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EDITORIAL

Dear readers,

We are pleased to present Volume 1, Number 1 of the LAJC Latin-American Journal of Computing, published by the Faculty of Systems Engineering of the National Polytechnic School of Ecuador.

The works presented here were selected from a call of papers that received eleven contributions, five of which have been selected to be part of this number. Among the authors, we have researchers affiliated with universities in France (Université Grenoble Alpes, Université Paris 1 Sorbonne), Switzerland (Université de Neuchâtel), Spain (Polytechnic University of Madrid - UPM) and Ecuador (National Polytechnic School - EPN, University of the Armed Forces - ESPE).

The research topics of the published articles include: an experience in using qualitative analysis methods to evaluate the users' technology acceptance of specialized tools for Strategic Intelligence, a review of literature on the use of the Software Product Lines - SPL approach in Enterprise Resource Planning solutions, an implementation of the algorithm Rate-Based Synchronous Diffusion and two proposals in the area of Telemedicine.

We thank all the authors that contribute to generate research in Computer Science, and we always welcome contributions from researchers who have the interest to present their work in this journal.

For detailed instructions on the preparation and submissions of manuscripts, please check the URL below:

http://lajc.epn.edu.ec/index.php/LAJC/pages/view/call-for-papers

Enjoy reading.

Best Regards,

LAJC Editorial Committee

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Qualitative Assessment of User Acceptance within Action Design Research and Action Research: Two Case Studies

Edison Fernando Loza Aguirre and Alex Fernando Buitrago Hurtado

***Abstract*—Nowadays, there are several models to evaluate technological acceptance of software developed through Action Design Research and Action Research. These models rely on quantitative techniques to study user behavioural intentions and thus predict the use of a technology. This paper presents our experiences in using qualitative methods to assess such acceptance in the development of specialized tools for Strategic Scanning. Our study suggests that qualitative methods can be an alternative to evaluate technology acceptance in situations where the number of users is small or where there are requirements for continuous improvement.**

***Index Terms*— Action Research, Action Design Research, user acceptance, qualitative methods, strategic scanning**

I. Introduction

SINCE the beginning of the decade of the 1990s, research in Information Systems (IS) began to integrate two seemingly disparate approaches: on the one hand, a conceptual approach, which focuses on the production of theoretical contributions. On the other hand, a practical approach, which focuses on solving problems that practitioners must face in their own environment and context [1,2]. This led to the propagation of research based on methods known as Action Research (AR), in which scientific knowledge is obtained as a result of studying the effects of an action taken with the intention of solving an existing problem in a particular social setting [3].

In recent years, a new research paradigm has evolved. It introduces the principles of Design Science (DS) to AR methods. DS advocates for the use of artifacts as a communication means between research participants and also as a mechanism to diffuse its results [4]. This new paradigm, called Action Design Research (ADR), proposes the development of technological artifacts to facilitate intermediation between professionals and researchers as well as the appropriation, intervention and validation of theoretical concepts in practical situations [5].

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In both AR and ADR, the evaluation of the implemented solutions plays a decisive role in the research process. Such evaluation can be based on terms of functionality, completeness, consistency, accuracy, performance, reliability, usability, or adaptation to the organization [4]. Among these, gain user acceptance is a key factor for obtaining satisfactory results for both researchers and practitioners. Several models have been developed to measure the acceptance of technology focusing exclusively on quantitative techniques. Still, developers interested in using such models may face difficulties when applying them to scenarios in which the number of users is reduced. Difficulties emerge, for instance: in specific developed tools for scientific research, systems using emerging technologies, or early versions of commercial software [6,7]. Additionally, these models tend to limit the possible responses of users, which does not allow to exploit the assets of information that can be obtained by a less restrictive approach and that could lead to new theoretical contributions for the model itself [6.8].

This article presents the results of the application of qualitative methods as an alternative to the use of quantitative methods when evaluating technological acceptance. Conclusions were obtained by applying AR and ADR paradigms in two case studies. The article is organized as follows. Section II is a revision of academic literature about AR and ADR methods and models of technological acceptance. Section III presents two case studies in which a qualitative assessment was used to evaluate acceptance. They report observations from the development of two Strategic Scanning (S.Scan) oriented systems. Finally, conclusions, limitations and research perspectives are proposed in section IV.

II. Literature Review

AR aims to study the organizational changes that arise from the implementation of an action intended to solve a practical problem. The solution to the problem is the result of a joint effort between researchers and practitioners ensuing in the creation and/or appropriation of knowledge from all participants [3,9]. However, although certain methods of AR aim to produce changes by developing a computer system, AR is not a methodology focused exclusively on developing such tools.

DS focuses exclusively on the production of knowledge through the construction and use of an artifact [4]. Since artifacts can be developed in DS without the existence of a practical problem to solve or the execution of validation tests in real environments, an interaction with AR was proposed to take advantage of both paradigms: from AR, its practical problem-solving orientation and its reflection mechanism for producing knowledge; and from DS, its orientation for designing and evaluating artifacts. This interaction is known as ADR [5].

In both AR and ADR, evaluation of the resulting system is an important part of the methodology. Among the various techniques that can be applied to this stage, assessment of user acceptance is one of the most used. It focuses on capturing perceptions as a mechanism for predicting the future use of IT. These concepts are detailed in this section.

A. Action Research

Widespread used in IS research, AR became popular thanks to the works of Avison, Baskerville, Myers and Wood- Harper (i.e. [3,10,11,12]) who contributed to developing and structure AR in the field of IS.

AR is based on the researcher conviction that a particular problem cannot be studied by other methods (i.e. questionnaires, case studies, observation). Consequently, only the introduction of an action would allow a greater understanding of the problem and its solutions [10]. Unlike other methods, the AR researcher seeks to produce an organizational change while he studies the changing process [3]. These changes must be based on the adaptation of academic theories into practical concepts applicable to a particular organizational context in order to both solve a problem and feedback to the theoretical knowledge [13]. AR is recognized as a strategy of practical change due to its aims of improving practices and situation of participants [9].
AR is a five-stage cyclic process (Fig. 1):

1) Diagnosing. Identification of the main problems.
2) Action planning. Specifying actions to improve or solve identified problems. A theoretical framework should guide this stage.
3) Action taking. Implementation of the action planned through active intervention in the participating organizations.
4) Evaluating. Joint evaluation of the results by researchers and study subjects.
5) Specifying learning. Identification of new knowledge for the scientific community as a result of the success or failure of the actions taken or from the use of the theoretical framework.

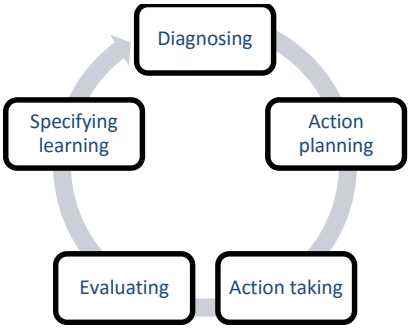

Fig. 1. AR process model [14]

TABLE 1
AR FORMS INVOLVING THE DEVELOPMENT OF AN IS [3]

		IS prototyping	Multiview
Process model	Iterative. Continuous repetition of AR cycle.	✓	
	Linear. Tasks executed in simple sequence.		✓
Typical involvement	Collaborative. The researcher is an equal co-worker. The study tasks are shared without distinction.	✓	✓
	Facilitative. The researcher is an expert helping the subjects with expert advice, technical knowledge or independent viewpoint.	✓	✓

Changes are executed in a collaborative environment that involves both researchers and practitioners. As a result of this, knowledge of all participants is increased [12]. Thus, alternatively or simultaneously, the researcher adopts the role of a participant observer (describing, understanding and analysing the organization that is studied in its own environment) and an actor (participating, guiding and influencing the behaviour, understanding and actions of the organization intervened) [3].

While there are other recognizable AR forms (i.e. canonical AR, action science, participant observation, action learning), Table 1 presents only those whose main objective involves the development of an IS.

B. Action Design Research

ADR proposes a new way of thinking and conducting research using a data artifact as a central element for solving the initial problem. This reduces the gap between theoretical knowledge of researchers and practical knowledge form practitioners. Thus, ADR pursues four goals [5]:

1) Proposing an approach in which scientific knowledge is the basis for shared conceptualization and development of an artifact.
2) Finding new theoretical knowledge by using the artifact in a particular organization.
3) Allowing practitioners to solve problems.
4) Providing guidance for integrating the concepts of DS with the principles of intervention of AR.

Generally, artifacts are constructs, models, methods or other adapted instances. These artifacts should be the instruments

solving those problems that have not yet been solved or providing better solutions than the existing ones [4]. The term computing artifact corresponds to a special type of artifacts embodying constructs, models and/or methods in a physical implementation [15].

The ADR process consists of 4 stages and 6 principles (Fig. 2). ADR follows a cycle based on collaboration and adaptation. Initially, the researcher assumes an exploratory to elucidate the problem of the organization allowing then to plan an intervention. Next step is intervention, firstly designing and constructing a computer artifact. This artifact will occupy centre-stage during the implementation period in which: behaviours are observed and data is collected. The data collected are analysed at the end of intervention and, depending on the results, it may require planning new intervention strategies. The planning-execute-analyse-formalize process can be repeated iteratively until the researcher gets to a sufficient understanding of the problem and implement a solution fixing it.

The results should be validated from three perspectives: (1) the researcher, focusing on the theoretical or conceptual contributions, (2) the practitioner, concerning by practices and tools that improve the quality and productivity of his work, and (3) a methodological perspective regarding the improvement of rules for designing new devices.

ADR was conceived as a method to ensure teamwork in a group with several complementary roles (i.e. professional experts, researchers). This allows that the interests of all the participants could be reflected in the results.

C. Evaluating User Acceptance

The successful introduction of an information technology (IT) has been historically studied in two research approaches that, although developed in parallel, were never reconciled: user satisfaction (i.e. [16,17]) and user acceptance (i.e. [18,19]). From these two approaches, the latter has attracted more the attention of researchers mainly because of its ease of use and its focus to studying the effective use of IT.

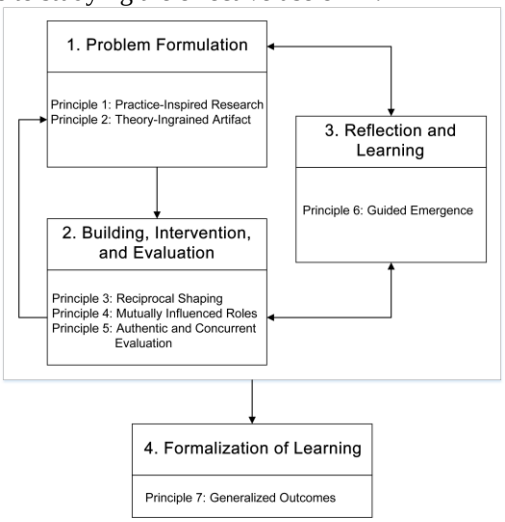

Fig. 2. Stages and principles of ADR [5]

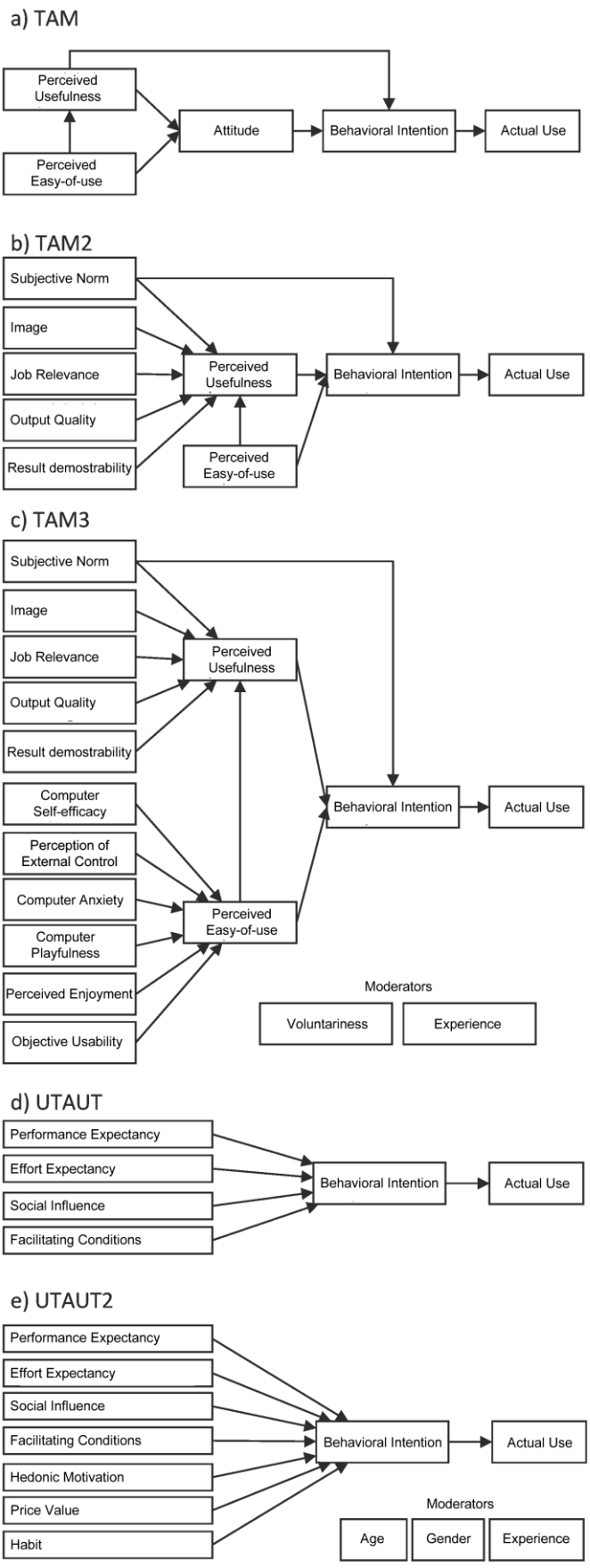

Fig. 3. IT acceptance models

The study of technological acceptance has its origins in the difficulties experienced in the early 80s with the refusal of some users to voluntarily use the ITs that were designed to assist them in their daily tasks. Since then, the understanding of acceptance has been developed mainly thanks to the models proposed by Davis, Venkatesh and others (Fig. 3): Technology Acceptance Model (TAM) [18], TAM2 [20], TAM3 [21], the Unified Theory of Acceptance and Use of Technology (UTAUT) [19], and UTAUT2 [22].

These models were developed based on the Theory of Reasoned Action (TRA) [23], and its extended version, the Theory of Planned Behaviour (TPB) [24,25]. These socio-psychological behavioural theories state that the perception of a person over the consequences of an action or behaviour can predict his future actions. The individual perception depends, for its part, on individual beliefs and behavioural predispositions [26]. On this basis, TRA and TPB have allowed to explain individual actions and behaviours in different disciplines.

The application of these theories in IT is justified by the idea that to increase the use of IT, the first thing to do is increase its acceptance by users. Such acceptance, according to TRA and TPB, will depend on the intention of individuals to use IT. Knowing the factors that influence this process, enables organizations to take actions in order to promote acceptance and therefore the effective use of IT.

In TAM, authors sought to establish the criteria for understanding the behavioural intention of the use. They found that this intention is influenced by an individual attitude that has two determinants: perceived usefulness and perceived ease of use. TAM2 expanded the original model including a detailed explanation of the forces that influence the perceived usefulness, while TAM3 focused on detailing those that influence perceived ease of use. In turn, UTAUT, and its expansion UTAUT2, add a vision of how the determinants of intention and behaviour evolve over time thanks to the incorporation of elements from other theories: Social Cognitive Theory [27] and the Theory of Diffusion of Innovations [28]. Thus, these two models helped redefine several concepts of TAM and provided new determinants to the understanding of behavioural intention.

Over the years, these models have been largely used to explain user acceptance in systems designed for mass markets. However, several researchers have pointed out its limitations as tools for explaining the acceptance in other types of conditions and scenarios [7.29]. Therefore, the study of the applicability of these models in some particular situations (i.e. highly specialized systems, prototyping) can facilitate the understanding of different determinants and relationships, and consequently it opens an opportunity to improve the models themselves [6].

Many of the criticisms of acceptance models rely on its exclusive focus on quantitative methods [8, 30]. This approach has conferred strength to these models (i.e. universality, reliability of results), which explains their recurrent employment on scenarios of generic software development (i.e. homogeneous massive systems easy to use and independent of the score or the user role) [6]. However, the panorama of applicability of quantitative methods is complicated for other settings.

Thus, the use of qualitative methods can be presented as an alternative. Qualitative methods have several advantages: (1) they are applicable to environments where the number of users is reduced, (2) they give an insight into other aspects that are not necessarily covered in a questionnaire or are difficult to quantify [31]; (3) they provide rich description of the perceptions of users and on their social and cultural contexts [32, 33]. This is why we present below our experiences using such methods in the evaluation of acceptance of S. Scan systems.

III. Case Studies

A. Research context

An organization is not exempt from the changes and evolution that may occur in its socio-economic environment. This is the reason why organizations conduct, to a greater or lesser extent, S.Scan activities in order to: keep up with the developments and trends of its environment [34,35], identify new threats and opportunities [36], anticipating changes and understand the forces that engender them [37,38], reduce the risks arising from uncertainty [39], and support their decision making [40]. S.Scan has been defined as: “the acquisition and use of information about events, trends, and relationships in an organization’s external environment, the knowledge of which would assist management in planning the organization’s future course of action” [41]. This process of acquisition and use of information is modelled as shown in Fig. 4.

Once managers encounter a problem that can involve a strategic decision, they proceed to the identification of the part of its business environment to be monitored in order to collect information related to the problem. As this is done, a stage of selection of information is performed in order to identify the relevant information and save it in a database. Executives then interpret this information during collective meetings before circulating the results to the people who can implement actions.

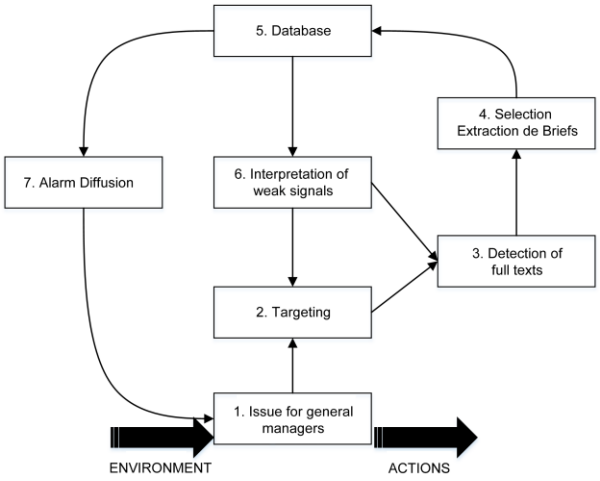

Fig. 4. S.Scan process [42]

This article presents our experiences in the qualitative assessment of the acceptance of two software tools developed within a research team of the Centre for Studies and Applied

Research in Management (CERAG) of the University Pierre Mendes France. The tools correspond to steps 2, 3 and 4 of S.Scan process presented in Fig. 4. Acceptance of both tools was evaluated in real interventions within the framework of AR and ADR as detailed below.

B. *TargetBuilder*

The objective of the targeting stage of S.Scan relies on defining and delimiting the parts of the external environment that represent, at any given moment, a critical priority for the organization [43]. Limiting the scope of the environment is important in S.Scan because a very large spectrum can lead to: an overload of information [44], ignore important information [45,46], or the failure of the S.Scan project [47]. TargetBuilder is a tool that was conceptualized to help managers to target S.Scan.

1) *Context*

The implementation of Sustainable Supply Chains (SSC) is a subject of great interest for the scientific community and industry. However, collect information on S.Scan for SSC is complex due to the crosscutting nature and the broad spectrum of issues involved [48,49] Therefore, developing and or improving methods to assist managers to target S.Scan in this context is crucial. Thus TargetBuilder was developed as part of a research project whose purpose was to find ways to help managers implement S.Scan in order to implement SSC initiatives. The project was funded by the French Agency for Environment and Energy Management (ADEME) within the research program for transport PREDIT 4.

2) *Intervention Process*

TargetBuilder was implemented following the IS prototyping method, which is part of the AR family. The method includes an iterative process of prototyping and evaluation that is repeated until the tool meets the objectives for which it was designed [3]. TargetBuilder was developed following the steps given below:

a) *Diagnostics*

The objective of this stage was to identify managers' information needs in order to perform S.Scan for SSC. This task was carried out through interviews with 50 executives within 42 organizations from different sectors. As a result of this stage, it was concluded that there was a need for developing mechanisms that would facilitate targeting S.Scan in such context, which was considered as very extensive and crosscutting, and where the collaboration of actors from different organizational units was also required.

b) *Action Planning*

In order to solve the difficulties encountered in the diagnosis stage, an existing S.Scan targeting method [43] was adapted on a system from the family of Group Support System. We choose meetings room system to facilitate face-to-face interactions [50]. The system should allow the identification of actors and topics and to for S.Scan in SSC context, but would be applicable also in other contexts. A target matrix will then interconnect the actors and topics to scan. Then they can be prioritized and filtered using two criteria: the current capacity of the organization to gather information about a pair topic-actor, and the perceived relevance the pair in the short-, medium- and long-term.

c) *Action Taking*

This stage included the implementation of improvement of a prototype through interventions in organizations interested in staring S.Scan in SSC context. The prototype was implemented as a web tool based on a three-tier architecture using a server that combines Apache, AJAX, PHP and MySQL. The tool has two modules: the Actor/Topic Manager and the Target Matrix editor. Examples of interfaces of both modules are presented in Fig. 5 and 6.

The tool was tested and improved due to interventions in the headquarters of 10 organizations involving 27 executives. In each of the interventions a S. Scan target was identified using TargetBuilder as support. Following a participant observation approach [3], all the meetings were recorded and transcribed for later analysis. The interventions were performed until a saturation point in which the system was validated as useful for S.Scan targeting. In total, four iterations were required to achieve this state as shown in Fig. 7.

d) *Evaluating*

As part of the system evaluation, a discussion about its acceptance was included at the end of each intervention. Questions were established based on TAM model. The responses collected were then subjected to a thematic analysis. The details of this evaluation are provided in the section III.B.3.

Fig. 5. Actor/Topic Manager Module

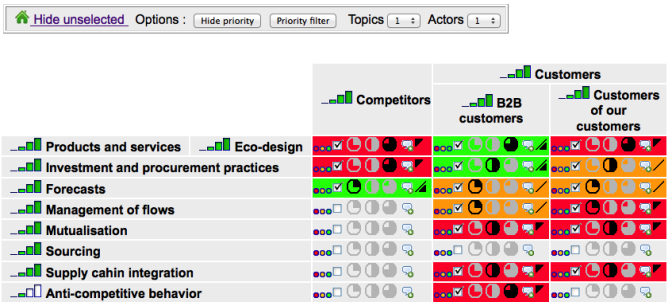

Fig. 6. Target Matrix Module

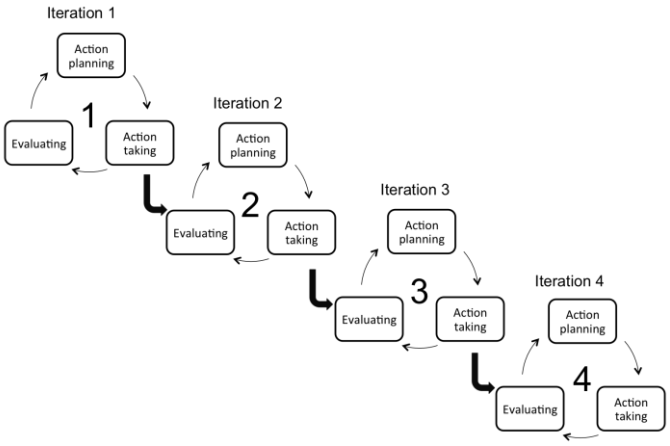

Fig. 7. AR iteration for TargetBuilding development

e) Specifying Learning

Thanks to the interventions using TargetBuilder, it was possible to propose improvements to the chosen method for S.Scan targeting [51]. Some of them were introduced as a result of suggestions from participants. Consequently, by developing TargetBuilder it was possible to capitalize on new scientific knowledge as well as a system that solved the need for supporting managers to identify targets within S. Scan for SSC.

3) Qualitative assessment of the acceptance of TargetBuilder

To qualitatively assess the acceptance of TargetBuilder, the first step consisted of coding transcripts of meetings. At the end of each intervention, a discussion was engaged about the usefulness and easy-of-use of TargetBuilder for S. Scan targeting. Also, coding included all those passages of the transcripts in which users expressed their criticisms and suggestions to the system. Thus, the coding was performed on the basis of three categories: positive reviews, negative criticism and suggestions for improvement. The first two were used to measure acceptance, while the third was used for making improvements at each AR iteration.

Two researchers independently coded the transcripts. The inter-coder agreement rate was calculated based on the number of agreed encoded fragments in relation to the total number of encoded fragments [52]. The resulting rate was 83.8%, which exceeds the required minimum of 70% for this type of study [53].

Coding results were used to assess the evolution in user acceptance as result of improvements made to the system in each phase. As shown in Fig. 8, the positive reviews tended to increase. Quite the contrary negative reviews tended to decrease.

Later, the coded elements were compared with the two criteria of TAM: perceived ease-of-use and perceived usefulness [18] where: the first concerns the degree to which a user believes the use of TargetBuilder does not require much effort. The second is the degree to which a person believes that using TargetBuilder can increase his performance in identifying the S.Scan target.

As can be seen in Fig. 9, TargetBuilder was assessed positively in terms of perceived usefulness. This suggests that users considered that the tool is useful for the task of identifying targets of S.Scan. As illustrated by one of the participants: “I like it because it’s visual, it’s functional, it’s interactive and not boring at all. I think that if we have done it with paper and pencil, it would be more tedious and time consuming” [Intervention 08].

Regarding easy-of-use, it was more difficult to assess. On the one hand, the tool was operated by one of the researchers during interventions. Consequently, there was no direct contact between the end user and tool. On the other hand, since many suggestions for improvement had to do essentially with interface improvements, easy-of-use perception changed as interventions proceeds.

4) Lessons Learned

Our results allowed a visual assessment of the system acceptance in an environment where it would be impossible to survey because of both the small number of participants and the principle of continuous improvement used in its development. The coding and use of participants’ recommendations for improvement allowed obtaining best reviews of the tool as interventions proceeds. With the application of the concepts of the TAM model it was possible to evaluate the acceptance in relation to perceptions of usefulness and ease of use, and therefore we were able future venues for research focusing on improve the perceived ease-of-use on the basis of TAM3.

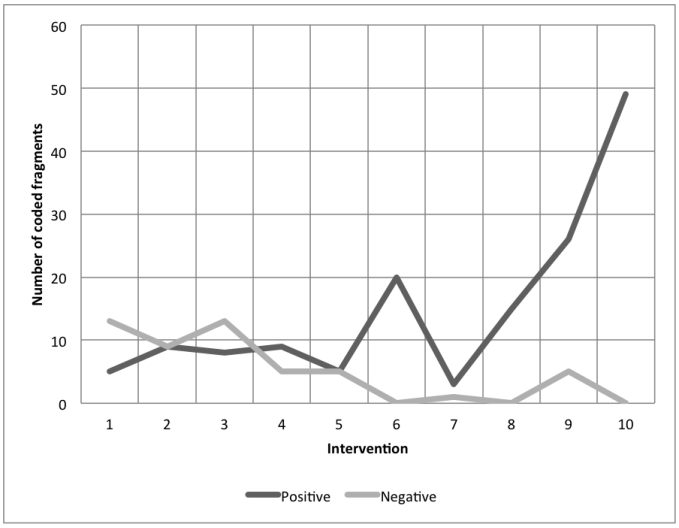

Fig. 8. Criticism evolution per intervention

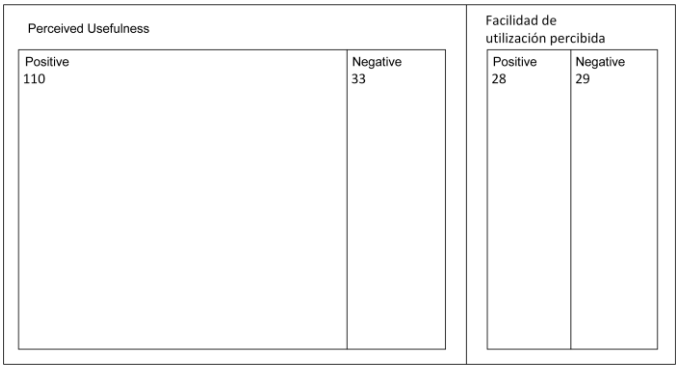

Fig. 9. Criticisms by acceptance criteria

C. Aproxima

Aproxima is a computer artifact built to support an ADR research. This tool implemented several S.Scan concepts for

finding relevant information available on the Internet. These concepts are framed in research topics concerning S.Scan and weak signals. The purpose of Aproxima is to serve as a bridge between organizations and researchers in disseminating search and selection of information techniques useful to implement a continuous process of organizational intelligence.

1) Context

The Colombian Direction for Fiscal Support (Dirección General de Apoyo Fiscal, DGAF) is an agency of the Colombian Ministry of Finance and Public Credit. It is responsible for support regional and local governments to: strengthen their tax and financial processes, monitor their fiscal status and use of national founds, and adopt fiscal consolidation and control programs.

DGAF requires financial and background information from each territorial agency in order to anticipate potential problems preventing compliance with their services providing to the community. The financial information is easily accessible through territorial agency reports or through an IS developed by the Colombian government. However, background information is not easy to obtain. It relates to political, demographic, natural, financial and legal factors that may generate a fiscal risk. Our interest was focused on developing an IS to obtain such information and properly distributed to the various executives of the DGAF.

2) Intervention Process

The research followed the steps of the ADR method in two iterations. The problems associated with the first iteration were to demonstrate the usefulness of digital press as relevant sources of information for DGAF. The second iteration focused on the problem of processing and distribution of collected information.

a) First iteration

(1) Problem formulation

Initially, efforts were made for obtaining information that could support the DGAF decision-making process for avoiding misusing public funds.

In Colombia, regional and local newspapers are a large source of information. Most of them are digitized and are accessible via the Internet. News of interest to the DGAF corresponds to the communication about public projects. It includes the views of local journalists, the impact of projects in the region and the perceptions about the financial and political management of the project. However, exploiting this information is not easy. The large amount of published information may generate a data overload and this limit its use. Additionally, the solution was to take into account that DGAF requires anticipatory information and not historical information. Also due to their limited time, decision makers required short and concise pieces of information. Therefore, the problem of this iteration focused on mitigating data overload and demonstrating Internet usefulness as source relevant information.

(2) Building, Intervention and Evaluation

In order to find a solution to the problem of information overload, a version of Aproxima was implemented in the DGAF. The aim of the device was to extract full texts from Internet sites of Colombian regional newspapers and present them in a concise form.

Our efforts focused on automatic collection of a "brief of information" [54], which is the result of extracting keywords from each of the full texts. In order to be useful in our study, these keywords were related to an anticipatory signal [43]. Thus, briefs of information were built grammatically from structures representing future actions and keywords associated with a specific theme.

After the development of the system, it was carried out an intervention in two DGAF financial subjects: (1) monitoring of budget authorizations and (2) changes in fuel legislation and their potential impacts on a territory.

(3) Reflection and learning

As a result of the intervention, the artifact demonstrated its utility as a tool for automated extraction of briefs. But its usefulness was limited since the implementation depended on the constant intervention of the researcher. Although the participants perceived the potential of the system outcomes, they suggested improvements on autonomy and distribution of information.

(4) Formalization of Learning

As conclusion of the first iteration of the research process, we were able to demonstrate that digital newspapers could be a relevant source for S.Scan if we are able to extract relevant information from a large body of data information. A second iteration was planned to improve the shortcomings of the first implementation.

b) Second Iteration

(1) Problem formulation

A frequent problem in the conceptualization of decision support systems is the lack of criteria for the appropriate presentation of information. It is necessary that the information can be presented in a concise, short and meaningful way when such information is addressed to decision-makers [44]. Thus in this second iteration, our efforts focused on improving ease-of-use and autonomy [55].

(2) Building, Intervention and Evaluation

The new iteration of our artifact integrated concepts of data overload [56] on the basis of the multidimensional concept of data overload [57]. After its construction, the artifact was used in a one-year intervention in DGAF. 44 members among experts, managers and external consultants participated in this intervention. A case study observation [4] was followed for the evaluation of results. The details of this evaluation are presented in section III.C.3.

(3) Reflection and Learning

From the analysis of our intervention, we could identify positive and improvement aspects for Aproxima. These results are presented in section III.C.5.

(4) Formalization of Learning

Thanks to the intervention carried out with Aproxima, it was possible to identify practical and theoretical contributions. On a practical level, specialists and contractors of DGAF found the artifact as a helpful tool. It enabled them to be more reactive as well as allowing them to stay informed about the daily work of local and regional authorities. On the theoretical level, it was possible to improve the understanding of the brief of information and its importance in S.Scan.

3) Qualitative Assessment of the Acceptance of Aproxima

Case study process using a computer artifact was developed by Runeson and Höst [58] and is presented in Fig. 10. The first stage is the design of the case study by defining objectives. The second corresponds to the preparation for data collection in which the tools are designed and to enable data collection. The qualitative analysis started with the construction of a coding guide that, in our case, was based on TAM2 [20]. For coding and data management we used Nvivo. The result of our coding is presented in Fig. 11 on the form of a surface diagram.

From our thematic analysis, the most important positive outcomes for Aproxima were: its relevance, its usefulness for dealing with information asymmetry, its interaction usefulness, its usefulness to complement already known information, and the ease of extracting information. The most frequent negative aspects were: deficiencies in the organization of information, misrepresentation, deficiencies in filtering relevant information, and the low credibility of some sources. With respect to the resulting information, it was considered easy to read and interpret, which facilitated its immediate use. Such use is reflected in the aspects shown in Fig. 12. The information obtained was considered in most cases as rich and diverse in content.

Easy-of-use and autonomy are aspects that still require work. With regards to ease-of-use, the presentation, format and organization of the information were suggested, by most of the users, as opportunities for improvement. On the side of autonomy, there was identified some improvement opportunities concerning thematic organization of information and information filtering by subjects, keywords and sources.

4) Lessons Learned

Qualitative analysis has not only enabled us to assess the computing artifact through the criteria of TAM2, but it has also allowed us to explore new possibilities of use of the artifact. The depth that provides thematic analysis grants not only an exploration of ease-of-use, but also deals to the very effective use. Its effective use is demonstrated by the actions that users take thanks the exposure of the information provided by the computing artifact.

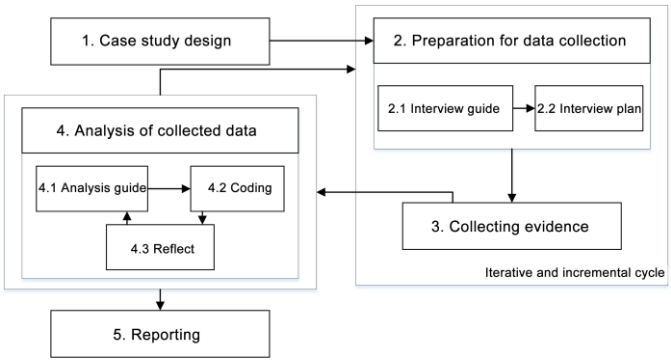

Fig. 10. Qualitative assessment process [58]

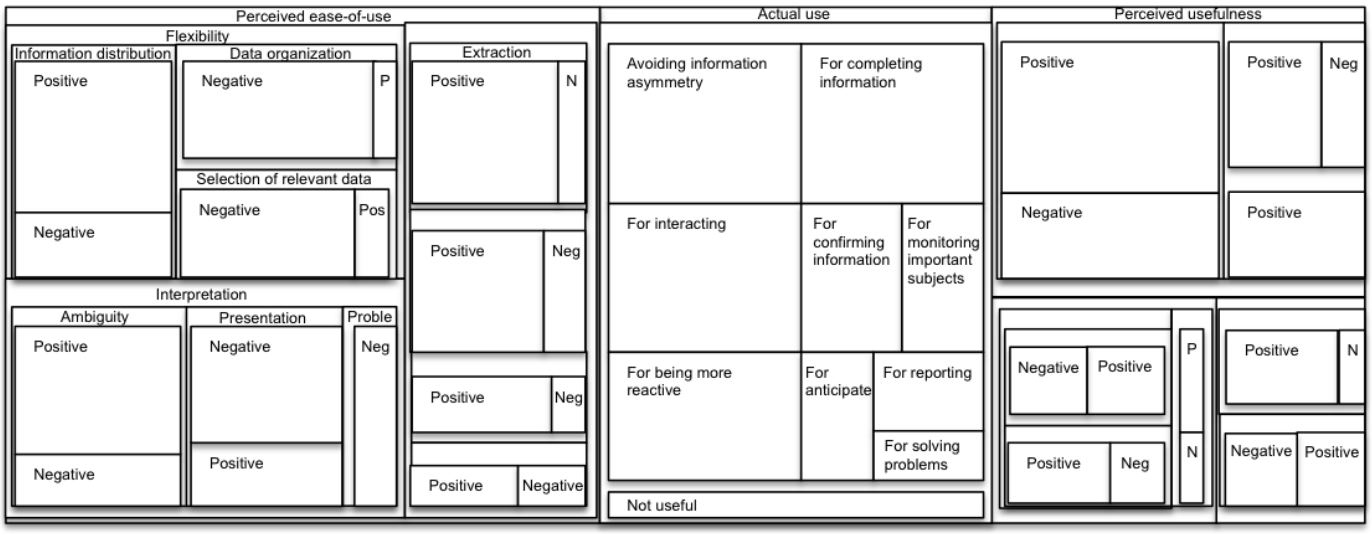

Fig. 11. Coding surface diagram

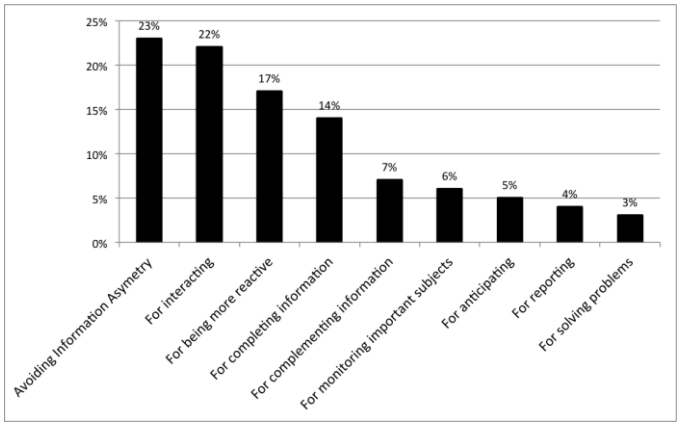

Fig. 12. Use of information in practice

IV. Conclusions, Limits and Perspectives

This study is one of the first contributions on the use of qualitative methods to assess the technological acceptance. The application of these techniques has enabled us not only to evaluate acceptance based on the existing models, but also to exploit into the wealth of the information collected during assessments in order to improve the functionality of the tools developed. The use of qualitative methods identified design problems related to ease-of-use of both tools. We were able to going further on these problems and to facilitate user feedback in order to recognize improvement aspects to be implemented in each tool in the future.

From our experience, we can conclude that the application of the techniques of qualitative analysis is an alternative to measure technology acceptance in cases where the number of users is reduced or where continuous improvement is a requirement for development. However, these methods should not be considered as opponents of quantitative methods, but rather, both should be seen as complementary. In fact, the strength of a quantitative study can be complemented with the ability of a qualitative study to exploit and deepen the evaluation aspect not commonly arisen through the use of quantitative methods. Quantitative-qualitative applications are an interesting research perspective in the field of technology acceptance.

Finally, the results presented in this article correspond to the qualitative assessment of the acceptance made in the development of applications for S.Scan. Future efforts may focus on studying its applicability in other cases and to develop specific procedures for this type of evaluation.

V. Acknowledgements

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Using Software Product Line to improve ERP Engineering: Literature Review and Analysis

Raúl Mazo, Saïd Assar, Camille Salinesi, and Noura Ben Hassen

***Abstract*—On the one hand, getting advantages of Enterprise Resource Planning (ERP) systems largely depends on their capacity to be configured and adapted to fit the customer and domain requirements. On the other hand, product line engineering (PLE) is a promising approach for configuring and adapting products by means of configuration and derivation processes. While the literature and industrial experiences show the benefits of PLE methods, techniques and tools, there is still a lack of interest in addressing ERP engineering issues with the product line strategy. The aim of this paper is to identify and analyze the different ways presented in the literature to improve ERP engineering issues with the methods, techniques and tools provided by PLE. To achieve that objective, we reviewed the literature and analyzed available publications. This literature review analyzes six research papers at the intersection between ERP and PLE. It shows that the product line strategy can indeed be applied for ERP configuration and customization. It further shows the evolving interest on this topic and discusses existing contributions.**

***Index Terms*— Enterprise Resource Planning, ERP, ERP configuration, ERP customization, Software Product Line, Systematic Literature Review**

I. Introduction

MANY companies adopt Enterprise Resource Planning (ERP) systems to improve their performance in terms of operational and management control and optimization. The primary goal is to integrate activities across functional departments including planning, manufacturing, purchasing, controlling and maintaining inventory, tracking orders, etc. On the one hand, return on investment (ROI) for companies involved in ERP development largely depends on their ability to properly design, develop and evolve ERPs to respond to all requirements from current business needs up to strategic goals. On the other hand, for companies involved in ERP usage and adoption, and beyond end-user acceptance, ROI depends on their ability to select, configure and maintain the ERP system they implement [1, 2].

According to a recent review [3], ERP implementation seems to play a dominant role in IS research on ERP. ERP implementation is the process that transforms a standard ERP product into an operational system in an organization. By ERP implementation, we mean in this paper two major critical issues: configuration and customization [4, 5, 6, 7]. Configuration is about assigning values to a number of parameters recorded as data in the ERP [8]. Customization is about extending ERP functionalities by adding new modules or changing code in the ERP software [9]. This is done to support a particular non-standard business process, to implement a business rule, to provide new features to the ERP users or to establish interfaces with other applications. The goal is to take into account the "specific" needs of the organization – specific in the sense that they cannot be achieved by ERP's standard and configurable features.

Product Line Engineering (PLE) is a new design and production paradigm that has proved extremely useful to reduce costs and time to market while developing systems families. As PLE addresses the domain level, it seems to be promising to address several challenges encountered with ERP systems, in particular the variability and complexity issues. A software product line is defined as a group of similar software applications within a market segment that share a common set of functionalities, but also exhibits significant variability in terms of requirements that can be satisfied [10,11]. Of course, as opposed to a software product line, an ERP system is not a family of applications, but a single application. However, just like a product line, configuration mechanisms are used to satisfy the various requirements from different companies. According to Clements & Northrop [11], the distinction between product lines and single adaptable system (such as ERPs) is twofold: building a product line implies the development of a family of products with often "choices and options that are optimized from the beginning" and not just one that evolves over time. Second, it implies a preplanned reuse strategy that applies across the entire set of products rather than ad hoc or one-time-only reuse [9]. At the same time, ERP systems and PLE concur on two concepts: variability management and the ability to be configured/customized and adapted to a potentially undefined number of environments [12]. However, variability and configuration management in PLE and ERP systems are treated differently. Variability in ERP systems is implemented by representing organizational data in operational tables and configuration parameters in strategic tables describing varying operational information. In PLE, configuration and variability

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management are handled differently. Configuration is based on a Product Line Model (PLM) representing the constraints of a particular domain and resolving the constraints of the PLM until having a valid solution.

These observations raise the research question: do PLE techniques contribute to ERP engineering? We seek an answer by reviewing the literature. A positive answer calls for further investigation of the extent of this contribution by analyzing how PLE techniques are used in ERP engineering methods, which variability models and software tools are used and how this usage has been applied and validated. The goal of the paper is to synthesize the knowledge available on these topics and discuss research issues. Our findings positively answer the research question; i.e., PLE techniques are indeed exploited for ERP configuration. However, the available literature is scarce: only six papers satisfied the search and inclusion criteria, and the extent of these contributions is restricted to a limited number of methods, models and tools.

The rest of this paper is structured as follows. Section 2 briefly presents the concepts needed to understand the rest of the paper. Section 3 gives an overview of the method that was employed to perform the literature review. Section 4 presents the process and results of the literature review that was conducted and section 5 discusses briefly these results. Finally, conclusions about the results, open issues and forthcoming challenges are presented in section 6.

II. Background

Product line engineering has long been described, adopted and reflected upon, as a promising approach for dealing with families of similar products [11]. In product line engineering, products are built from a collection of artifacts that have been specifically designed as a reusable core asset base [13]. Core assets include the software architecture, its documentation, specifications, tools and software components. These assets are gathered because they can be used throughout different combinations to generate products. Such products belong to the same family or "product line" in the sense that even though they show varying features (depending on the product) they still share some commonalities, in particular a common purpose or market segment. The assets are thus prescribed and reused in a preplanned fashion; for instance by using feature models [14], decision models [15], constraint-based variability models [16, 17] and orthogonal variability models [18]. PLE is, in fact, an essential medium to reduce the time to configure new products and to release them on the market.

Thus, variability is the ability of a product to be extended, changed, customized or configured for use in a particular context and PLE is an important tool for implementing it. Interestingly, variability is also a driven dimension of ERPs: not only ERPs are designed to address requirements that vary across the different customers that will purchase them, but also because it appears that user requirements show variability even within ERP implementation projects [19].

ERP Configuration is about balancing the way the customer wants the system to work, i.e. customer requirements, with the way it was designed to work, i.e. ERP configurable functionalities. ERP systems typically build many changeable parameters that modify system operation. For example, an organization can select the type of inventory accounting to employ —FIFO or LIFO, whether to recognize revenue by geographical unit, product line or distribution channel and whether to pay for shipping costs when a customer returns a purchase [20]. Moreover, ERP system relies on monolithic software architecture in which customer requirements are met by a large number of parameters, options and configurable functionalities. Organization information is represented in operational tables and configuration parameters are represented in strategic tables.

If ERP configurations do not respond to some customer requirements, companies tend to add on additional functionalities. Thus, ERP customization refers to interface development or code modification. ERP customization requires to be regularly updated and have an important impact on strategic alignment and system agility [7]. Some ERP vendors provide the customer with the program code that can be modified when desired. Some others have their own specific programming languages and tools that can be used by the customer to modify the system or add on additional functionality. This complexity of ERP systems is maybe the most important obstacle to using ERP systems in an efficient and predictable way. For instance, ERP systems configuration can take several months and no results, can be guaranteed at the end of this long and expensive period [21].

III. Research method

The literature review was conducted using Kitchenham's et al. methodological guidelines [22] [23]. Performing a systematic review is grouped into three stages: planning, conducting and reporting. A key element in systematic literature reviews is the explicit definition of a review protocol in the planning phase that guides its execution. It aims to reduce researchers' bias and helps in structuring the retrieved results. The protocol defines:

- the research questions for the literature review (focus),
- the search strategy (sources and timeframe for searching, rationale for choosing particular sources),
- the search strings (terms used for searching),
- the selection and quality assessment criteria's (general restrictions, inclusion and exclusion criteria for selecting a relevant subset of the publications found), and
- the data extraction process (storage procedures for retrieved files, data extraction forms).

The review protocol shall typically be validated by experienced researchers. In our case, the review protocol was conducted by one of the authors of this article and was validated by three senior researchers. Fig. 1 is an overview of the main stages of the research process.

IV. LITERATURE REVIEW CONDUCT AND RESULTS

A. *Research questions*

Our review was guided by the following research questions:

RQ1. For which ERP implementation stage is the PLE approach applied?

RQ2. What method (or approach) is proposed in the study?

RQ3. Which variability model is used and what are the artifacts presented in the model?

RQ4. Who is (are) the actor(s) that benefit from this method (supplier, Partner Company, end user, etc.)?

RQ5. Which tool support is developed to automate software product line application in the system?

RQ6. How is the method applied and validated and what are the results?

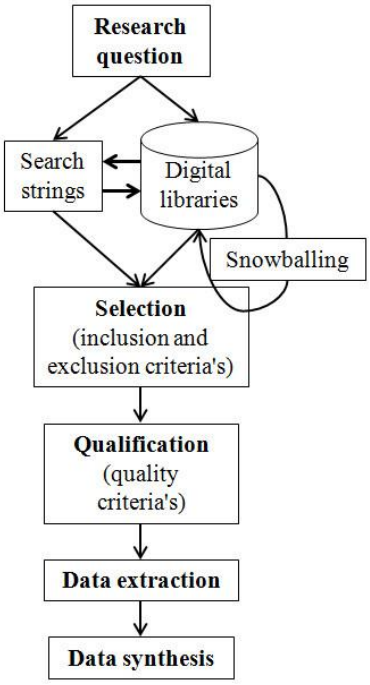

Fig. 1. Stages of the literature review process

B. *Search strings and digital libraries*

We referred in the search string to the title and the abstract of the paper and we defined the following search strategy: the sources (see Appendix 2) were selected based on an analysis of product line and ERP domain literature. The authors collectively elaborated the reference lists of the most important journals, conferences and other venues. The review included literature published from 2000 to 2013 reporting on research issues for ERP configuration and customization using software product line techniques. We conducted the literature review in 50 relevant sources.

Starting from these sources we conducted three iterations. In the first iteration, we retrieved 45 publications. We began by manually browsing the DBLP digital library[1], year by year, the proceedings of 33 conferences and 7 workshops, the content of 6 journals and 2 series of university technical reports. Then, using Google Scholar and the free search feature of DBLP[2], the following search terms concerning both software product line and ERP systems were used and combined: "Software product line", ''product line engineering", ''software product family engineering", "product family engineering", "variability", "ERP", "enterprise resource planning", "ERP selection", "ERP configuration", "ERP customization", "enterprise systems", "BAAN", "Saas", "Software As A Service", "COTS", "component off the shelf".

We used keywords like "Enterprise System", "COTS" and "SaaS" because they were used in several publications to refer ERP systems:

- *Enterprise System* (ES): this term is more general than ERP as today's ES have architectures and functionalities of a greater variety than traditional ERP systems [19]. Using this term, one additional publication was retrieved.
- *Software As A Service* (Saas): companies can use SaaS connections to set up ubiquitous business management systems as it allows ERP to be constantly accessible. On-demand ERP solutions are commonly referred to as Software as a Service (SaaS) ERP systems. This keyword led us to retrieve four additional papers.
- *Commercial off the Shelf* (COTS): ERP system is a commercial off-the-shelf product. "COTS ERP systems are software packages offered by commercial vendors that support core administrative processes such as budgeting, accounting, procurement, performance and human resource management by integrating the data required for these processes in a single database" [24]. Thus, if software product line approach can be applied on COTS, it can also be applied on ERP systems or COTS ERP package. Using this keyword, four additional publications were retrieved.

Then, we conducted a second iteration by searching in the DBLP library further publications published by authors of publications found in the first iteration. Five additional publications were retrieved. In the third iteration, as the total number of retrieved publications was limited, we used Google Scholar to browse publications that cited previously select papers, i.e., forward snowballing. Using this technique, four papers were added to our list.

In total, the search retrieved a total of 55 publications. Fig. 2 presents the number of papers retrieved per year of publication. The details of the library search are presented in Appendix 2. It is worth noting here that, separately, the numbers of publications concerning software product line and ERP are very large, but when the two subjects are combined, a remarkably small number of papers is obtained.

[1] http://www.informatik.uni-trier.de/~Ley/db/
[2] http://dblp.kbs.uni-hannover.de/dblp/

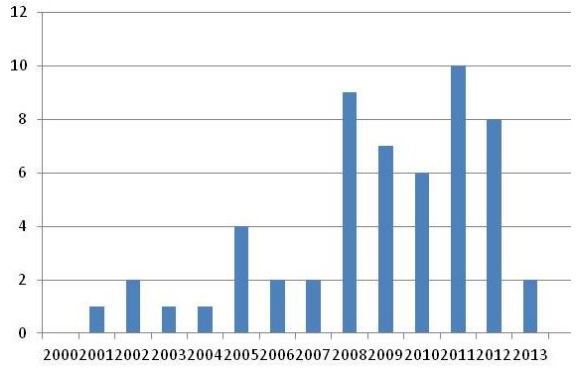

Fig. 2. Number of retrieved publications per year

C. Selection and qualification

As indicated in Fig. 1, the following exclusion criteria's were defined in the selection stage in order to narrow the current list of candidate papers:

- Criteria C1: we excluded papers that were not available in electronic form.[3]
- Criteria C2: the paper should be already published in a peer reviewed conference, journal, report or workshop. Tutorials and electronic books were excluded.
- Criteria C3: only publications written in English were kept. For example, papers written in Dutch or in Spanish were excluded.

Only papers where the proposed approach was applied in a case study, more precisely an ERP project, were qualified for inclusion in the study.

At the end of these stages, only 6 publications were left and constitute the primary studies that will be analyzed. They are presented in Appendix 1.

We note that in certain papers ERP and SPL keywords are mentioned but not in the same way as in our study. For example [25] describes and compares several industrial experiences with ERP system using product line engineering. This paper was not selected because its content is spread in two other papers that were already included: [S4] and [S5].

Based on the initial collection of publications retrieved, one could assume that there is a growing interest in the combination of software product line and ERP implementation. However in practice, only few software product line experiences are done in a real ERP engineering context. It is worth noting that when looking for papers on ERP selection by means of PLE techniques, we only found papers talking about COTS systems; none were actually about ERP selection.

According to our research, the earliest experience was in 2008 by supporting runtime system adaptation through product line engineering and plug-in techniques [S5]. Nevertheless there were no selected article published between 2000 and 2007. We can deduce that this topic is recent and there is an interest in this domain but there is no clear image to compare several studies despite the importance of this theme.

[3] Our university does not offer access to paper based publications in the Computer Science domain.

D. Data extraction

We extracted data from the primary studies according to the research questions. Table 1 summarizes the implementation stages at which SPL techniques are applied. It is worth noting that for study [S3], configuration and customization are considered as being identical.

TABLE I
DATA EXTRACTION FOR RQ1: IMPLEMENTATION STAGE

Paper	Implementation stage
S1	ERP configuration
S2	ERP configuration
S3	ERP configuration (= ERP customization)
S4	ERP configuration and customization
S5	ERP configuration and customization
S6	ERP configuration and customization

Table II summarizes the various methods that exploit SPL techniques in ERP configuration and customization. As these methods are loosely structured and not systematically documented, their descriptions varies a lot.

TABLE II
DATA EXTRACTION FOR RQ2: PROPOSED METHOD

Paper	Proposed method
S1	▪ Mapping customization and configuration keys to the corresponding requirements ▪ Compiling these artifacts to a unified artifact called PL4X Feature Element ▪ Integrating artifacts with variability model and storing them in the Feature Model Store
S2	▪ The INVAR approach: Integrating and unifying heterogeneous variability models of different actors (vendor, supplier) stored in repositories ▪ Configuring through Web services which provide standard interface for different configuration front-ends
S3	▪ Using a decision-flow pattern as a variability resolution process which consist of a set of interrelated decisions for a suitable ERP configuration ▪ Further details unavailable
S4	▪ Decision-oriented software product line approach to support customization at three levels: derivation by suppliers, configuration by customers and customization by end-user
S5	▪ Integrating product line engineering and plug-in techniques to support system adaptation
S6	▪ Proposing a Variant Description Model that comprises all variants resolved and based on the variability defined in the feature model. ▪ Mapping between the feature model and the family model, which contains ERP configuration options and documentation. ▪ Deducting a Variant Result Model which means the concrete product configuration

Table III presents variability models and modeling tools used in each method, if any. Unsurprisingly, feature modeling and FODA notation are the most frequent notations. The only tool that is proposed explicitly for variability modeling in ERP engineering context is DOPLER in [S4] and [S5].

TABLE III
DATA EXTRACTION FOR RQ3: VARIABILITY MODEL

Paper	Variability model
S1	▪ Feature model ▪ Variability modeling tool not mentioned
S2	▪ Integrated variability models: Feature model, DOPLER models
S3	▪ Variability model not mentioned; in general, variations points are ERP functionalities according to users requirements ▪ Variability modeling tool not mentioned
S4	▪ Variability model not mentioned (architectural elements, software components, documentation, test cases, requirements, plug-ins, setting…) ▪ DOPLER tool for variability modeling
S5	▪ Feature model (plug-ins) ▪ DOPLER tool for variability modeling
S6	▪ Two layer feature model 'FODA' - First layer: business processes features - Second layer: configurations features for specific customers

Table IV presents the actors that are concerned with the variability model. End-users are often – if not systematically – implicated in the configuration process.

TABLE IV
DATA EXTRACTION FOR RQ4: ACTORS INVOLVED

Paper	Actors involved
S1	Partner company
S2	Stakeholders performing the configuration
S3	Partner company end users
S4	Supplier, customer and end-user
S5	End-user
S6	Partner company

Table V describes the tools proposed to support the proposed method and the variability modeling approach. Studies [S4] and [S5] propose a complete configuration tool suites to support variability modeling and to prepare and guide product derivation and customization. As a model-driven approach is developed in study [S6], the support tool includes a transformation engine to derive customizing parameters from the variability model.

TABLE V
DATA EXTRACTION FOR RQ5: VARIABILITY TOOL SUPPORT

Paper	Variability tool support
S1	▪ *PL4X ERP configurator* links ERP configuration to the answer option(s) of each question
S2	▪ *FaMa* and *DOPLER* tools for variability modeling ▪ INVAR service configuration interface to access the variability models by means of questions and configuration options
S3	▪ *Product Line Unified Modeller* (PLUM) tool suite for the design, implementation and management of Software Product Lines (SPL) following a Model-Driven Software Development approach (further details unavailable)
S4	▪ *DecisionKing* to support variability modeling and management ▪ *ProjectKing* to support preparing and guiding product derivation and customization ▪ *ConfigurationWizard* to support decision making in product derivation and customization, according to the role of each user
S5	▪ NET-based plug-in platform for dynamic loading, unloading and composition of components ▪ *DecisinKing*, *ProjectKing* and *ConfigurationWizard* (see [S4]) comprising the *DOPLER* tool
S6	▪ PURE: a variant tool shipped as Eclipse plug-ins ▪ Three plug-ins: - a model validation plug-in to enforce the correct structure while modeling - an import plug-in to build up the Family Model in an automated way - a transformation plug-in to set the ERP customizing parameters according to the Variant Result Model

Last, table VI presents the case studies in which the proposed methods were validated and the final results of the research work.

TABLE VI
DATA EXTRACTION FOR RQ6: CASE STUDY AND RESULTS

Paper	Case study and results
S1	▪ Concrete examples from Microsoft dynamic AX platform ▪ Support for sales consultants and customer application configuration ▪ PL4X approach boosts the sales activities by providing rapid prototype configuration
S2	▪ The approach is tested in a real world product line of the industrial partner *BMD Systemhaus GmbH* (BMDCRM solution, see [S4] and [S5]) ▪ Integrates three different models where an ERP vendor relies on two suppliers (3 scenarios) ▪ The approach and its implementation are feasible and can be integrated in and ERP system example
S3	▪ The experience was done in the *Reuse-Cluster Approach Project* with four ERP major companies in Egypt (further details unavailable) ▪ Approves the systematic reuse adoption potential to open new business opportunities ▪ Interest of companies to continue with this approach
S4	▪ A case study in collaboration with the industrial partner *BMD Systemhaus GmbH* (CRM solution) in which authors represent the different modules of ERP systems as elements of a feature model with different levels. ▪ The components are stored in repository containing all features available, i.e., assets. The variability model captures the components that need to be undertaken or not based on user decisions and leads to identify all possible ways in which the system can be managed. ▪ It also allows capturing the dependencies of the product line assets. In this case CRM solution and all the features that respond to the user need are activated and other features are deactivated.
S5	▪ Conducts a case study in collaboration with the industrial partner *BMD Systemhaus GmbH* (CRM solution) ▪ Develops 6 advanced usage scenarios ▪ Shows the feasibility and usefulness of the approach by means of these usage scenarios where the variability of the ERP system is represented by means of variability models. ▪ The elements of these variability models represent

	modules of the ERP system and the relationships among these modules
S6	▪ Applying the method in three European divisions of a metal forming company. Each company uses an SAP ERP system. ▪ Describing 3 scenarios ▪ Quantitative analysis to prove the feasibility of applying SPLE to ERP system

In the section below we discuss our observations concerning ERP configuration and customization in light of the literature review results.

V. Discussion

We notice that the product line paradigm was adopted to configure and/or customize ERP systems using different methods with varying approaches. For example, Nobauer et al. [S1] and Dhungana et al. [S2] benefited from the advantages of software product line just to configure ERP systems, contrary to Wolfinger et al. [S5] who were interested in ERP customization (RQ2). On the other side, Rabiser et al. [S4A] and Leitner et al. [S6] have used this approach to both configure and customize the system, while Hamza et al. [S3] have seen that there is no differentiation between ERP configuration and customization.

The difference between the experiences reported in the papers collected in our study stands in the way variability is modeled, artifacts are represented and in how the method is automated, and depend on the organization goal. For instance, Leitner et al. [S6] represented business process features and configuration features in a two-layer FODA model in order to manage different ERP configuration variants whereas Wolfinger et al. [S5] represented plug-ins in a feature model to customize ERP system and support system adaptation at runtime. They use different tools to automate their method.

VI. Conclusion

The purpose of this paper is to identify the different ways to apply the software product line strategy to ERP systems. To realize this, a systematic literature review was carried out by following a search strategy and applying selection criteria and a qualification process. According to the data extraction process, we found that this approach has been recently applied for ERP configuration and customization.

Although the selected literature shows the importance of product line engineering methods, techniques and tools, there is still a lack of interest in addressing ERP engineering issues with the product line strategy.

In this context, compared to the vast amount of research works on developing and modeling product lines, only few approaches are proposed to deal specifically with ERP systems. Based on the literature on ERP configuration and implementations, this paper seeks to understand how ERP systems could be handled with the product line strategy: namely (a) configure and customize, (b) configure or customize, and (c) configure means customize.

According to our research, we found that in order to cope with ERP complexity, especially ERP configuration and customization, product line engineering seems to be promising in solving several challenges encountered in these systems. In particular, we found three results. The first result is that the product line strategy can be adopted both to configure and to customize ERP systems. This hypothesis is that of Rabiser et al. [S4], according to which "product lines have mainly been used by software producers to derive and deploy customized products for different customers" and thus, they seek to "demonstrate that the use of product lines can be extended to provide personalization support for end users" (p. 1). Indeed, their paper presents an approach to support both configuration and customization at three levels: supplier, customer and end-user. However, to implement this approach, support is needed to move from a level to another. The second result is that the software product line strategy can be adopted from one perspective only: configuration or customization. This result is in line with Nobauer et al. [S1] which applied the variability concept and product line approach on the organizational level to deal with ERP configuration. The third result is grounded on [S3] in which Hamza et al. asserted that there is no differentiation between customization and configuration: configuration means customization. From the point of view of ERP customers and users, it is difficult "to differentiate between product variability" and customization; thus, "Given that they do not clearly differentiate between product configuration and customization", they indeed tend to use the same pattern (p. 264).

Finally, we expected that PLE approach would be more integrated with the future ERP projects; we hope that our results are useful for researchers and practitioners when developing software product line applications in ERP systems or when evaluating existing approaches

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APPENDIX 1: LIST OF SELECTED PUBLICATIONS (PRIMARY STUDIES)

[S1]	M. Nöbauer, N. Seyff, D. Dhungana, and R. Stoiber, "Managing variability of ERP ecosystems: research issues and solution ideas from Microsoft Dynamics AX", Proceedings of the 6th Int'l Workshop on Variability Modeling of Software-Intensive Systems (VaMoS '12), Leipzig, Germany, p. 21-26, 2008.
[S2]	D. Dhungana, D. Seichter , G. Botterweck, R. Rabiser, P. Grünbacher, D. Benavides and J. Galindo, "Configuration of Multi Product Lines by Bridging Heterogeneous Variability Modeling Approaches", SPLC conference, Munich, Germany, p. 120 – 129, 2011.
[S3]	H. Hamza, J. Martinez and C. Alonso, "Introducing Product Line Architectures in the ERP Industry: Challenges and Lessons Learned", SPLC conference, Jeju Island, South Korea, pp. 263-266, 2010.
[S4]	R. Rabiser, R. Wolfinger, P. Grünbacher, "Three-level Customization of Software Products Using a Product Line Approach", Proc. of the 42nd Hawaii Int'l Conf. on System Sciences (HICSS-42), Waikoloa, Hawaii, USA, IEEE Computer Society, January 5-8, 2009.
[S5]	R. Wolfinger, S. Reiter, D. Dhungana, P. Grünbacher, and H. Prähofer, "Supporting Runtime System Adaptation through Product Line Engineering and Plug-in Techniques", Proc. of the 7th IEEE Int. Conf. on Composition-Based Software Systems (ICCBSS), Madrid, Spain, p. 21–30, 2008.
[S6]	A. Leitner, C. Kreiner, "Managing ERP Configuration Variants: An Experience Report", Proceedings of the 2010 Workshop on Knowledge-Oriented Product Line Engineering, (KOPLE'10), Article No. 2, 2010.

APPENDIX 2: DIGITAL LIBRARIES AND NUMBER OF PAPERS RETRIEVED AND SELECTED

Sources	Digital library	Retrieved	Selected
Conferences			
ACSAC--Asia-Pacific Computer Systems Architecture Conference	DBLP.....	0	0
ACSC--Australasian Computer Science Conference	DBLP.....	0	0
ACST --Advances in Computer Science and Technology	DBLP.....	0	0
ADVIS--Advances in Information Systems	DBLP.....	0	0
AHS--Adaptive Hardware and Systems	DBLP.....	0	0
AIM--Conference of the Association Information and Management	DBLP.....	0	0
AMCIS--Americas Conference on Information Systems	DBLP.....	5	0
APCCM--Asia-Pacific Conference on Conceptual Modelling	DBLP.....	0	0
APMS--Advances in Production Management Systems	DBLP.....	2	0
ARC--Applied Reconfigurable Computing	DBLP.....	0	0
ASAP--Application-Specific Systems, Architectures, and Processors	DBLP.....	0	0
SCM --System Configuration Management	DBLP.....	0	0
PFE--Software Product Family Engineering	DBLP.....	0	0
MDEIS--Model-Driven Enterprise Information Systems	DBLP.....	0	0
PRIMIUM--Process Innovation for Enterprise Software	DBLP.....	0	0
SSR--Symposium on Software Reusability	DBLP.....	1	0
SBCARS--Brazilian Symposium on Software Components, Architectures and Reuse	DBLP.....	0	0
ICSR--International Conference on Software Reuse	DBLP.....	1	0
AOSD--Aspect-Oriented Software Development	DBLP.....	0	0
VaMoS--Variability Modelling of Software-Intensive Systems	DBLP.....	4	1
SPLC--Software Product Lines	DBLP.....	13	2
CAiSE--Conference on Advanced Information Systems Engineering	DBLP.....	2	0
HICSS--Hawaii International Conference on System Sciences	DBLP.....	1	1
REFSQ--Requirements Engineering: Foundation for Software Quality	DBLP.....	0	0
COEA--Component-Oriented Enterprise Applications	DBLP.....	0	0
ICEIS--International Conference on Enterprise Information Systems	DBLP.....	0	0
CBSE--Component-Based Software Engineering	DBLP.....	0	0
CIAO!--Advances in Enterprise Engineering	DBLP.....	0	0
COMPSAC--Computer Software and Applications Conference	DBLP.....	0	0
ICRE--International Conference on Requirements Engineering	DBLP.....	0	0
PoEM--The Practice of Enterprise Modeling	DBLP.....	0	0
RE--Requirements Engineering	DBLP.....	0	0
SEA--Software Engineering and Applications	DBLP.....	0	0
Workshops			
Principles of Engineering Service Oriented Systems, 2009 (PESOS 200, ICSE Workshop)	IEEExplore.....	1	0

Proceedings of the 2010 Workshop on Knowledge-Oriented Product Line Engineering (KOPLE'10)	http://www.esi.es/workshop/KOPLE2010/	1	1
International Workshop on Software Product Management, 2006 (IWSPM'06)	IEEExplore……..	1	0
	SpringerLink……	1	0
Workshop on Software Variability Management for Product Derivation	DBLP……..	0	0
International Workshop on Software Architectures for Product Families (IW-SAPF)	DBLP……..	0	0
	DBLP……..	0	0
International Workshop on Self-Adaptive Software (IWSAS)			
International Workshop on Self-Organizing Systems (IWSOS)	SpringerLink……	1	0
	IEEExplore……..	0	0
Journals	Elsevier……	1	0
Journal of Intelligent Manufacturing	IEEExplore……..	0	0
IEEE Intelligent Systems	DBLP…….....	1	0
Journal Advanced Engineering Informatics	Emerald……	1	0
IEEE Intelligent Systems and their Application			
European Journal of Information Systems			
International journal of web information systems			
Reports			
University technical Report	http://elib.uni-stuttgart.de/	0	0
Software Engineering Institute technical report	http://sei.cmu.edu/	1	0
Others	Available from publishers	1	0
One page from the article 'Product Line Engineering in Enterprise Applications'		4	0
		7	0
Google scholar		5	1
DBLP free search			
DBLP search author			
Totals		55	6

Rate-based Synchronous Diffusion Algorithm Sensor Networks

Danilo Burbano, José Luis Carrera, Didier Aeberhard and Thomas Rouvinez

***Abstract*—Sensor networks applications often require global time synchronization between numerous sensors. In this paper we implemented the Rate-Based Synchronous Diffusion Algorithm as described in [RE1] on TelosB Motes with Contiki. We report the development procedure and the results obtained on the TARWIS testbed from the University of Bern, Switzerland.**

***Index Terms*— time synchronization, mobile reference node, TARWIS testbed, Rate-Based Synchronous Diffusion, synchronization initiator.**

I. Introduction

GLOBAL synchronization is a crucial issue to deal with in sensor network applications. This work relies on the Rate-Based Synchronous Diffusion method to achieve global synchronization within a sensor network. The implementation of the method in this work was divided in two general phases:

- Neighbours discovery, and
- Convergence phase

The main goal of this project is to achieve a global synchronization between the 40 nodes in a sensor network. The algorithm solution was developed with Contiki operating system and its performance was tested using TARWIS testbed management architecture.

II. Neighbours discovery

Defining the Neighbour Tables is important and one of the first steps in the initialization of the sensor network. In this work a deterministic neighbor discovery method is used.

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A. Discovery

In order to acquire the Neighbour Table, each node transmits broadcast messages according to a schedule defined by the user. This broadcast contains the id of the node and its clock ticks when is send. When a broadcast packet is received, the entry is checked to find out if it is already present in the Neighbour Table or not. If not, the offset between both nodes is computed and added to the Table with the node id. The Ratio Signal Strength Intensity (RRSI) is also computed and added to the Table. The user can schedule the broadcast with 3 different parameters:

(1) the time the node waits after started to begin broadcasting,
(2) the time the node waits after sending the broadcast, and
(3) the number of times the broadcast is resend

Note that the time the node waits after sending a broadcast will be tuned in Section 5 and called broadcast interval.

III. Convergence Phase (Clock Synchronization)

We are using an internal synchronization mechanism. This means that each node knows how the clock of its neighbours works and then translates from one clock time to another. In order to reach such behavior on each node, a fully localized diffusion based method is implemented in which each node exchanges and updates information locally with its neighbours.

A. Principle

The Rate-Based Synchronous Diffusion is a fully distributed and localized method to synchronize locally the nodes without a global synchronization initiator. This diffusion method achieves global synchronization by spreading the local synchronization information to the whole system and then each node in the overall network agrees to change its clock readings to a consensus value. In the end the times of each node will converge to a global common time.

B. Unicast

Each node will iterate over all its neighbours and will determine the offset between the clocks using unicast messages with a modified Round-Trip (RTT) Synchronization schemes. The original scheme uses four different clock times when the message is sent form the neighbor node and when it

is received from the node we want to synchronize the time. So that the offset of those clock times is more accurate. Then the node will adapt its time by a factor r to the neighbours' node time. Finally, after a non-deterministic number of rounds of diffusion the clock in each sensor will have the same value. Note that the factor r will be tuned in the Section 5 and called r-value.

IV. Methods

The functions for sending/receiving unicast messages are described in this section as it is a modified version of the RTT synchronization. A unicast message contains four parameters:

(1) a Boolean value to know if the message is complete or not,
(2) a clock time value, and
(3) a node id

The function **send_uc( )** prepares a message to be sent to a node from the Neighbour Table. The message contains the id of the node (so that the other node knows who the sender is) and the Boolean value false to know the message is not complete.

```
static void send_uc(){
 //Write the id of the current node
 tmRoot.originator = node_id;
 tmRoot.completed = false;
 //Prepare the unicast packet to be sent.
 packetbuf_copyfrom(&tmRoot, sizeof(tmRoot));
 //Send
 unicast_send(&uc, &addr);
 }
}
```

The function **recv_uc( )** is separated in two parts. The first part concerns the messages that are completed and the second otherwise.

If the message is complete, the new time of the node is directly computed using the following formula:

*newTime = clocktime()*r_(clocktime()-tmSlave.time)*

And the new clock time is set. Using this formula is slightly different from the RTT sync one. In fact, here we only take the two times of the different node to do the offset.

Otherwise, the message is filled up with the id and clock time of the node, set completed and sent back to the originator node.

```
static void recv_uc(struct unicast_conn *c, const rimeaddr_t *from)
{
 //Read the message
 packetbuf_copyto(&tmSlave);
 //If the hardware is not waiting for a message, update the time
 if(tmSlave.completed){
  newTime = clock_time() - r*(clock_time() - tmSlave.time);
  clock_set(newTime);
 }else{
  //Directly get the time when a runicast message is received
  tmSlave.completed = true;
  tmSlave.originator = node_id;
  tmSlave.time = clock_time();
  //...then copy the message and send it back...
  packetbuf_copyfrom(&tmSlave, sizeof(tmSlave));
  unicast_send(&uc, from);
 }
}
```

V. Experiments

The first part of the experiments was done using the Telos nodes. Two parameters were tuned:

(1) the r-value of the syncing algorithm, and
(2) the broadcast interval

The r-value was set to 0.5 and will be tuned afterwards. The broadcast interval was set to at least 5 seconds in order to let the nodes discover each other. The second part consisted in testing our algorithm on the TARWIS platform.

A. Broadcast interval and r-value tuning

The tuning of the broadcast interval is crucial to avoid congestion and packets loss while the r-value tuning will increase the syncing convergence.

Three values were chosen for the broadcast interval: 5, 10 and 15 seconds. Using an interval of 5 seconds was not enough as the nodes were able to sync only for a short period of time before receiving wrong values. With a 10 seconds interval, the results were far better and the node kept on synchronizing during the whole period. With the 15 seconds interval, the results were worse than with 10 seconds.

In fact at the end of the period, the nodes were not synchronized as nicely as before. For those reasons, an interval of 10 seconds was kept for the rest of the tests. As the r-value has to be between 0 and 1, the value 0.25 and 0.5 were chosen.

In fact as the synchronization is made between 2 nodes, values higher than 0.5 mirror the value lower than 0.5. The value 0.5 gave a better convergence between all the nodes after the test period.

Figure 1 shows the results with an r-value of 0.5 and an interval of 10 seconds.

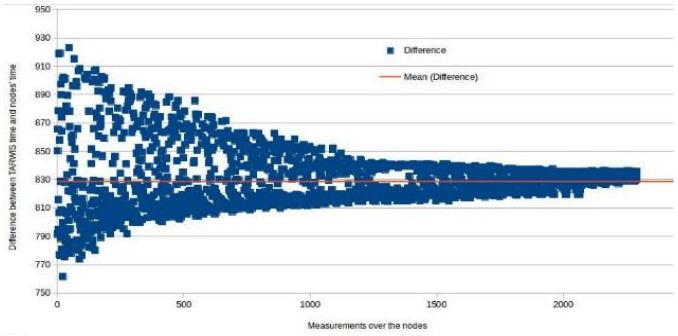

Fig. 1. Graph of the difference of time between a node and the TARWIS time through time with a r-value of 0.5 and a broadcast intervals of 10 seconds

B. *General tuning*

The r-value and the broadcast interval are not the only tunable parameters.

Firstly, a different protocol (X-MAC) for sending/receiving packets was tested.

Secondly, as we modified the RTT synchronization algorithm, we also tested the original one.

The X-MAC protocol was used with the same parameters as before. As expected, the nodes take more time to converge. This is due to the fact that the nodes are not constantly checking for an incoming message.

The genuine RTT synchronization is also tested with the same parameters. As the time is measured four times and the offset is calculated differently, the results show that the synchronization is converging slower but more constantly. Figures 2 and 3 show the result graph of those two tunings

VI. Improvements

Even if the synchronization works well, there is still room for improvements.

Firstly, we were unable to let a node synchronize its clock further than 2^16 clock ticks. In fact, it seems that a cast is wrongly implemented in our code but we were unable to find it.

Secondly, with more time we could have made more tests between our modified RTT and the genuine one in order to see more meaningful differences.

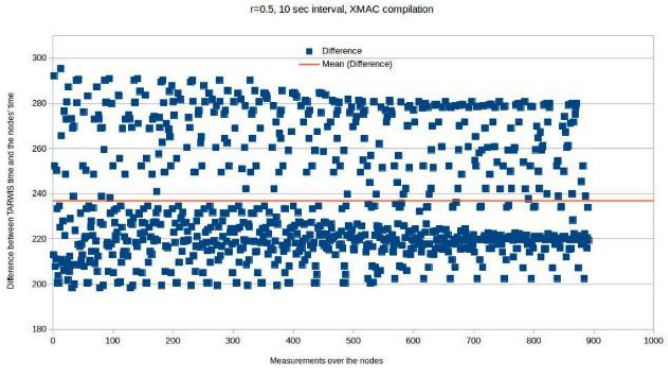

Fig. 2. Graph of the results using X-MAC as compilation parameter protocol

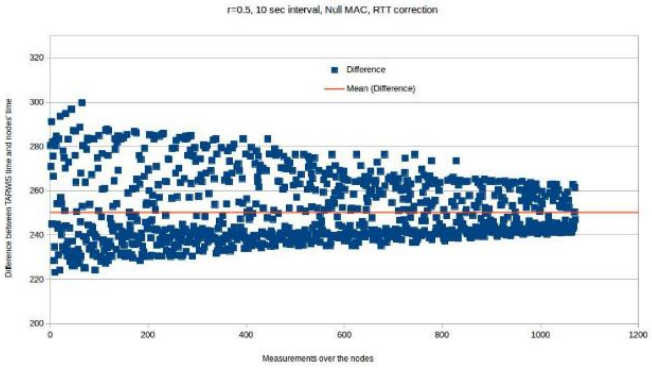

Fig. 3. Graph of the results using the original RTT Synchronization algorithm

VII. Conclusion

Isolating the optimal interval for the neighbour discovery phase in real world scenarios is a challenge. Indeed not only we need to consider energy efficient mechanisms but also intelligent algorithms for establishing and adapting appropriate broadcasting intervals. The reason behind it lies in impacting as little as possible the synchronization phase.

Determining neighbour relationship between two nodes is a challenging process too. The environment conditions of the network can suddenly change during the working time, influencing parameters like RSSI or round trip time which are used to define neighbour tables.

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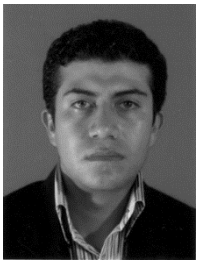

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Personalized Medical Alert System Trend Configuration and Follow-up

Juan Pablo Suarez Coloma and Christine Verdier

***Abstract*—The continuous increasing needs in telemedicine and healthcare, accentuate the need of well-adapted medical alert systems. Such alert systems may be used by a variety of patients and medical actors, and should allow monitoring a wide range of medical variables. This paper proposes Tempas, a personalized temporal alert system. It facilitates customized alert configuration by using linguistic trends. The trend detection algorithm is based on data normalization, time series segmentation, and segment classification. It improves state of the art by treating irregular and regular time series in an appropriate way, thanks to the introduction of an observation variable valid time. Alert detection is enriched with quality and applicability measures. They allow a personalized tuning of the system to help reducing false negatives and false positives alerts.**

***Index Terms*— Alert, Fuzzy logic, Introduction, Personalization, Quality metric, Tempas, Time series, Trend, Valid time.**

I. INTRODUCTION

ALERT systems have been largely implemented in different domains as home, car, natural risks surveillance, or medical follow-up. In most cases, alerts are notified when a monitored variable value is out of a predefined range. In medical domain, alerts concern different users and a variety of interests. More automatic and popular alert systems concern drug prescription [1]. Alert systems detect drug interaction, contraindication, cross allergies, and other drug related events [2] [3] [4]. Such alert systems are often included in drugs databanks (in France, Claude Bernard's, Vidal's or Thériaque's). More expert alert systems are used in Intensive Care Units (ICUs) [5] [6]. These systems are based on the same model: vital parameters monitoring and alert notification when the measured value goes beyond predefined thresholds. Alerts are notified to physicians and nurses. Medical alert systems are

mostly used in health professional environments (office or hospital).

Telemedicine tends to a largely and legal development for different and complementary reasons as reducing health costs and improving patients' quality of life. Transferring medical actions towards paramedical professionals or patients themselves become a reality. Context-aware medical alerts measuring trends becomes particularly important in the new private environment where there are no, or few, medical skills. Some already existing systems are dedicated to elderly surveillance (physiological or home sensors). These Alert systems are preconfigured with most often no actions except: on or off position. Systems are activated manually by elderly people themselves each time they feel in danger. A customer service is informed and decisions are taken.

This paper presents Tempas, a context-aware alert system based on linguistic trends. Tempas works with different kind of variables, and can be used in all environments (specialized or not) by every kind of users (expert or not). Trends are detected over regular and irregular time series extracted from patient observations. Linguistic trend values are stemmed from fuzzy logic. The application index measures the quality of the trend classification. It is used for alert filtering [7]. A previous version of this paper has been submitted to [8].

Tempas extends Pas [9], an alert system, based on fuzzy logic and linguistic values, connected to medical and environmental databases. The linguistic values are expressed in natural language such as "low", "normal", and "high". Tempas introduces time management in the system. Linguistic values are used to classify variable evolution such as "decreasing", "stable", and "increasing". Tempas has been implemented and integrated within an ERP solution called Futura, owned by Calystene S.A.

Section II presents a global view of Tempas and focuses on alert configuration. Trend definition and trend detection are explained in detail in section III and section IV, respectively. Section V presents related works on alert systems, time series, and trends. We present our conclusions and perspectives in section VI.

II. TEMPAS

In this section, we present an overview of Tempas and a brief summary of the alert configuration process. Tempas is not an expert system but a decision making help tool. Next sections explain how the user defines trends and how the algorithm detects alerts.

Tempas is a context-aware alert systems based on trend analysis and user personalization. The personalization allows medical actors to create their own alert system by defining:

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- **The variables to monitor**, vital and non-vital parameters, environmental conditions, etc.
- **Specific valid value ranges** for the monitored variables. This information allows overriding default values if required.
- **Relevant trends** leading to alerts during variable monitoring. For example monitoring increasing trends in body temperature to alert detection.
- **Target population**, patient or group of patients potentially concerned by the alert.
- **Alert notification parameters** as the users to notify and the notification method.
- **The expected alert quality.** This is provided by the *application index*, which expresses how much an alert concerns a patient.

An example of alert definition is the following: "Send an alert to all nurses if a decreasing body temperature trend is detected for patient Johnson". The alert behavior is adapted to the whole context (user, patient, alert itself) e.g. use a range of [36°C – 42°C] for body temperature in all alerts, and [37°C – 40°C] in alerts created by Dr. Smith. Only the alerts with an *AI* superior to 0.8 are notified.

Personalization and context-awareness tend to reduce the false negatives and false positives, and to have always relevant alerts. Anyone can use Tempas. No high mathematics or informatics skills are required to create or edit trend alerts. The more the system is used, the highest its quality becomes.

III. Trend Definition

We explain in this section how the user defines linguistic trends. Each linguistic value is stemmed from fuzzy logic. Each fuzzy set represents a linguistic value. Segments are classified in a trend from its slope (angle) and the fuzzy sets. In section IV we explain how to find segments in time series and how to proceed to alert detection.

Before being informed by alerts, users need to define how trends can be linguistically classified e.g. "decreasing", "stable", "increasing". A range of angles is specified for each classification set. Tempas provides a fuzzy set generation algorithm to help the user to avoid the tedious task of trapezoidal sets definition. The algorithm requires two input values: the number of sets (the different linguistic values) and a classification tolerance *CT*. Generated fuzzy sets can be modified by users if needed. Fig. 1 shows the generated sets for different *CT* and five linguistic values.

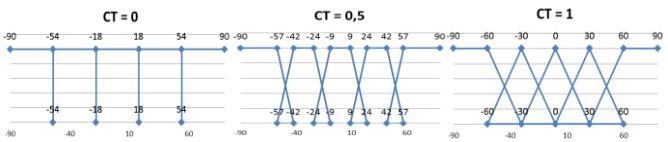

Fig. 1. Five generated fuzzy sets changing *CT*. Each set represents an ordered linguistic value among: "strongly decreasing", "decreasing", "stable", "incresing", "strongly increasing"

The *Trapezoidal membership function* maps each element from the universe X to a value between 0 and 1. The membership degree (computed from trapezoidal membership function) covers the classification ambiguity. Fig. 2 shows the trapezoidal membership function that computes the *AI* of a segment. The segment *AI* is the same as the alert *AI*. Equation (1) computes the membership degree.

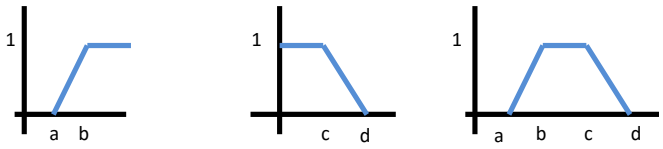

Fig. 2. Trapezoidal membership function

$$AI(x)=\begin{cases}0, & x<a\\ \frac{x-a}{b-a}, & a\le x\le b\\ 1, & b\le x\le c\end{cases}\quad AI(x)=\begin{cases}0, & x>d\\ \frac{d-x}{d-c}, & c\le x\le d\\ 1, & x\le c\end{cases}\quad AI(x)=\begin{cases}0, & x<a \text{ or } x>d\\ \frac{x-a}{b-a}, & a\le x\le b\\ 1, & b\le x\le c\\ \frac{d-x}{d-c}, & c\le x\le d\end{cases} \tag{1}$$

Segment classification is closely related to false positives and false negatives. Users may reduce false positives increasing the *AI* quality filtering, redefining the number of classification sets, or redefining the *CT*. In case of false negatives, users may decrease *AI*, redefine the number of trends, or redefine the *CT*.

IV. Trend Detection

Trend detection in Tempas consists in three steps explained in the next subsections. The normalization process transforms the observation information (measured value and timestamp) into a space between 0 and 1. Segmentation and fusion finds the most important k segments on regular and irregular time series. Finally, segment classification classifies each obtained segment as a linguistic trend.

A. Normalization

Data normalization translates data obtaining values between 0 and 1, allowing using segment slope as unique criteria for its classification. The algorithm uses segment angle, easy human eye understandable, for trend detection. The advantage is to avoid graphic perception problems. Graphically, the slope in Fig. 3 seems to be the same at left and right. Apparently, Unit changing does not affect the trend form. This happens when axis units are well chosen to draw both time series. In fact, the slope (defined as "vertical changing over horizontal changing") changes if unit does. A temperature changing from 37.7 to 38.2 degrees Celsius in an 8 hours period can be presented as a changing from 99.86 to 100.76 degrees Fahrenheit in a 28800 seconds period. Slope is defined as 0.5/8 in the first case and 32.9/28800 in second. Slope is 0.1 in both cases if data are normalized. Tempas normalize data using variable and time ranges obtained from variable context and window length, respectively.

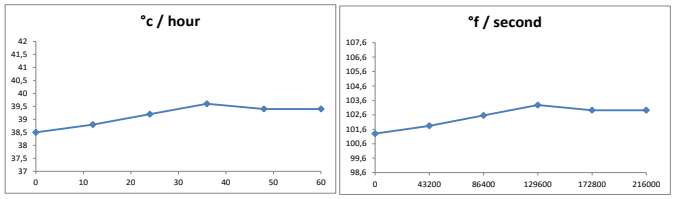

Fig. 3. Left graphic uses degrees Celsius for temperature and hours for time. Right one uses degrees Fahrenheit and seconds instead. Body temperature range is [37 °C - 42 °C] equivalent to [98.6 °F - 107.6 °F], time range is [0 h - 60 h] equivalent to [0 s - 216000 s]

B. Segmentation and fusion

In this step, Tempas gets the observation set, segments the data, and merges until obtaining the *k* most significant segments. The *k* value is defined by the user. The segmentation algorithm uses a Piecewise Linear Representation [1] and data approximation by linear interpolation for two related reasons. It is easy to understand, thus, users can configure alerts by themselves.

The segmentation algorithm uses a bottom-up approach and a window based approach to deal with real time data streams [2]. A window corresponds to time series containing a patient observation set. The user specifies (1) the period length containing the desired observation set, and (2) the wished number of observations (*no*). These two parameters are used by the algorithm to create a hybrid window. A hybrid window has two measures, size and length. The window length is a temporal distance between the two extreme points of the observation set. The size is a quantitative measure defined by the number of points of the window. The window size and length do not always correspond to the number of observations and the period length specified by the user. A two-step algorithm uses the window to find the *k* most representative segments. Each segment is used to calculate one trend.

The first step is the segmentation. Tempas pass from *n* points to *n-1* or less segments. Tempas uses the observation variable valid time *OVVT* (how long the variable value is true for trend detection) [3]. OVVT is a segmentation parameter (see *Trendability*). This parameter let to handle regular and irregular time series differently. Segment fusion comes after time series segmentation.

Trendability is the ability that two consecutive points have to belong to the same trend. If the temporal distance between them is superior to the OVVT, they cannot belong to the same trend. Consequently, it is possible to find non-connected segments after segmentation. Fig. 4 shows two segmentations. One segmentation process (top-right) generates two non-connected segments. The second segmentation process (bottom-right) generates three connected segments.

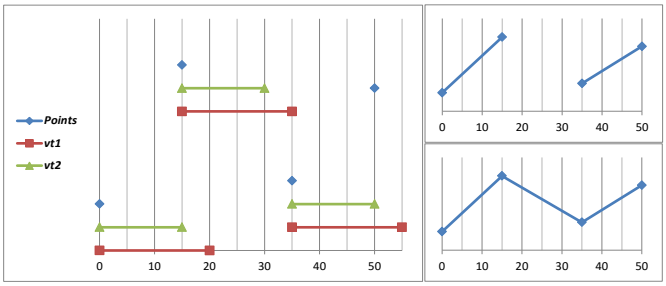

Fig. 4. At left, a 4 points time series with a valid time vt1 (square markers) and a valid time vt2 (triangle markers). At the top right, the segmentation uses vt1 and produces 2 non-connected segments. At the bottom right, the segmentation uses a valid time vt2 producing 3 connected segments

An iterative algorithm finds the *k* most representative segments. Each cycle merges two connected segments into one. The decision is based on the smallest *merging cost*. *Merging cost* is a metric for merging two connected segments. It represents the Manhattan distance between the extreme points of two segments. If there is more than one smallest *merging cost*, the rightmost one is chosen. It is nearest the current time. The algorithm stops when the *k* segments have been found, or when the smallest *merging cost* goes over a user defined value. Fig. 5 shows the iterative fusion process until getting two segments.

C. Segment classification

Segment classification is the final step of trend detection. Final Segments are classified using the fuzzy sets generated by the user. Each segment classification returns a linguistic trend value and an *AI*. Detected trends with an *AI* over the threshold are notified to users e.g. a segment is classified as “stable” and “increasing” with a membership degree of 0.4 and 0.6, respectively. If threshold defined by the user is inferior or equal to 0.6, then, the system sends an increasing trend notification.

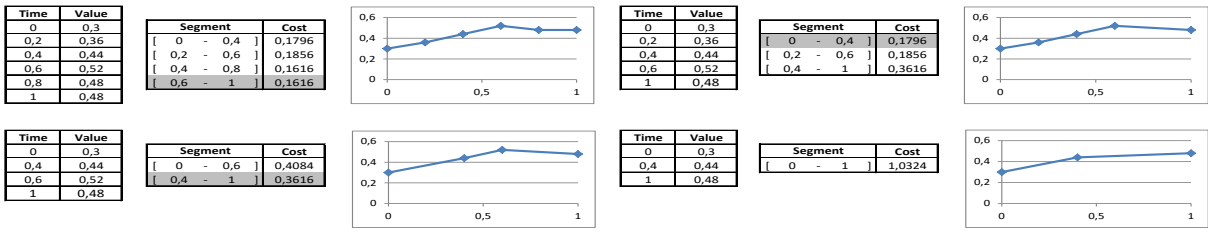

Fig. 5. Iteration process. A shadowed row contains the selected two consecutive segments to be merged. At the top left, the merging cost for the segments [0.4, 0.8] and [0.6, 1] is 0.1616 and is the smallest. The system chooses the rightmost one ([0.6, 1]).

V. Related Work

Medical alert systems are often preconfigured alerts. The main problem is that users lose interest in these types of alert systems because: they produce many false positives, false negatives, not well targeted alerts, or useless alerts [4] [5] [6]. For this reason, alert systems are not well accepted in clinical information systems [1].

Time-series are multidisciplinary and produces huge amounts of data. Many works use dimensionality reduction based on signal treatment [7] [8] [9] [10]. Charbonnier and Gentil [5] define three thresholds to detect a trend in a signal. Their values are chosen from normal behavior of monitored variables. Their algorithm uses these thresholds to classify online-detected segments as one of seven temporal shapes. Fuzzy logic on time-series helps to get human understandable results according to context situations [11] [12] [13]. These works find only one trend on the time series from predefined fuzzy sets. In some cases, fuzzy sets are domain independent. Time warping techniques are used to compare time-series with different time length with the purpose of pattern matching [14]. Existing works are domain-dependent. To the best of our knowledge, no other works propose trend and variable information normalization.

Most online segmentation algorithms use a sliding window approach. The algorithm tries to merge the new segment with the current segment. In case of positive merging, the current segment grows, else, the new segment becomes the current [5] [10]. Other approaches extend from two to three consecutive segments merging [15]. Time-series segmentation is achieved by bottom-up techniques [16]. SWAB is a generic algorithm for time-series segmentation [17]. SWAB mix a sliding window approach with a bottom-up approach for online segmentation. Systems express trends using rules over time-series segments e.g. “oxygen interval slope > 0.4 Kilopascal per second”.

Papadimitriou, Sun et Faloutsos introduce SPIRIT [18]. SPIRIT monitors multiple streams at same time to found k hidden variables. Each hidden variable corresponds to a summarization of a group of correlated streams. Hidden variables are used to found (forecasting) trends using multiple variables. Forecasting trends are commonly used for anomaly detection [19] [20]. TrendX use trend templates to express expected behaviors (trend) of specific disorders [21]. Normal or abnormal behaviors are used for diagnostics. A trend template contains a temporal pattern in multiple variables.

VI. Conclusion and Perspectives

This paper presented Tempas, a temporal alert system allowing customized variable monitoring. It facilitates alert configuration by using linguistic trends. The system is generic – working with several kind of variables – and can be instantiated in any application domain. Tempas has been implemented in a real ERP solution. Preliminary experiments have been made. A non-expert user was able to create an alert to monitor rising body temperature. He adjusted the application index and the classification tolerance following his common sense. An expert user validated the results. More experiments will be realized in the near future. Automatic validation is not advised given that quality is a subjective value in alert systems.

This work introduced a quality index expressing how much an alert concerns a patient. Future work will improve quality information by introducing a trust index metric. This trust index will reflect how much the user can trust the alert. We will investigate the introduction of complex alerts combining trends and simple events (as medicine taking) and simultaneous trends.

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A Review of Algorithms for Retinal Vessel Segmentation

Monserrate Intriago, Fernando Uyaguari Uyaguari and Elizabeth Salazar Jácome

***Abstract*—This paper presents a review of algorithms for extracting blood vessels network from retinal images. Since retina is a complex and delicate ocular structure, a huge effort in computer vision is devoted to study blood vessels network for helping the diagnosis of pathologies like diabetic retinopathy, hypertension retinopathy, retinopathy of prematurity or glaucoma. To carry out this process, many works for normal and abnormal images have been proposed recently. These methods include combinations of algorithms like Gaussian and Gabor filters, histogram equalization, clustering, binarization, motion contrast, matched filters, combined corner/edge detectors, multi-scale line operators, neural networks, ants, genetic algorithms, morphological operators. To apply these algorithms pre-processing tasks are needed. Most of these algorithms have been tested on publicly retinal databases. We have included a table summarizing algorithms and the results of their assessment.**

***Index Terms*— Terms—fundus, fundus analysis, image analysis, morphology, retinal vessels segmentation, retinopathy, vessel detection.**

I. INTRODUCTION

THE blood vessels of the retina are a complex network. The assessment of retinal vascular network is basic for various medical diagnoses, such as retinopathy caused by diabetes, retinopathy caused by hypertension, glaucoma or retinopathy of prematurity (ROP). Automatic extraction of the retinal vasculature can assist to the doctors in the implementation of screening programs for retinopathies. The measure of the state of retinal vessels network allows to do other characterizations for each kind of pathology. For example in ROP diagnosis, the severity level and the tortuosity index are based on percentage of well-formed network. There are several automated and semi-automated proposals to do it [1].

The examination of the retina encloses a fundus exam. Generally, it is done with high definition ophthalmology camera, for example RetCam (Clarity Medical Systems Inc., Pleasanton, CA, USA). Though, there are hospitals or complete populations where they do not have this kind of sophisticated equipment. They should diagnosis with bad quality image or video. Some algorithms have been designed and tested for those kinds of images too.

The inputs for algorithms are fundus color images and the requirement is to be able to classify each pixel as vessel or non-vessel and give an output image with the blood vessels network. For doing this complex task, researchers use and improve many algorithm like Gaussian and Gabor filter, histogram equalization, clustering, binarization, motion contrast, matched filter, combined corner/edge detector, multi-scale line operator, neural network, ant, genetic, morphological operators. Combined algorithms create one method to obtain successful results.

Methods have been tested in databases with more than 20 images. Some of the databases are available freely, for example DRIVE, STARE [2] and REVIEW [3]. Results have been quantified in terms of sensitivity (True Positive) and graph under ROC curve [4].

There are a large number of works for segmenting the blood vessel from retina image. In this article, we present the last and relevant papers (publications of year 2014 and relevant papers of prior years). We have also studied past researches based on previous papers review [5] [6].

This paper is organized as follows: In Section II, we described recently and relevant works. Then, a discussion is presented in Section III. At last, we conclude this paper in Section IV.

II. ALGORITHMS FOR SEGMENTATION

A set of relevant article ordering by date are described. A summary of those descriptions is in Table I.

In 2014, a method for extracting retinal blood vessels using an optimized Gabor filter is presented [7] . The Gabor filters are a set of orientation and frequency sensitive band pass filters which have the optimal localization in both the frequency contents and the patterns [8]. This proposal starts with a RBG (red, blue, green) retinal image, like pre-processing tasks they extract green channel, apply an adaptive histogram equalization, and convert to grayscale and binary image. They used [3×3] size of median filter to reduce the salt & paper noise, and length filter is used to remove isolated pixels by using concept of connectivity in binary images. They quantified the results by true positive and false negative. They compared its proposal with other four proposals and they got accuracy equal to 97.72%, better than other ones.

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TABLE I
SYNOPSIS OF PROPOSALS

Ref.	Year	Techniques/ Algorithms	Accuracy/ Effectiveness	ROP Assessment	Pre-processing	Input Image
[7]	2014	Optimized Gabor filter, histogram equalization. Image format conversion.	Accuracy: 99.72 % Sensitivity: 98.15%	No	Yes	2D
[9]	2014	Unsupervised classification, spectral clustering, entropy-based binarization.	Accuracy: 94.44%	No	Yes	2D
[12]	2014	Motion contrast method, matched filter, combined corner/edge detector, morphological dilation.	---	No	Yes	2D
[13]	2014	Multi-scale line operator, Weber's law, k-means clustering. Image format conversion.	Accuracy STARE: 94.83% AUC STARE: 94.31% Accuracy DRIVE: 93.87% AUC DRIVE: 93.03%	No	Yes	2D
[14]	2014	Back propagation neural network, Gaussian and Gabor filters. Image format conversion.	True Positive: 99% False Positive: 50%	No	Yes	2D
[15]	2013	Matched filter, B-Splane illumination correction, contrast equalization, thresholding.	Healthy-Img. SE: 78.61% SP: 97.50%; ACC: 95.39%; AUC: 97.42% DR-Img. SE: 74.86% SP: 96.19%; ACC: 94.45%; AUC: 95.82%	No	Yes	2D
[23]	2009	Ant, Matched filter. Image format conversion.	--	No	Yes	2D
[25]	2007	Genetic algorithms (Encoding, fitness function) - Gaussian matched filter. Image format conversion.	MAA DRIVE: 94.22% AUC DRIVE: 95.82%	No		2D
[26]	2006	Morphological operators: maximum of openings, reconstruction by dilation, threshold by hysteresis. Image format conversion.	---	No	Yes	2D

AUC: area under the ROC curve; ACC (Accuracy); SE (Sensitivity): True Positive rate; Selectivity: False Positive rate; SP (Specificity); These metrics are described in [4] . DR diabetic retinopathy. DRIVE: publicity database of normal retinal images. STARE: publicity database of pathological retinal images.

An unsupervised classification method by finding patterns of blood vessels in retinal images is proposed in [9]. That patterns are used to determine whether a pixel belongs to a vessel or not. Before that, a morphological top-hat transform [10] is applied for improving contrast of the retinal image. This method was tested over two publicly databases DRIVE [2] and REVIEW [3]. Results were compared with related works.

Matched filter techniques are widely used for the detection of blood vessels [11]. In [12], three technics are combined for segmenting all vessel network of retinal images. Images are acquired in video format, with an Adaptive Optics scanning laser ophthalmoscope (AOSLO). A motion contrast is used to get a single image from all the division images. Multi-scale matched filter (MF) method is applied to distinguish vessels and false edges. After that, they applied the combined corner/edge detector to eliminate the effect of motion artifacts. And finally, they did a dilation for restoring the contour of vessels. That techniques were tested in 89 AOSLO images (available from the University of California, Berkeley).

A method to detect retinal vessels in normal and abnormal fundus images is proposed in [13], this method is based on vessels linear features and implement multi-scale line operator. A line detector which is based on the evaluation of the gray intensity average along lines of fixed length passing through the target pixel at different orientations is applied to the green channel of an RGB image and the response is thresholded to obtain unsupervised pixel classification. This method is evaluated on two public databases STARE and DRIVE [2].

In [14], retinal blood vessels are identified by using a multilayer perceptron neural network. Input images are color fundus, they are pre-processed by eliminating the hue and saturation information, retaining the luminance and converting to grayscale images. Then, grayscale images are smoothened using Gaussian filters and vectors features are obtained applying Gabor filter. These vectors classify each pixel like vessel or non-vessel. The set vessels is given as input to neural network training. A back propagation algorithm is applied in the neural network. DRIVE database is used to assessment. True positives reported 99%, and false positive 50% in highest wrong cases.

In [15] the segmentation of blood vessels in a pre-processed image utilised a MF approach. B-spline-based illumination correction method and contrast enhancement were used as pre-processing tasks over green channel of the original input image. Matched filter cross-sectional profiles were heuristically classified into five classes of differing blood vessel thicknesses, their objective was to achieve a reliable and precise detection of all possible blood vessel segments with an acceptable width resolution. This method was tested in public DRIVE and STARE databases [2].

Ant-based approaches has been applied in edge detection [16]-[22]. Based on that previous state-of-art, a combined model of matched filter and ant colony algorithm is proposed in [23]. Ant parameters (number of ants, iteration and memory sizes) are taken from prior empirical work. Ant algorithm includes exploration of vessels using marked blocks, merging blocks and binarization. Match filter consists of green channel normalization, LogSig scaling and Gaussian filtering to find vessels [11]. The ant algorithm result is combined with matched filter for getting a previous resultant image. Finally,

length filtering is applied over that previous image and vessels are achieved.

Genetic algorithms operate on a set of individuals called population, where each individual is an encoding of the input problem data and are called chromosomes. Each fitness individual is calculated using an objective function. One iteration of the search is called a generation. From each generation the fittest individuals are selected and pooled out to form a base for a new population with better characteristics. Genetic algorithms are characterized by attributes such as objective function, encoding of the input data, crossover, mutation, and population size [24]. On the other hand, as we mentioned above matched filter techniques are widely used for the detection of blood vessels. In [25], genetic algorithms have been used for choosing best parameters to Gaussian matched filter and give a better approach in comparison with empirical estimation. The results showed a better assessment.

A set of morphological operators was used to extract the skeleton of the vascular network from fundus color image in the proposal [26]. First, a grayscale image was obtained from the fundus green channel, next the maximum of openings [27], [10] operator is applied for diminishing noise and getting a uniform background. The extraction of skeleton is made in two processes: sum of valleys (first approximation and noise artefacts), and thresholding by hysteresis and a reconstruction by dilation [10]. This proposal was not assessed or compared with other methods.

Previous similar reviews are: in 2004, in [5] is published a large review that classifies the algorithms in eleven categories. A complete state-of-the-art until 2011 is presented in [28]. In [6], there is a short survey that presents advantages and limitations of the methods founded until 2012.

III. Discussion

To perform this work, we made a systematic review exploring in three major search engines (Web of Science [29], IEEE Xplore [30], and Google Scholar [31]). First, the results have been filtered by a previous year and ordered by relevance. Next, we read the abstract of each article and performed a selection of the best works for the full reading. Finally, we proceeded to decide whether to include or discard the article from the survey.

Typical edge detection techniques, such as Sobel operator, Canny border detector, and Prewiit operator [32] are not appropriate for vessel detection. We have revised several combination of algorithms (ant, genetic, clustering, match filtered, mathematical morphology) for the retinal vessels extraction. So, we can say that it is necessary more than one processing algorithm to acquire acceptable results, and before segmenting the image, it is convenient to do pre-processing tasks. In comparison with the manual labelled and segmentation, in manual process experts do not need pre-processing but it is a harder task. In order to test automatic methods there are some databases with labelled images [2].

Most methods detect vessels in normal retina images well, but they do not have any procedure to cope with lesions on images of abnormal retinas. In order to resolve it, more pre-processing tasks are required.

One common pre-processing task, is to obtain grayscale image from the green channel. Generally, blood vessels are darker than the background, although there are areas where the vascular network is not visible because its level is similar to the background. Several studies showed that green channel saves the best pixel information. Contrast enhanced is another of the most common pre-processing task, it is used both in healthy and pathological retinal images.

About the results, true positive cases are over 90%, but we note three points: in medicine we need to achieve 100% in both true positives and false negatives cases, and that they must work in bad quality images well.

IV. Conclusions

The set of algorithms studied reveals that to improve automatic segmentation of retinal vessels it is necessary to pre-process images and create segmentation methods by combination. This requirement has been a venue of research by itself in the last decade.

Pre-processing tasks are required before applying segmentation algorithms. The most common ones are contrast enhanced, extraction of green channel and convert to grayscale image. Also, since most cases algorithms work on grayscale intensity, users can convert to color image again after the process.

Best results are obtained in healthy retinal image. It seems that more research is needed over pathological retinal images and bad quality images. On the one hand, improving results on pathological retinal image is a mandatory goal for supporting medical diagnosis. On the other hand, improving results in bad quality images is a valid objective to achieve for populations where neither expensive nor sophisticated ophthalmology cameras are available.

In order to share the latest findings and to help perform effective diagnosis, this kind of algorithms could be part of a telemedicine system. Also, it could be available on the internet cloud.

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