have been created in order to guide the user in a personalized manner towards the resources of interest. Thus, we shall recommend to users the interesting, relevant and most quality resources. It is our opinion that recommender systems must be able to adapt to the user's needs, on the basis of identifying and harvesting the collective intelligence generated within the portal.

The essential contributions of this thesis have materialized in the development of global models which manage to identify, gather and use the collective intelligence within a portal, for the purpose of locating and recommending valuable resources. They function as personalized guidance services and have the capacity to successfully adapt to the dynamics of the collective environment changes. We thus propose two systems for the recommender of content within portals: WRS (Wise Recommender System) and WSNRS (Wise Social Network Recommender System).

WRS recommends similar content to that which the user visits during the current session. For supplying recommendations, the system uses the association rules extracted from the user's navigation sessions. The extraction of useful data takes place by default, online and in real time, using a proactive approach. One novelty element is that the proposed approach allows for the extraction of association rules for resources accessed together (frequently and occasionally). Another is the processing of navigation sessions and extraction of the association rules takes place online within a transactional process. Their storage within the database takes place incrementally, and the recommendations made by our system can be delivered to the users starting with the first page in their current surfing session. The proposed system is entirely online,

scalable and does not suffer from the “cold-start” issue, allowing for successful implementation into any portal.

WSNRS is a social recommender system that uses collective intelligence and user interactions within a portal. WSNRS calculated user trust scores allow for identifying the types of relationships that are established. According to this, the most recently published resources within social media structures are recommended. If given a favorable review, the recommended content becomes viral shortly after, traversing a multitude of social (media) structures. A second characteristic is the identification of interest groups and ranking users within social structures. Ranking implies identifying leaders and isolated users alike. The third characteristic is the automatic moderation of resources published inside a portal. The proposed approach brings benefits, as opposed to classic methods when regarding the “cold-start” and “serendipitous recommendations” issues (the supplying of recommendations which pleasantly surprise and are specifically not sought out).

Keywords: portals, Content Management Systems, Web 2.0, collective intelligence, recommendation systems, association rules, social networking

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1. INTRODUCTION

Information technology and the Internet have experienced in recent years an exponential increase in the amount of information they have to process every day. The large volume of data stored in separate archives that cannot be accessed in real time and information overload reduce the effectiveness of users. They are put in the situation to channel the attention to search for information and not use them in a constructive manner to achieve key objectives. Therefore may result in a number of decisions that are taken based on incomplete or outdated information. Finding relevant information has turned into an expensive operation in terms of time and often requires checking many different system interfaces.

A solution for these problems lays in the form of portals and content management systems because they aid in eliminating the chaos which exists within businesses, corporate networks and the Internet. In order for a portal to develop, it must satisfy the needs of users as diverse as they are exigent. Thus, it is imperious that a portal be able to shape itself to diverse behavioral patterns, to have the ability to supply the information that each user needs and finds interesting. In achieving this goal, recommender systems play an essential role.

Taking into account that the user's, and the current society's in general, most frequent issue is the lack of time, a portal's survival largely depends on the manner in which its users' time is used and managed. The major contribution of recommender systems is best made evident by this, for they aim to give users access to the information they desire in the shortest time possible. Essentially, recommender systems based on users' profiles conclude that there is an increased interest for certain categories of information, so they will recommend them as being of priority.

The purpose of this thesis is the development of certain global models which would identify, gather and utilize the collective intelligence within a portal towards finding and recommending valuable resources. Thusly, we set out to identify the quality of a portal's existing content, as well as its relevance, in order to recommend the parts of most interest to each user.

1.1 THESIS' PURPOSE AND OBJECTIVES

The main goal of the research within this thesis is to offer concrete solutions in the context of portals' overload of existing information and to provide remedies to the problems with which classic recommender systems are faced. To achieve this goal we aim to first of all identify the content's relevance to a certain user. Secondly, we wish to identify the valuable content within a portal through calculating and attributing certain quality scores. We wish that the proposed solutions and approaches may act as a guiding service that provides personalized content and adapts to the users' needs. This way, users will be up to date with the valuable (meaning relevant and of quality) resources, whether they be recent or not, without being made to waste precious time looking for them. In the following we will detail the objectives this research aims to accomplish.

The first objective we have laid out is compiling a research to determine the most popular functions which a WCMS must encapsulate. We will make an analysis of the factors that influence the development, acquisition or implementation of an open source WCMS for the purpose of creating a portal, building a community and creating an online social network, respectively. On the basis of specialty literature, we will classify the portals existing on the market and we will outline the advantages their development and implementation brings. We will also make a parallel between portals and content management systems (CMS).

The second objective is studying the ways through which recommender systems can represent a viable solution to the problem of information overload. In this respect, we will attempt to predict, based on a vast amount of resources, those that are most relevant to a user's interests. For achieving this goal, we will employ web usage mining techniques to extract the existing association rules between the resources sought by users as a whole in the past within the same surfing session.

The third objective is identifying the quality of the content generated by the users inside social networks. We aim to identify social structures, the most trusted users, and groups of interest, leaders and isolated individuals. Towards achieving this goal, we will collect, log and analyze user interactions with each other, as well as with

resources existing within the network. Besides interactions, we will identify the data sources that can be used as entry data for extracting collective intelligence.

The fourth objective is studying the opportunity to add a contextual dimension to recommender systems with the help of tags. In order to do this, we aim to develop a system that allows users to add tags to resources. We will analyze collected data to discover potential existing associations between tags, alongside their stability and evolution in time. Starting with tags and the relationships extracted based on joint association in text labeling, we aim to measure the degree of similitude between tags. Taking into account the similarities, we will analyze the opportunity to develop a recommender system that can recommend tags and resources that have been labeled using these tags.

1.2 DESCRIBING THE PROBLEMS AND MOTIVATIONS OF THE RESEARCH

In the following we will describe the problems and motivations of the research into studying portals, content management systems, recommender systems and creating a recommender system based on association rules and one designed for social networks.

1.2.1 THE STUDY OF PORTALS AND CONTENT MANAGEMENT SYSTEMS

By analyzing the CMSs available on the market we may observe that both the offer and the offered functions are extremely diverse. This leads to a developer having a difficult decision to make when buying, developing or implementing an open source CMS [92]. Due to this assessment, the motivation to conduct a case study to determine the most popular WCMSs present in practice, along with the most important functions they must contain has arisen. We consider it important to analyze specialists' opinion regarding the factors that influence choosing a WCMS and the functions it must contain, separated into creation, management and content publishing modules respectively.

Web 2.0 represents a new era in the evolution of the Internet and gives users the possibility to huddle together into communities based on common interests. The portals of the Web 2.0 generation adapt to the community's users, based on the collected collective intelligence. Capturing the collective intelligence generated by users' participation in creating new information and using it to build new certain global models that would adapt to the dynamics of environment changes represents a field of research with multiple challenges [128]. Using these models, applications will have the possibility to develop long term relationships with users through offering value and personalized experiences, motivating them to return to the online medium within adaptive applications. Therefore, we aim to identify, within a portal, the data sources which may be used as entry data within recommender models based on composing collective intelligence.

1.2.2 THE STUDY OF PERSONALIZATION AND RECOMMENDER SYSTEMS

The potential for personalization is evident to application developers who can provide improved services, as well as to final users who can satisfy their need for personalization within applications. Personalization and recommender systems have attracted the attention not only of researchers from academic communities, but also practitioners in the industry. The interest by Netflix[1] is already notorious, due to its 1.000.000$ prize given to the "Bellkor Pragmatic Chaos" team during the „Netflix Prize"[2] contest organized towards improving the algorithm of recommending movies. Amazon.com has begun recommending products using a phrase that has become famous on e-commerce sites: "Clients that have bought this product also bought". YouTube recommends trending video content, popular and personalized content, taking into account the preferences and browsing history. And Facebook recommends content, potential friends or different communities that might be of interest to the user.

Even if in practice recommender systems are omnipresent, by analyzing specialty literature in the academic medium we were surprised to conclude the lack of a well defined model assembled as a recommender system. The proposed systems don't

[1] http://www.netflix.com
[2] http://www.netflixprize.com

simultaneously fulfil the requirements of collecting entry data, processing it and delivering online recommendations in real time. The vast majority of works provides a frame for recommender systems and briefly describes the already existing types of systems. Most of the time they are merely suggestions, of which very few have been implemented into online portals. As such, taking into account the specialty literature and the existing needs of the portals domain, the motivation to propose and offer a completely functional prototype of a recommender system that may be implemented into any portal or content management system has appeared.

1.2.3 CONSTRUCTING A RECOMMENDATION SYSTEM BASED ON ASSOCIATION RULES

Because of the fact that any portal runs on a web server, all user interactions are stored in the server's log files. As such, an immense amount of data that may be used to extract useful models for content recommendation is resulted. Personalization systems based on log file analysis imply 3 phases [103]: collecting, preparing and transforming data; discovering models and patterns and recommending content. In classic approaches, the first two phases are conducted offline by means of separate software that don't communicate with each other, and the transfer of data between the three phases is done manually. This leads to the impossibility of shaping collective intelligence and listing recommendations in real time.

Log file analysis raises a series of issues [159], especially: the existence of a high number of non-relevant recordings of the web usage mining process; difficulties in identifying users and sessions; lack of information regarding the content of sought pages; data processing is done in time, being batch and a great consumer of computational resources. Taking into account that the reactive analysis of log files is a difficult task, we have concluded that identifying proactive strategies [149] will be a challenge for us. We are also motivated to find solutions to the above problems that may be solidified through the proposal, development and implementation of a system in which the three modules communicate online, by transaction, in real time.

The classic approaches used to extract association rules are very costly in terms of computational resources and encounter great difficulties when it comes to scalability.

They imply the extraction of all the association rules possible, calculating the support and trust in each rule and eliminating those rules that don't satisfy the minimum threshold requirements. This also happens in the case study [146] in which analyzing a set of data which contained 24.717 pages and 21.914 browsing sessions took days. Establishing high thresholds [175] for support and trust increases algorithms' performance in detriment of less frequent, but potentially interesting association rules. Establishing low thresholds, however, leads to a significant rise in processing duration. Also, most recommender systems are capable of providing recommendations only after users have visited at least two pages during a browsing session.

As such, we are motivated to propose and approach that offers solutions to the aforementioned problems. We aim that it offer recommendations online and in real-time by taking into account only the first page in the browsing session, regardless of its popularity amongst visitors.

1.2.4 CONSTRUCTING A RECOMMENDATION SYSTEM FOR SOCIAL NETWORKS

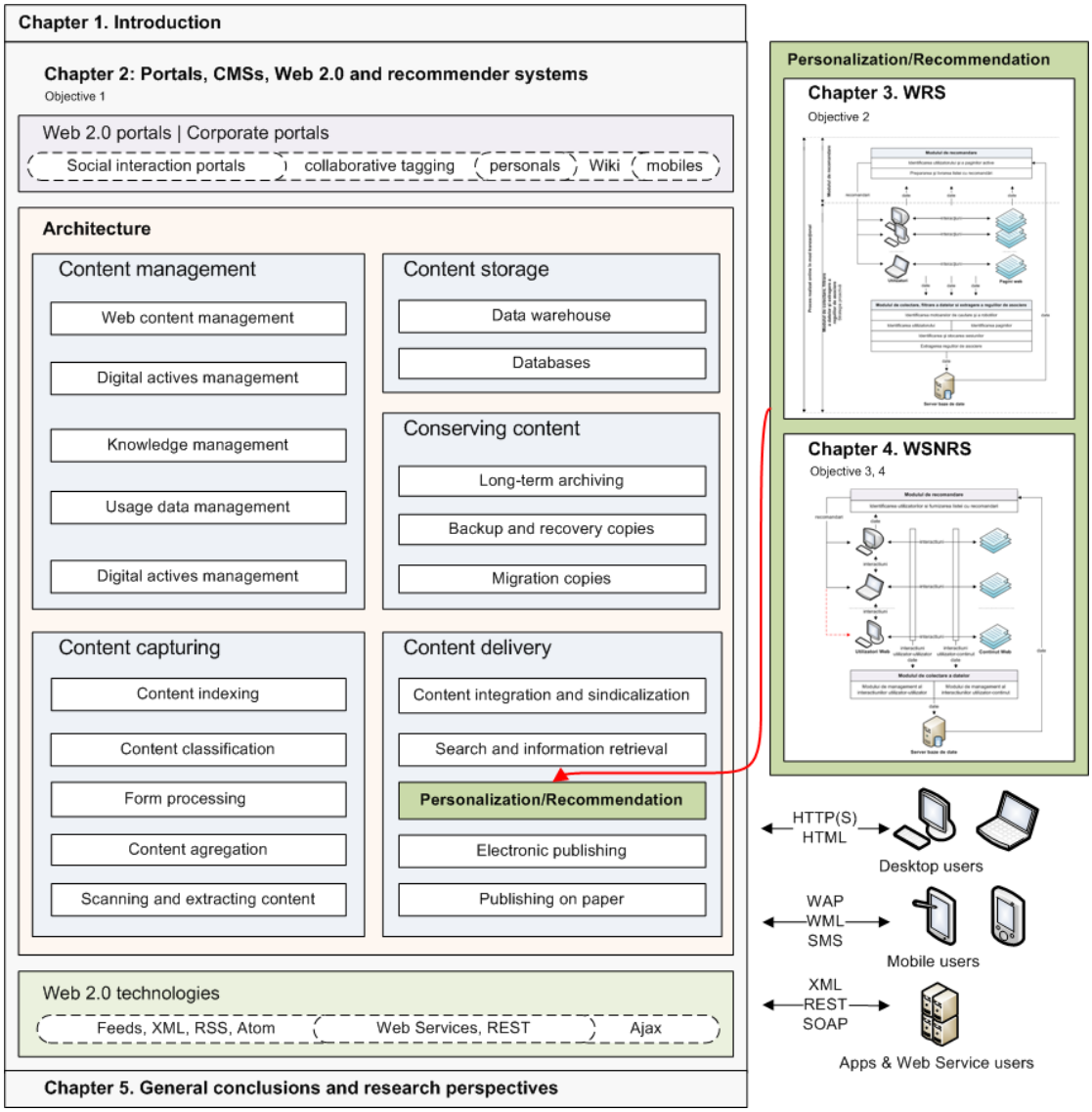
The new technologies and concepts that Web 2.0 brings to web applications, together with the ever increasing expansion and reach of the Internet have lead to the emergence of a high number of communities and online social networks based on common interests. The explosive increase in popularity for online social networks has attracted the attention of hundreds of millions of users worldwide. At the same time, it has brought a new series of challenges for developers and researchers in charge of online social apps. The purpose of a social network is to help keep in touch with friends, follow certain celebrities, meet and interact with new people. This is achieved through resources shared within the network. Based on the resources shared, preferences and interactions, people come to know each other better, to know new things and people.

In a social network, content is published at a dazzling speed, and a user will find it difficult to read and keep up-to-date with all the newly published resources. The quality of these resources varies from very poor to very high, and this is reflected in

the feedback offered by the community members. In a system in which the amount of user-generated content is massive, manual moderation becomes virtually impossible. Identifying quality and recommending new resources based on gathering collective intelligence becomes a challenge. This would allow for an automated resource moderation system in which only the quality ones will be promoted and recommended to users.

1.3 THESIS STRUCTURE AND ORGANIZATION

In the schematic below we will briefly present the structure of the chapters, the way in which the objectives are structured and the zone of a portal's architecture we aim to improve.



Chapter 2 presents the general frame, the theoretic concepts and the degree of knowledge. In this chapter we study portals, content management systems and content personalization and recommendation. We will also present the study on evaluating WCMSs and the importance of their functions.

Chapter 3 presents the WRS recommender system, together with the problem's description and content, model formalizing, its architecture and aspects concerning implementation. Also in this chapter, we conduct a case study concerning the evaluation of scalability and comparison of association rules extraction in WRS using different approaches.

In chapter 4 we present the description and context of social recommendations, the formalizing of the WSNRS recommender system, architecture and aspects concerning implementation. We will conduct a case study based on the data collected by the WSNRS system, towards analyzing interactions, assessing trust and recommending resources within social networks. Also in this chapter we will conduct an analysis of tag dynamics within social labeling systems in order to study the possibility of adding a contextual dimension to the WSNRS system. With the help of tags, the suggestions given inside the network could contain context as well. Towards the end of the thesis we will present conclusions, contributions and future directions in research.

2. PORTALS, CMS, WEB 2.0 AND RECOMMENDATION SYSTEMS

In this chapter we have analyzed the theoretical concepts, the degree of knowledge and the field in which we wish to contribute, by means of the present thesis. We have laid out the functions, architecture and advantages of implementing a portal, together with a parallel between portals and CMSs. In continuing this chapter, we have shown the evolution of the internet and have classified niche portals that are based on gathering and unionizing content. We have also presented the influence of Web 2.0 upon portal development and have highlighted by means of examples the most important characteristics of the utilized web technologies.

In this same chapter we have detailed the concepts of content personalization, recommendation and adapting by using web mining techniques. We have identified and described the main sources of collective intelligence, the categories of recommender systems, together with ways of evaluating recommendations. We have also highlighted the issues faced when developing recommender systems based on extracting association rules and log file processing. At the end of this chapter we've summarized the results of the research carried out in order to determine the most popular functions of a WCMS.

Considering the multitude of existing WCMSs on the market and the diverse functions they contain, we have put together a research based on the structured interview method, using the questionnaire present in Annex B as a tool. The purpose was that of determining the most popular WCMSs in use and the most important functions that they should contain.

Because WCMSs are a niche domain and the specialists developing web apps and portals based on them are hard to find, we've chosen a reduced sample of subjects, made up of 40 individuals, IT specialists with relevant knowledge and experience in the WCMS field. In this situation, we have made a prospective study which aims to gather as much information from specialists working with WCMSs as possible.

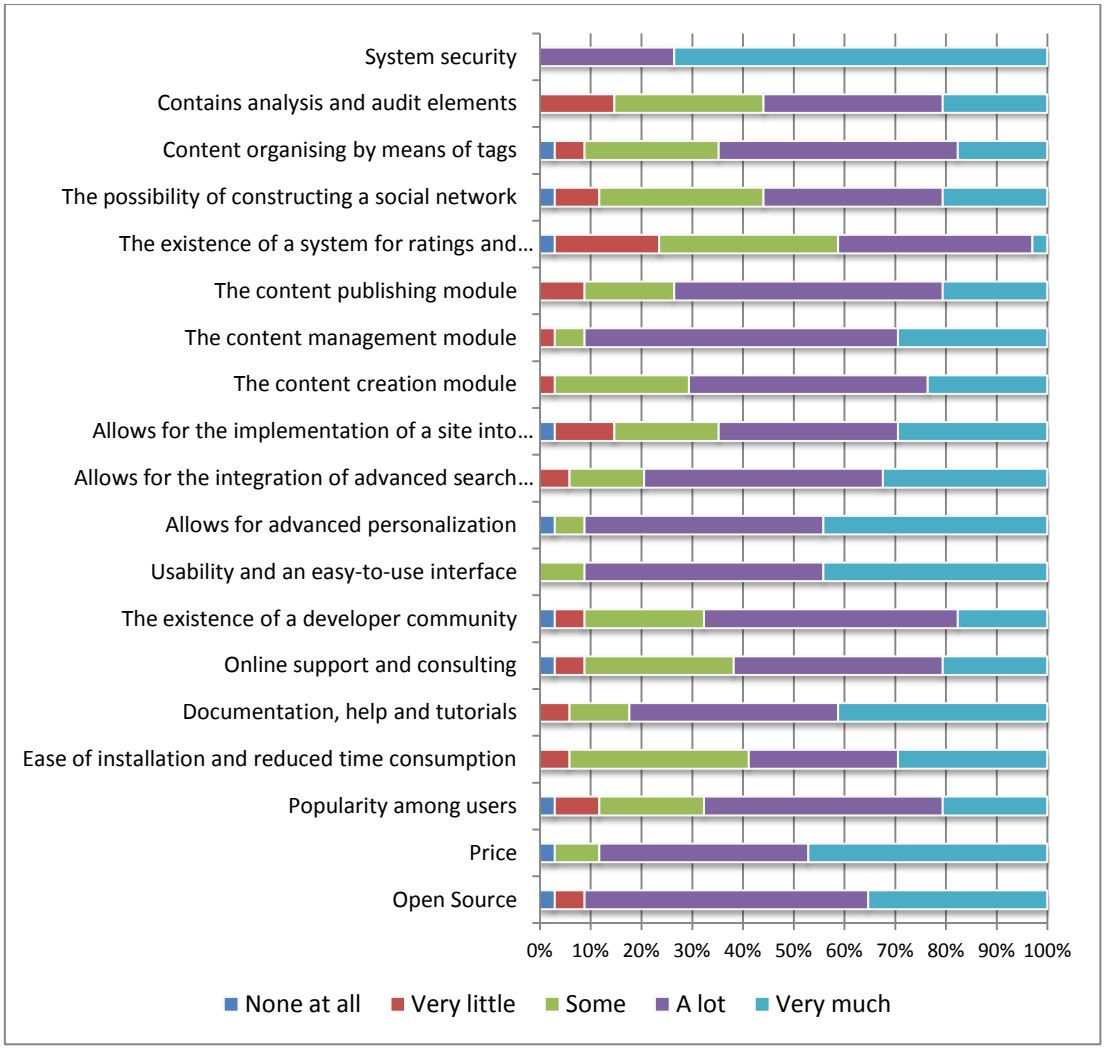


Figure 30. **Influential factors in choosing a WCMS**

After centralizing and analyzing the obtained data, we have reached a series of results which are detailed in section 2.7. The most important factors which influence choosing a WCMS may be observed in figure 30.

2.1 CONCLUSIONS

By analyzing the specialty literature referring to portals and CMSs, we have reached the conclusion that the border between the two is very blurry and ambiguous. The two concepts intertwine when it comes both to functionality, as well as purpose with a notable overlapping. Thus, we may say that a portal, as well as a CMS contains modules for creating, gathering and integrating data from multiple sources, together with managing and delivering them by means of a unitary interface and in a

personalized manner. Therefore, it is becoming increasingly difficult to tell where a portal ends and a content management solution begins.

Based on the case study conducted earlier, we have concluded that WCMSs offer an optimal technical solution for creating collaborative online communities and social networks. The most important functions a WCMS must contain are: heightened application security, the possibility of interface and content personalization by each user, heightened usability, an easy to use interface, feeds and web services, an editor for source-code editing, the ability to import data from different formats and sources, the existence of a WYSIWYG editor and a high-performance backup function.

The findings of this chapter were published in [93, 94, 95, 98, 100].

3. WRS - THE PROPOSED ASSOCIATION RULES-BASED RECOMMENDER SYSTEM

In chapter 3 we presented WRS, the recommender system based on extracting association rules from users' browsing sessions. In the beginning we described the context of the problem and made a general formalization of the frame. We continued with presenting the system's architecture, the collecting, filtering and extraction process for association rules and recommendation, respectively. We described sub-models and the way in which they communicate with each other to solve the problematic described in Section 1.2.3 and achieve the goals described in section 1.1.

In continuing with this chapter, we've presented aspects concerning system implementation. In order to highlight them, we've detailed the method through which the system identifies and filters search engines, and to this purpose we have given examples of browsing sessions. In the following, we have exemplified the method of extracting association rules and their incremental storage in the database's tables. We have also shown the way in which the calculations for delivering the list of recommendations are done. In the ending, we have provided a few case studies concerning examples of using the system, evaluating scalability and comparing the extracted association rules to other approaches.

WRS (Wise Recommender System) is a recommender system which predicts the resources relevant to a user by taking a larger group into account. To achieve this goal, the system employs web usage mining techniques to extract association rules that exist between the resources sought out by users together, in the past, in the same browsing session. Extracting the association rules is done both for the resources frequently accessed together as well as for those accessed only on occasion. This is done without establishing constraints for support and trust. The recommendation is done by taking into account a single existing page in the user's browsing session.

Considering the architectures of personalization systems present in section 2.6.1 and their shortcomings, presented in sections 2.6.2 and 2.6.3, we propose a new architecture for recommender systems based on WUM and association rules. In the

following, we will present WRS [97], the recommender system proposed for adaptive web portals. Our approach, present in Figure 33, brings a series of improvements to classic personalization systems [102]. In the case of classic architectures based on browsing behavior analysis, the first stage is that of gathering, filtering and pre-processing log files. The next stage is that of extracting browsing patterns. Due to the large size of log files and the time it takes to process, the first two phases are conducted offline in a batch process. It is also worth noting that the two phases don't communicate with each other, and in most cases are executed by separate programs.

In the architecture put forward by us, we have innovatively integrated several sub models in order to increase adaptive ability, as well as personalization. We may observe that within our architecture we have only one module for the two stages of the classic architecture. The module for data collection, filtration and extraction of association rules contains sever sub-models that communicate with one another.

Data collection and browsing pattern extraction is done online and in real time by using a proactive approach. Because of this, a major part of the problems faced in pre-processing log files and rebuilding users' browsing sessions is resolved. One of the advantages is that a large part of recordings, like those generated by search engines, those caused by accessing image files or Java scripts are not taken into account. As such, the storage space required is reduced due to the fact that only the data relevant to the process of web usage mining in a transactional process is stored. The data extracted in this way is of high quality, complete, noiseless and without errors. Extracting data regarding browsing behavior, preferences and user activities is done by default, without the need for explicit involvement from the user in the gathering process. This is observable in sections 3.3.1 and 3.4.

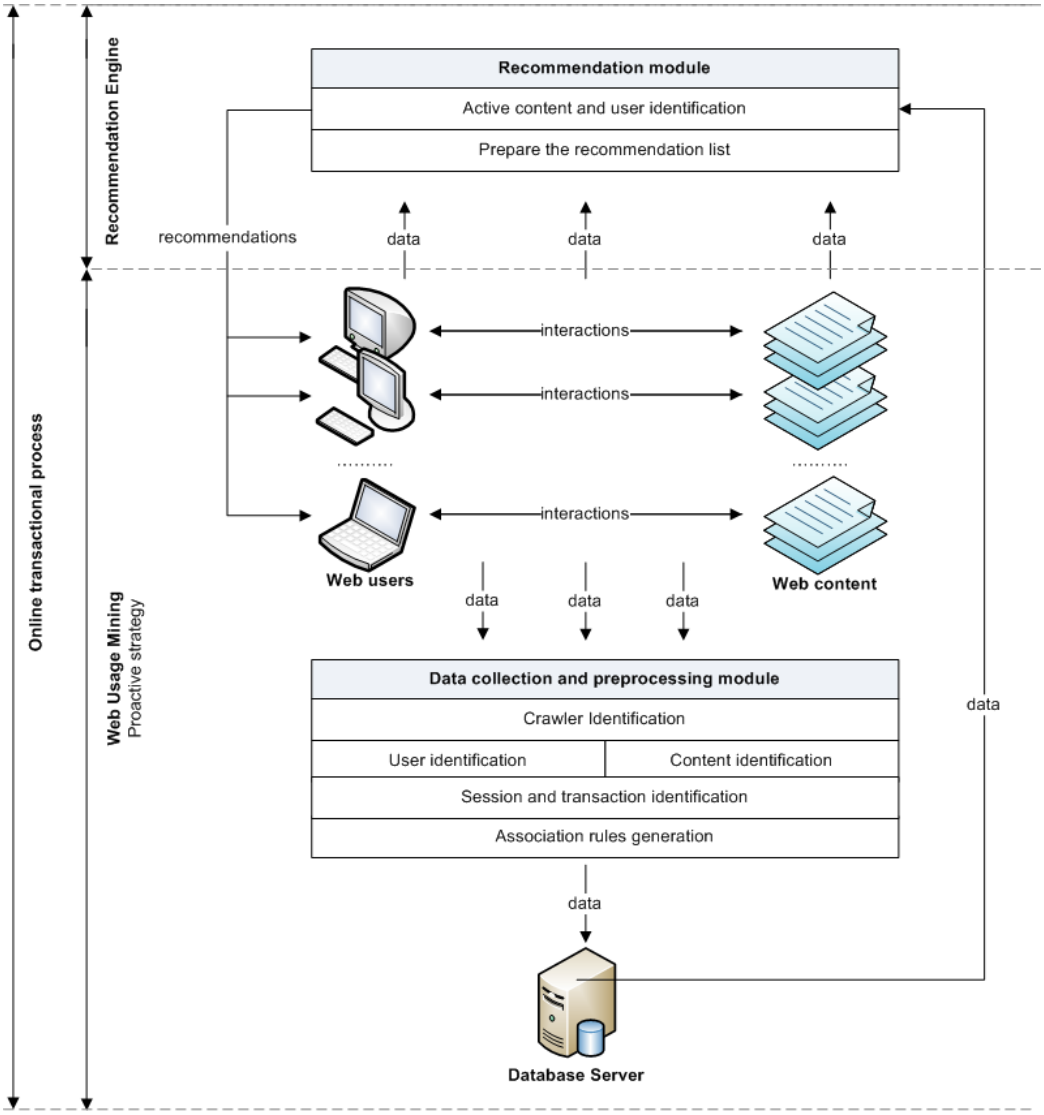


Figure 33. **WRS. Suggested architecture for content recommendation**

Our approach is based on association rules and takes into account the frequently accessed content, as well as the one only seldom accessed. In order to be scalable, the vast majority of recommender systems eliminate the association rules with a low support from the system. This leads to the impossibility of providing recommendations when it comes to niche content accessed by only a small amount of users. Even if a certain type of content is accessed more rarely, it may still be a necessary piece of information to some users. As such, the architecture we propose allows for storing relationships established with rarely accessed content without affecting the scalability of the system, as can be seen in section 3.6. In the following we will show an example of the recommendation system's functioning, as applied on the website www.intelepciune.ro.

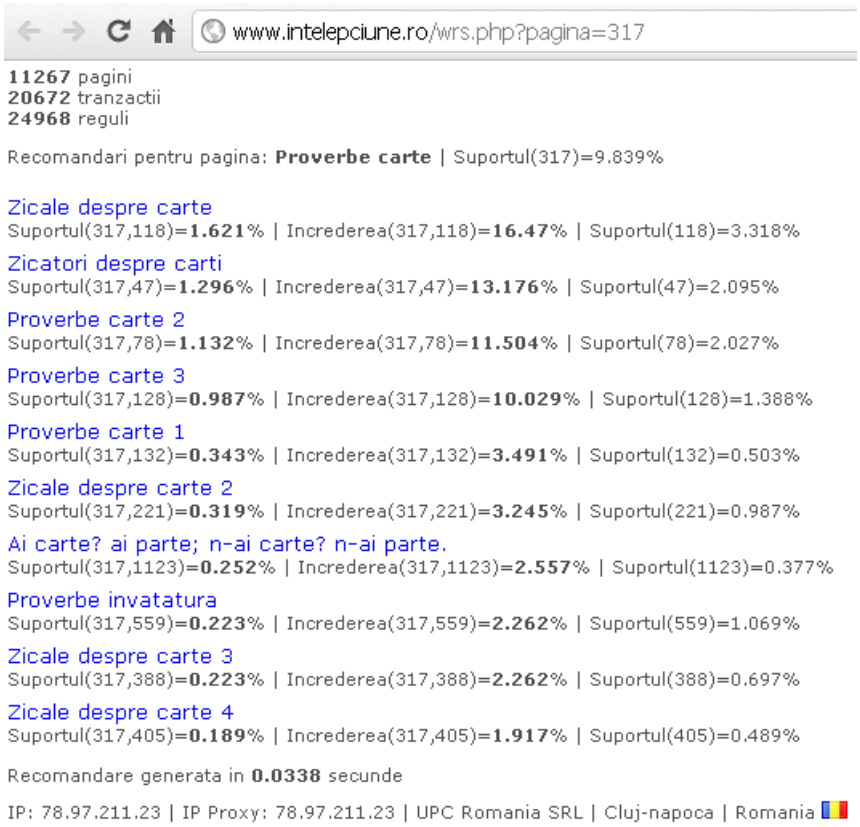


Figure 40. **Calculations made for delivering the list of recommendations**

In figure 40 we can observe the list of recommendations delivered for the current page, together with the values calculated for support and trust. The values were calculated taking into account 11.267 visited pages and 24.968 rules generated by processing 20.672 browsing sessions. The time taken to generate the list is 0.0338 seconds. We can also see that the user is from Cluj-Napoca, using the UPC network and is behind a proxy server.

3.1 CONCLUSIONS

Considering all that's been said, we can say that WRS can easily be integrated into any portal thanks to the efficient incorporation of the three phases into a transactional process that takes place online. Collecting data on browsing behavior and user activities is done automatically, with the help of the data collection sub-module, using a proactive approach. Thanks to the fact that the sub-module communicates in real time with the one that extracts association rules, processing user sessions is done

transactionally and the extracted rules are stored incrementally into the database. This allows for all the extracted association rules to be stored, which permits recommending content accessed both frequently and seldom. The fact that rules are updated after processing each browsing session leads to the system adapting quickly and efficiently to the user's browsing tendencies.

We think that our approach solves the problems met in pre-processing log files and rebuilding users' browsing sessions. Thus, the need to clean, filter and eliminate recordings which are not relevant, as well as those generated by search engines disappears. By analyzing browsing patterns and search engines, we've extracted multiple rules, on the basis of which we may identify and eliminate the sessions they initiated with precision. The data extracted thusly is high quality, complete, noiseless and without error. A decrease in required storage space is thus achieved, thanks to the fact that only data relevant to the goal is maintained in the system. Developing an integrated collection module has the added advantage of allowing metadata to be attached to the content before it is delivered to the users. Metadata can be used by all the system's sub-modules and help establish the content we wish to take into account in the recommendation process.

The findings of this chapter were published in [97, 99, 146].

4. WSNRS - THE PROPOSED SOCIAL RECOMMENDATION SYSTEM BASED ON TRUST SCORES

In this chapter, we introduced WSNRS, the recommender system based on the quantification of interactions and on gathering collective intelligence from social networks. To begin with, the context of the issue was described and a general formalization of the background was created. The architecture of the system was described next, followed by the interactions harvesting module, and respectively, the recommender system. We then described the sub modules and put forward elements related to the implementation of the system. For the remainder of the chapter, we created a case study in order to observe the way in which interactions can be quantified and gathered in view of identifying the types of relationships that are formed between users. We continued by determining the level of trust that one user offers to another user and we exemplified the way in which such relationships based on trust can be used when recommending resources within the network. At the end of the chapter we created a case study in order to analyze usage models and the dynamic of tags within systems of collaborative labeling.

WSNRS (Wise Social Network Recommender System) [96] is a social recommender system which logs, gathers and uses collective intelligence resulted from the interaction, related to content, between users, in order to calculate the trust scores between users. Using these trust scores, the most reliable users can be identified within the social structure of a network. The trust one user has in another is a piece of information which enables us to identify the resources that could be of interest. These are represented by the resources which encouraged the user to become involved. Within our system, involvement results from posting comments, adding the resource to favorites, adding notes to it, the number of clicks and shares within social media websites. The conceptual model of WSNRS can be seen in Figure 44.

We will now present the architecture of WSNRS, the chosen social recommender system [96]. The main purpose of the system is identifying and recommending valuable, recently published resources. In order to accomplish this desideratum, the system acknowledges the collective intelligence resulted from the interactions

between the users within the network. Collective intelligence is gathered and quantified with the help of the data collector module. Interactions between users are managed using the „User-user interactions management module" and those between users and resources by using the „User-content interactions management module". The architecture of the system can be seen in Figure 46.

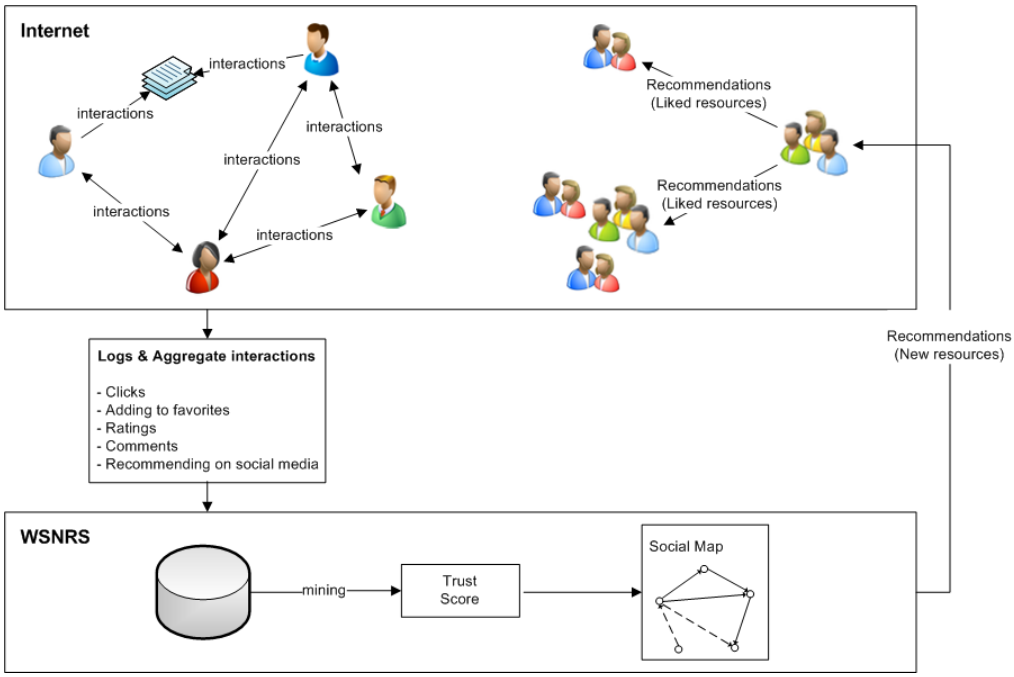


Figure 14. **Conceptual model of WSNRS**

In order to analyse the structure of a social network, and of interest groups respectively, we created a case study based on the data collected from within the social network developed around the inner circle of Înţelepciune.ro. The interactions that took place during the period of data collection resulted from 511 active users, from a total of 6,723 registered users. We quantified a total of 16,620 direct and indirect interactions between users or resulted from posting resources. The number of interactions resulted from adding notes, adding to favourites, recommendations, comments or clicks. 1,388 links between users resulted from analysing the interactions. 6.23% of these were clearly stated follower-type relationships, and 18.62% were implicitly deduced using the chosen algorithm. The structure of the social network, and that of interest groups, can be seen and analysed based on the relationships developed between users.

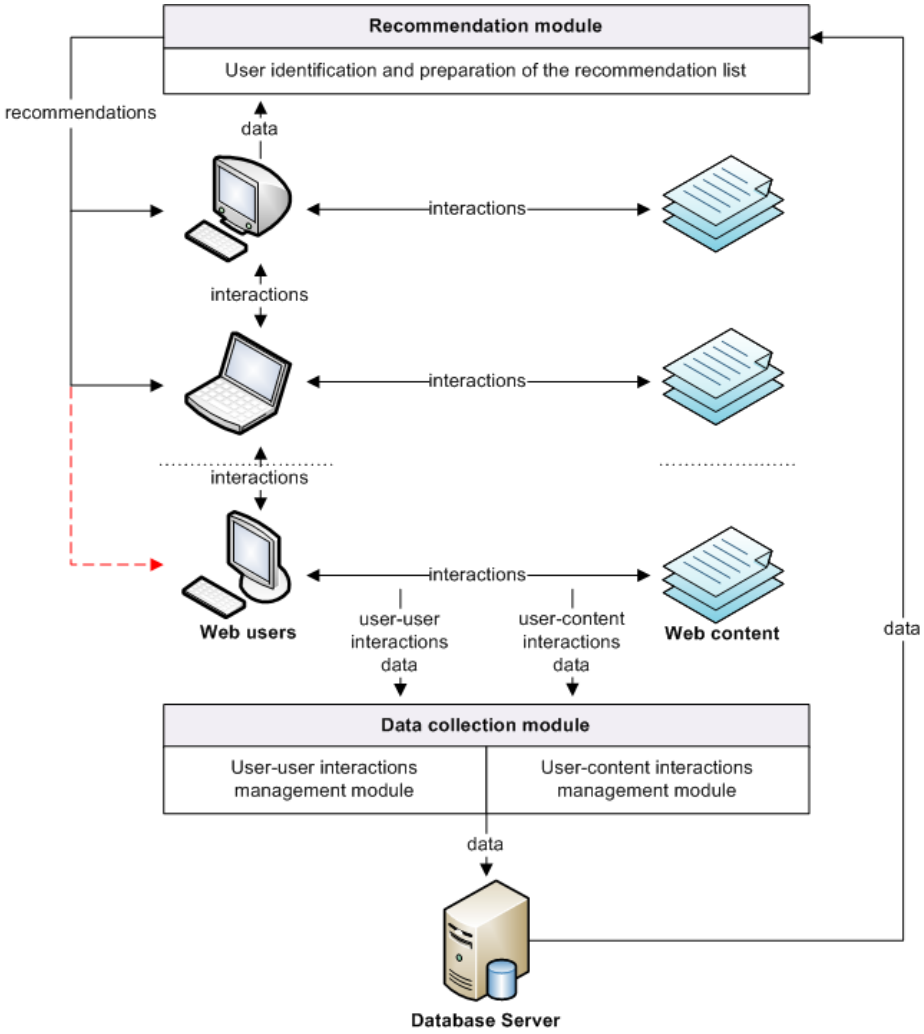


Figure 46. **The architecture of WSNRS**

The visualisation of the structure of the social network is shown in Figure 47, with the help of a sociogram [96]. It is illustrated by means of an oriented graph in which, the strongest links within the network can be seen. Due to limited space and in order for the graph to be intelligible, only the first 50 links were shown using arcs. Within these links, 41 nodes were involved. The graphic representation of the links and users can thus be seen and also the measure of trust developed between users. Furthermore, group structures are highlighted, which allows for identifying interest groups, leaders and isolated individuals.

Each node from the graph represents a user and the size of the node indicates the importance of each particular user within the network. The arcs between nodes highlight the links that were formed between users and they are labelled with the trust quotient which came about after using the proposed algorithm. The resulting values

were normalised in order for them to be found within the [0.00, 1.00] interval. The hierarchy of links was decided based on how close they were to the best result, which will tend towards the value of 1. If there is an explicit link between two nodes, the arc will be shaped as a straight arrow; whereas if the link is implicit, the arc will appear as an intermittent arrow.

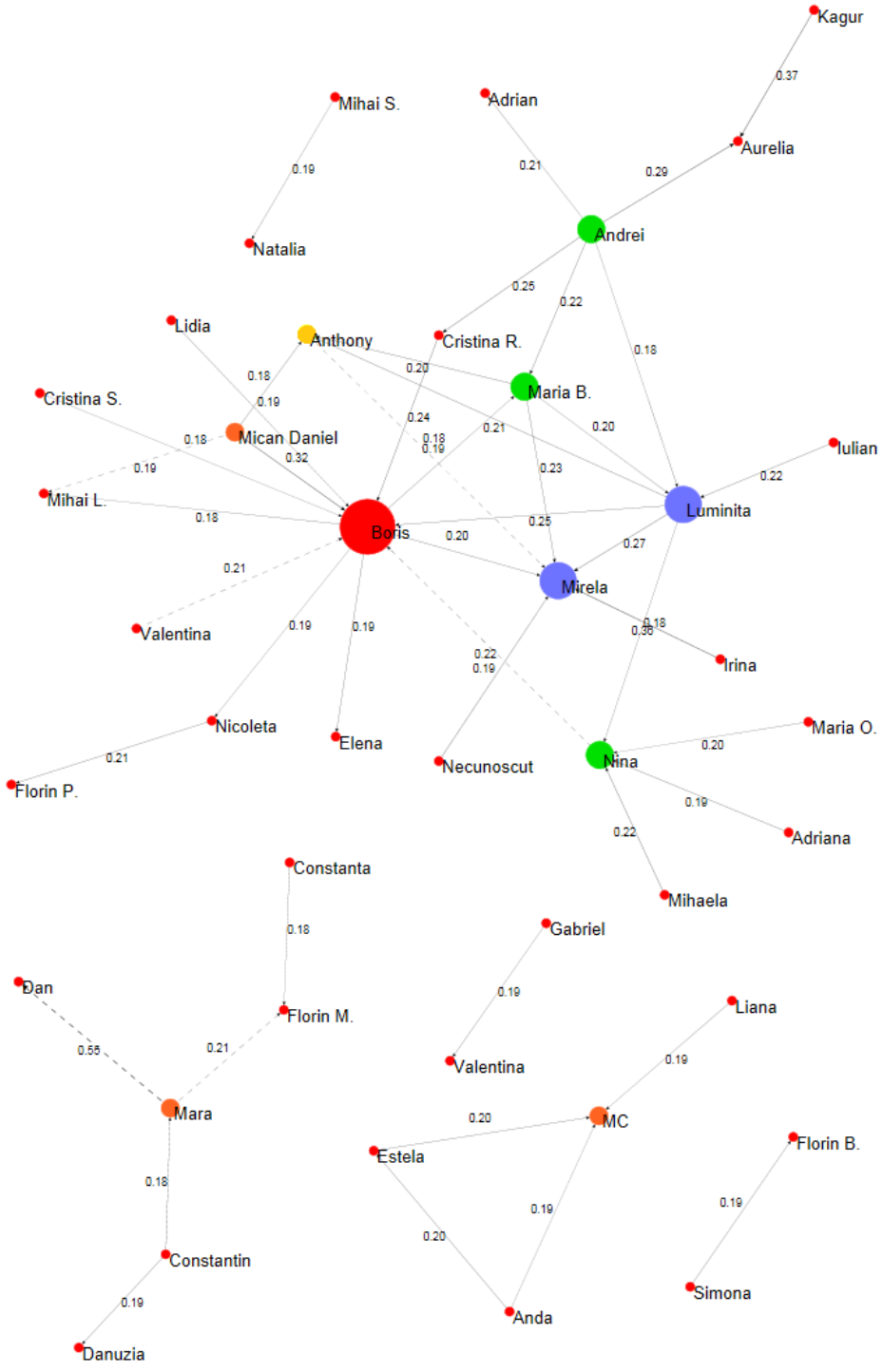


Figure 47. **Social relationships and trust levels between users**

We will now look at an example in order to see how trust relationships between users can be used for recommending resources within the network. In order to receive recommendations, a user needs to be a follower, regardless of whether this was expressed explicitly or implicitly deduced. Within the current version of the recommender algorithm, the newest resources will be recommended. These will be published resources or ones that were positively marked by the users of whom the current user is a follower. In Figure 48, we can see the list of resources recommended for the user Daniel Mican [96].

Figure 48. **List of recommendations for the user Daniel Mican**

The proposed recommender system was implemented and can be accessed online at http://www.cenaclu.intelepciune.ro. Access to the system can be gained by creating a new user account or by using the test account created by us. The login and password for this account is WSNRS.

4.1 CONCLUSIONS

Having noted the abovementioned, we can say that trust scores between users, calculated by WSNRS, allow for identifying the types of relationships that develop. Taking into account the types of relationships that the user has within the social structures, he or she will be recommended the most recently published resources. In

order to calculate the trust scores, the interactions between users and between users and content respectively, are logged and gathered. Moreover, the collective intelligence is collected from added comments, favourited resources, noted resources, clicks and from recommending within social media websites. If a recommended resource is positively rated, it becomes viral quickly, being shared in a large number of social structures.

A second characteristic is identifying interest groups and creating a hierarchy of users within social structures. Creating a hierarchy involves the identification of leaders and of isolated users. The third characteristic is the automatic management of the resources published within a portal. This feature is particularly important within a social network due to the fact that manual management is virtually impossible. The proposed approach is more advantageous than classic approaches when it comes to the issue of "cold-start" and "serendipitous recommendations" (providing recommendations which will pleasantly surprise but which are not particularly searched for).

The findings of this chapter were published in [94, 96].

5. GENERAL CONCLUSIONS AND RESEARCH PERSPECTIVES

The main goal of the researches in this thesis was that of offering concrete solutions in the context of the existing information overload in portals. In order to achieve this, we have studied, for starters, portals and the technologies that lie at the basis of their development. Through analyzing specialty literature concerning portals and CMSs, we've reached the conclusion that the border between the two is very blurry and ambiguous. The two concepts intertwine in both functions and objectives, there being a substantial overlap. Through the structured interview method, by means of the questionnaire, we have conducted a research to determine the most popular CMSs in use. The most popular functions have been studied, together with the factors that influence the development, acquisition or implementation of an open source CMS towards creating a portal, a community or an online social network. The preferences concerning certain WCMSs, programming languages together with the functionalities, divided into creation, management and publishing modules have been presented in sub-section 2.7. As such, we consider the first objective of the present thesis completed.

Next, we studied the way in which recommender systems may be used within portals in order to identify and provide relevant resources to users. More precisely, we looked for, and found two solutions for identifying and recommending valuable resources existing within a portal. The suggested approaches gather collective intelligence produced as a result of user interaction with each other and the portal's content. Accounting for the amassed collective intelligence, we have built two global models capable of identifying and supplying users with relevant content. The first model allows for recommending relevant content based on the webpage the user has open in the current browsing session. The second model takes into account the social structure the user is part of and allows for recommending quality resources that may be of interest. The two systems behave as a personalized guidance service for the user and hints to the pages he should visit next.

The first approach appears by means of the WRS recommender system. This, taking into account the association rules extracted from the user's browsing sessions, is

capable of gathering useful data by default, using a proactive approach and storing them incrementally in the database. Through the methods laid out in Section 3.4, we can uniquely identify users and the browsing sessions associated to them. As such, the extracted data are of high quality, complete, noiseless and bereft of errors, which leads to reduced storage space and execution times, due to the fact that only data relevant to the proposed goal is kept in the system. Both the gathering of useful data, as well as the extracting of association rules is done online and in real-time, thanks to the fact that the system modules communicate transactionally. For the same reason, our research allows recommending content accessed both frequently and seldom. This process is done without the need to put in place restrictions in support and trust in order to extract association rules.

Moreover, the system is capable of successfully recommending resources taking into account only one page in the user's browsing session. Thanks to this, we consider as being solved the issues raised by log file analysis and association rules extraction as presented in Section 1.2.3. In order to verify scalability, we implemented the model online within a portal in order to test it on real data. As a result of the case study presented in Section 3.6, we have concluded that the model is scalable and can be easily implemented within any portal. As such, we consider that through this approach we've managed to fulfil the second objective, as formulated in Section 1.3.

The second approach is put in place through the WSNRS social recommender system. It recommends resources accounting for member relationships and the social structures they are a part of. The proposed system is capable of logging and cohering user interaction with each other, as well as with the content. The collective intelligence is collected based on interactions produced by adding comments, favourite resources, grading them, clicks and recommendation within social media sites. By taking into account the collective intelligence extracted from user interactions, we have calculated trust scores between users. Based on them and the types of relationships established, the system may filter and recommend recently published valuable resources. The recommended resources account for the type of relationships the user has within social structures and adapt to the medium's collective dynamic.

The trust coefficients also allow for identifying the types of relationships established between users and establishing interest groups. Also with the help of the trust scores we may find the most trusted users existing within the network's social structures. The system allows for efficient identification of valuable resources and acts as an automated resource moderation tool. This is especially important in a social network because of the fact that manual moderation is practically impossible. All these statements are backed up by the case study conducted in Section 4.4. Taking the above into consideration, we believe that the proposed system successfully solves the issues concerning identifying quality and recommending new resources based on cohering collective intelligence, as stated in Section 1.2.4. As such, we believe the system manages to fulfil the third objective of the present thesis as well.

Following the case study carried out in section 4.5 regarding the possibility of creating a contextual extension by means of the WSNRS tag system we have concluded that in time, associations appear between tags. The estimated degree of similarity between tags is generally stable and may be used in tag or resource recommending. Thus, we consider the fourth objective, as formulated in section 1.3, accomplished. In the following, we will detail the main contributions of this research and will enumerate future directions in research.

5.1 DETAILING CONTRIBUTIONS

In this thesis we have offered solutions and alternatives to the problem of information overload found in portals and web applications. We have identified the sources of collective intelligence and used them to find and recommend relevant and valuable resources. We've developed global models that are able to automatically filter and moderate relevant resources. They function as personalised guiding services and have the ability to adapt successfully to the dynamics of collective environment changes. In the following we will list the main contributions of this research:

1. We have examined personalization system based on log file analysis. They contain three phases: gathering, preparing and transforming data; model and pattern discovery and content recommending. Of the three, only content recommending is done online with classic approaches. In this thesis we've

proposed, implemented and tested a scalable model in which all three phases are done online and in real-time. The model is present through a WRS recommender system which contains three modules, one for each phase, and that communicate with each other transactionally. The proposed model allows for metadata that is attached to the content in the publishing stage to be used in the process of recommendation. As such, we may restrict the content we wish to take into account in the recommending process. This advantage is absent in classic approaches.

2. We have examined the issues raised by log file analysis: the presence of a large amount of recordings not essential to the web usage mining process; difficulties in uniquely identifying users and sessions; the lack of information on the content of sought web pages; data processing, being a batch process, is time and resource heavy. We put forward proactive methods, materialised through a system of collecting data relevant exclusively to the web usage mining process. Therefore, there is no more need for the cleanup, filtering and elimination of irrelevant information phase, as well as those generated by search engines. We have analyzed the navigation patterns of search engines and have extracted rules, based on which we can identify and eliminate sessions they initiated. We have also put forward a technique with which we may uniquely identify each used by the proxy server IP, as well as the workstation. The date extracted in this way is high-quality, complete, without noise or error. All of the above leads to reduced storage space requirements and increasingly scalable algorithms through lowered execution times.
3. We've investigated the specifics of extracting association rules. This is done offline in a batch process and is a major consumer of time and computing resources. In order to be scalable, classical models eliminate a major part of extracted rules based on minimum threshold conditions on trust and support. To solve this problem, we've put forward and approach that allows the transactional and incremental extraction and storing of all association rules. Due to the fact that in our method there is no need for restrictive thresholds, both frequently and seldom accessed content may be recommended. As such, the architecture we've put forward allows for the storage of relationships made with the rarely accessed content without affecting the system's scalability.

Another plus is the fact that the system can recommend content by taking a single page into account.

4. We have proposed, implemented and tested an approach that allows for the identification and recommendation of valuable resources within social structures. The approach is materialised through WSNRS, the social network recommender system that manages to identify collective dynamics and successfully adapt to environment changes. This allows for identifying groups of interest, leaders and isolated users in a social network. This represents a solution to the overload of information, by means of automatic moderation of newly published resources within the social network.
5. We have proposed an algorithm for calculating trust scores between users by taking into account their interactions with each other as well as the published resources. In order to calculate trust scores, the resulted collective intelligence generated through user clicks, comments, grading, adding to favourites, as well as recommendations in social media of the resources, as well as user profiles has been gathered and cohered.
6. We've proposed a method for deducing implied adept-type relationships between social network users by using the calculated trust scores. Accounting for the implied, as well as explicit relationships formed within the network we suggested an algorithm that recommends published and appreciated resources generated by users within the social structure the user is part of.
7. Our approach brings improvements, as opposed to classic collaborative recommender systems and those based on content, due to the fact that it allows for resource recommendation based solely on social structure and the user's relationships. This is done without the user having to note them down. Similarity to other users is represented by the calculated trust scores, and as such, the "cold-start" and scalability issues found in CF are resolved.
8. We have developed and implemented a collaborative labelling system by means of tags, and based on the extracted data we've studied the possibility of developing a contextual extension to WSNRS, more precisely the recommending of labelled resource by means of tags. We have identified and used several methods of calculating the similarity between tags and have reached the conclusion that they can be used in constructing a recommender system.

The contributions offered by this thesis have been distributed through a number of ten publications of the total 19 done throughout the doctoral training period. They are indexed in international databases such as ISI, Springer, IEEE, ACM, Scopus etc. These publications have reported a number of twenty citations in international databases such as ISI, Springer, IEEE, ACM, Scopus etc. The works published with the according citations are listed in the Publications section.

5.2 RESEARCH PERSPECTIVES

In the future, we are planning to create a model of recommender system which could be used for providing content, suggesting users and delivering personalised advertising within web portals. The recommender system will collect, gather and analyse collective intelligence in view of improving each user's experience, but also of organising and presentation of the portal as a whole. The collected data will be analysed using techniques such as data mining, in order to extract models on the basis of which predictions and recommendations could be made. The system we would like to suggest is a hybrid approach which would use tags in order to create contextual profiles for users, together with collaborative filtering techniques. This will pattern similarities and relationships developed between content, users and tags, by analysing surfing behaviour, preferences and the social structure to which the user belongs.

We also aim to study the way in which trust can be transferred from user to user, and from user to resources respectively. We will continue the research from [94] in view of improving the model by integrating a recommender system using tags. We would thus be able to identify experts and reliable content catering for different interest categories. We would also like to create a hybrid by aggregation with the system, based on extracting association rules from surfing sessions, proposed in [97]. We would focus our research on suggesting a hybrid system that would aim to solve the problems that arise in classic recommender systems.

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