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Information support and interactive planning in the Digital Factory: Approach and industry-driven evaluation

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Abstract

In the modern world we are continuously surrounded by information. The human brain has to analyse and interpret this information to transform into useable knowledge that is then used in decision making activities. The advent and implementation of Industry 4.0 will make it a requirement for systems within factories to interact and share large quantities of information with each other. This large volume of information will make it even more difficult for the human resources within the factory to sift through the large amount of information required since there is a limit to the information that our brains can cope with. Just in time information retrieval (JITIR) within the digital factory environment aims to provide support to the human stakeholders in the system by proactively yet non-intrusively providing the required information at the right time based on the users context. This paper will therefore provide an insight into the cognitive difficulties experienced by humans in the digital factory and how JITIR can tackle these challenges. By validating the JITIR concept, several industry scenarios have been evaluated: an exemplary model, concerning the machine tool industry, is presented in the paper. The results of this research are a set of guidelines for the development of a digital factory support tool.

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Keywords: Digital Factory; JITIR; Factory Planning

1. Introduction

Decisions regarding the design and operation of factories and manufacturing systems require technical understanding and expertise together with the ability to satisfy certain business objectives [1]. At the base of this expertise is the stakeholders knowledge, that can be described as an appropriate collection of information as depicted in the Data-Information-Knowledge-Wisdom (DIKW) hierarchy [2]. It is therefore implicit that the stakeholders in the decision making process need to possess the knowledge and information required if a good decision is to be made.

The reality is that decision makers in the manufacturing industry frequently face the problem of assessing a wide range of alternative options, and selecting one based on a set of conflicting criteria [3]. Therefore an important requirement of the Digital Factory is to provide stakeholders with information and knowledge support during decision making activities. Decision making activities occur throughout the factory life cycle and include site and network planning, material handling and equipment design, process planning or factory operation [4].

Ideally stakeholders within the Digital Factory check all the information available to them at the moment of taking a decision. Since a lot of information is available within the Digital Factory environment, including machine requirements and specifications, scheduling information and process information, it is impossible for the stakeholders to review all the information available.

At best stakeholders are limited to searching and gathering

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the information which is required. This can be done by searching different databases where information is stored, searching the internet for information about machine requirements or searching email archives for supplier communications. This said the Digital Factory stakeholders may not always be aware that information is available and accessible for them to search.

This problem has been further exaggerated with the advent of Industry 4.0 and the internet of things. In the smart factory [5] cyber-physical systems will be continuously collecting data from the shop floor that may be relevant to the factory planner who is reconfiguring a plant layout.

This data from the real factory will be available together with data being generated by the Digital Factory tools in the virtual factory during the factory planning process. These combined activities generate a very large data set that is difficult to store, access and analyse. Therefore it can be concluded that the smart factory paradigm brings along the challenges associated with Big Data, especially in the decision making stages [6]. Data management and information retrieval will therefore become an essential element of the factory planning process.

This said factory planning stakeholders cannot continuously be presented with large amounts of available information to process. This is because human stakeholders are limited by their mental brain capacity in what is defined as the human brain's working memory [7]. Only information which is of high relevance to the task and decisions currently being made needs to be presented to the stakeholders, otherwise there is the risk of information overload.

Therefore we can conclude that stakeholders in the factory planning process need to be provided with the right information at the right time, in a non-pervasive manner in order to take good decisions. This interesting challenge was behind the motivation of this research.

The aim of this paper is to illustrate how this research applied the novel approaches for Human-System Interfacing (H-SI) developed by the MIT for Information Retrieval (so called Just-in-time-Information Retrieval, JITIR) to production planning and control. This research was carried out as part of the development of the DREAM simulation platform ("simulation based application Decision support in Real-time for Efficient Agile Manufacturing", http://dream-simulation.eu/). DREAM is a research project whose ultimate objective is to provide industrial practitioners with easy-to-use, reconfigurable and efficient simulation based decision support tools for cross-functional decision processes at multiple hierarchical levels.

2. A possible solution: a Just in Time Information Retrieval-driven approach

2.1. Overview and history

The concept of information has been assimilated over time, compared and contrasted to that of data, knowledge, wisdom, and the other way the words information, text, document, are often used interchangeably [8].

Just-in-time Information Retrieval (JITIR) is an approach based on using as an input the users' environment and activity, and providing as an output to the user information retrieved, suggesting documents, which potentially match users' interest and, furthermore, which can be marked as relevant [9].

The information retrieval takes place by using queries generated from words. Such queries are then processed in a search engine, which can be both web based and/or local. One of the main technical issues encountered in typical information retrieval through search engines is that queries are too rich in keywords due to type of input and therefore might diverge the information retrieval action too much in a short time frame [10].

2.2. Just in Time Information Retrieval agents

Just-in-time Information Retrieval agents (JITIRs) are software agents that base their action on the user's local environment in order to retrieve real time information, which is relevant to the users. The strength of JITIRs is the way they operate: they are easily accessible and work in the background.

JITIRs take their input from users' context, giving as output nonintrusive information, not in the sense of a normal search engine but in a larger way [9].

The study of JITIRs covers various numbers of different branches of knowledge that can be summarized as follows:

- a psychological point of view (by answering questions as "How does the use of a JITIR affect the way a person seeks out and uses information?"),
- a relation among JITIR and Information Retrieval (IR) (by answering questions as "How can a JITIR agent automatically find information that would be useful to a person by looking at that person's current environment?"),
- and last, but not least consideration, is the relevance of information: the information gathered must be as relevant as possible to the users (by answering questions as "How should a JITIR agent present potentially useful information?").

2.3. Benefits of JITIRs

JITIRs are a class of software agents that proactively present potentially valuable information based on a person's local context in an easily accessible yet non-intrusive manner supporting the user through:

- encouraging the viewing and use of information that would not otherwise be viewed,
- reducing the cognitive effort required to find, evaluate and access information,
- providing useful or supporting information that is relevant to the current task,
- contextualizing the current task in a broader framework,
- providing information that is not useful in the current task but leads to the discovery of other information that is useful,
- providing information that is not useful for the current task but is valuable for other reasons.

3. JITIR Theoretical aspects

There are three main theoretical aspects to implementing JITIRs. The first is the psychological aspect of decision making, and mainly relates to time and the quality of information retrieved as experienced by the user. The second aspect deals with information retrieval in the strict sense and how JITIR formulates queries in a context aware application. The third aspect focuses on the concept of focused and divided attention, and how information being collected by JITIRs should be communicated to the users of the tool.

3.1. The psychological aspect to JITIR

The first aspect of knowledge, the psychological point of view, is concerning the way in which a person uses information. To introduce this point of view an explanation about intelligence augmentation is needed. Douglas Engelbart, in his work [10], describes how humans use their capability to approach complex problems in order to solve them. In this regard, he provides a short list of actions that people usually perform, described as follows:

- explicit-human process capabilities,
- explicit-artifacts process capabilities,
- composite process capabilities.

According to the goals of this analysis, the greatest interest for this research is in the third action: these are processes that JITIRs facilitate. They emerge from an interaction between people and artefacts and, after JITIRs retrieve information, these must be evaluated by the user.

Making decisions with the best cost/benefit trade off related to time is the main goal of JITIRs. JITIRs will provide the user the best performance in terms of time, trying to minimize the users' total future work [4]. Time affects highly the perception of a user; a small increase in the time to perform a task (such as the response to a query) might result in too long of a waiting time according to his/her perception. Robert Miller [11] argues that there is not a linear decrease in efficiency as response delay increases. Miller's theory also suggests that information retrieval should not to be performed if the cost of retrieval is more than the expected value of the information itself.

Furthermore, thanks to their structure, JITIRs agents are able to work automatically and thus to reduce significantly the cost of search but, on the other hand, queries are auto-generated and so there is not the accuracy that a human-query might have. JITIRs are not just a time-saver search, they also provide a real-time information retrieval when the user is not willing, capable or aware that performing a search would provide fruitful information.

3.2. JITIR vs IR

In order to introduce the JITIRs from the second disciplinary point of view, a definition of Information Retrieval (IR) is required. The importance of IR is mainly due to the gathering of information relevant to the user's needs: it is unthinkable that the user proceeds with the reading of all the documents returned, looking for those significant for its request (in this case there would be a situation of perfect retrieval).

In computing language, information retrieval can be properly defined as "the tracing and recovery of information from stored data in electronic format" [12]. This definition can be enlarged to the whole set of methods focalized to retrieve electronic information. But "information" must be mined in the meaning of the documents, metadata, and files which are in database, the World Wide Web or on the cloud. IR algorithms, such as the Boolean Retrieval Model and the Vector Space Model, can then be evaluated from the point of view of relevance to a given query. The main problem is that the judgments of these must then be made by a human for each document retrieved. A kind of ranking could be obtained with a language modeling approach to Information Retrieval, e.g. using statistics on hyperlinks. In this way, the user can feel the control over the system, e.g. hiding the basic ranking mechanism [13].

Just-in-Time Information Retrieval agents are based on queries that are implicit in the user's context and formulated from the user himself [14]. JITIRs watch an environment and can act basing themselves on that environment without direct user interaction.

By the use of queries, JITIR agents are able to find useful information for the user just by sensing the users' context. This is made possible by the use of employing Information Retrieval techniques where the semantics of a query is defined by an interpretation of the most suitable results of the query itself. JITIR therefore adds to the IR the feature that "queries" are generated based on a users' local context, using a domain-specific technique.

The definition of context is given by the Concise Oxford English Dictionary: it encloses the conditions and the circumstances that are relevant to an event, a fact, in fuzzy terms, the set of features not explicitly intended as input into the system being discussed [12]. Therefore a context-aware application, as mentioned by Rhodes, is a system that works independently from a direct input but, at the same time, depends on the intent of the user [9].

The above mentioned two aspects of JITIR need to be integrated and completed by a third one, without which the information gathered, would not to be taken into account by the user.

3.3. Relevance of information

Accessing the provided information must be a secondary task that does not divert the attention of the user from his/her primary task. A way has to be found in which the information is gathered but, at the same time, must be ignorable yet easily accessible by the user. JITIRs agent must have an "ignorable" interface yet easily accessible, so that it cannot be ignored by the user.

To design an interface that achieves both of these contradicting goals two different cognitive processes have to be taken into account. These are "focused attention" and "divided attention".

Firstly there is the focused attention, which is intended as the ability of a person to focus their attention on the task being performed, while ignoring the others. Paying attention to a JITIR whilst concurrently carrying out a planning task, might result very difficult.

Another cognitive process is the divided attention, which concentrates on the ability of a user to focus on various tasks. Unfortunately this is mainly possible only if the tasks involve the different abilities of the human brain, such as concurrently listening and focusing attention. That is why it is possible, and results easy, to drive whilst listening to the radio.

JITIRs therefore need to use both focused and divided user attention at the same time. Users must be allowed to focus their attention on the primary task but also to recognize the information gathered, diverting attention for a while. In order to allow focused attention, a JITIR agent should use tools which involve an ability of the brain not being used at that time. Furthermore, the information must be linked to the environment where it results useful. By making divided attention easier, JITIRs must present the information gathered without deviating the users' attention from the environment it relates.

The objective of JITIR agents is therefore to provide information basing their action to the users' local context, independently from the task performed. They are not a substitute of a traditional search tool since JITIR agent modifies the way in which people retrieve and use information.

4. Use case scenario

4.1. Industry-driven use case scenario

Balkan Textile and Cotton Gin Machinery have as their main business goals the design and manufacture of cotton gin machinery. The company is located in Aydin, Turkey, and severs both, Turkish and international markets. Textile machine manufacturing and ginning machine manufacturing takes place in separate but linked facilities and is the focus area of the Use Case Scenario. The Group employees up to 220 individuals and 40% is allocated to the textile machinery production line.

Flexibility in production is one of the strengths of Balkan. Customers often demand specific solutions and Balkan owns the competences and the experience to face these challenges. This results in a great diversity of products, machines and production lines. It is very common for Balkan to receive an order for a complete line which must fulfil a specific output, as well as orders with machines to perform a singular function.

The Balkan use case scenario brings to the platform many challenges, that can be summarized as follows:

- Reduction of the cycle time by 15% and reduced variability on cycle time by 10-20%;
- Improved customer service levels by 10-20%;
- Increase in first-time-right decision making by 50%;
- Reduction of process development and implementation by 25%;
- Improved efficiency in production with increased throughput by 10-20%;
- Reduction in energy by 20%;
- Quicker recovery from disruptions in production by 25%.

4.2. Industry-driven interactive factory planning

Balkan's management are aware that radical changes in their management system are needed to satisfy their desire of growth. According to the management, information support and interactive planning should provide means of capturing the logic of the textile machinery manufacturing line, the constraints and the interdependencies between various resources within the factory.

This new approach should enhance the company with a more systematic planning and documentation that can be used for future projects and traceability.

The scope of the developed approach is to therefore provide a platform that will enhance the textile machining manufacturing process with structured decision making methodologies through the use of interactive factory planning and simulation. The decisions to be supported concern the expected order-to-delivery lead time, the scheduling for the orders, and the conditions to accept a new order.

4.3. Use-case problem

The main deficiency to be tackled within this use-case scenario is the lack of available data that can be used during factory planning and simulation. Data required to build a valid model include:

- Characteristic machine production time data: such data must be digitalized. Because of the great customization of products, each process has its own characteristics, so an efficient tool should be implemented in order to get the best possible knowledge out of existing data;
- Failures of the existing machine: such data must be collected and retrieved to be used during decision making activities;
- Available worker capacity: this data must be made available in structured formats;
- Parallel processing of orders – information of the current space capacity: there are space capacity constraints to be followed;
- Work in progress: information of the current work in progress must be easily available.

The above data poses many challenges as to the parameters and information that should be available to the user of the interactive planning system to input in their interaction with the model. Thus, an information retrieval tool that will help in the easy, fast and correct retrieval of parameter information is required.

4.4. RTD requirements analysis

The Research and Technological Development (RTD) partner has noted that maintainable modelling and sustained use is a problem with implementing interactive factory planning and simulation. Therefore, the Human Computer Interaction (HCI) to be developed must focus on the high level goal of maintainable interaction. There are some points above this focus-point: the platform must allow the development of context applicable data/information interfacing.

Users also need an interface that allows them to maximise the speed and minimise the effort with which they map their system knowledge management into a simulation tool.

Due to the relatively low level of computer expertise in the company, the platform must be user friendly and easy to use. The user interface has to be intuitive in its usage. Prior experience with discrete event simulation or advanced computer software should not be taken as granted. The platform needs to provide data analytics tools for evaluating demands/orders to increase the length and quality of their planning horizon whenever needed and so that data (currently stored in MS-access) can be utilised to perform input data analysis for the simulation application.

The user interface has to exhibit the following attributes: user friendliness; a holistic report that can also be disaggregated to job or machine level details; ease of filtering information based on machines or jobs for the benefit of the handler of such jobs or machines, i.e. project managers and machine operators.

The Company articulated the need for decision support tools that retrieves and intelligently analyses current and historical information combining this with predictive capabilities to provide their engineers with on-time, real-time decision support and system information.

5. Identification of the human system interaction features

This section attempts to generalize the JITIR-approach in a way that it is applicable to the Human-System Interface (HS-I) of the factory planning and simulation digital tools. In order to do this the features needed to enable a smart support system in production planning were determine based on the use case requirements.

5.1. Proactive

The first feature of HS-I is proactivity. As previously explained for a system to be proactive the user need not have a query in mind, or even know that information relevant to his situation exists. This feature means that the H-SI should automatically provide the information required by the user during a particular planning task.

Due to the limitations in the technology available, and since it is impossible to read the human brain and sense what information is required, the query used to find useful information is limited to what can be sensed in the user's contextual environment. Hence the interface of the H-SI must be carefully designed in such a way so that unrequested information does not become a distraction from the user's primary task.

5.2. Non-intrusive, yet accessible

The second feature pertains to how the information is presented to the user. In order for the H-SI not to unnecessarily disturb the focus of the user, information should be presented in such a way that it can be ignored. At the same time it should still be easy for the user to access the information should it be desirable.

Rather than presuppose whether or not a particular piece of information is important or urgent, the H-SI system should allow the user to decide whether to view or ignore the information depending on his current task and level of cognitive load.

5.3. Locally contextual

The last feature of the H-SI is the user's local context. The H-SI needs to be provided with information from a source that may or may not be changing, based on relevance to a user's rapidly changing local context.

Local context is the user's spatially local environment, including his current task. As previously explained the information provided by the H-SI is not meant to pull the user out of his current context, but rather to add additional information that might be useful within that context, such as real-time information on machine failure data during the setting up of a simulation study.

5.4. H-SI features summary

A summary of the H-SI features is listed in Table 1. The sub-features have been numbered so as to be referenced in the analysis and mapping of the use-case requirements to the H-SI features.

Table 1: Human-system interaction features

H-SI Feature	Short explanation
Feature 1: *Proactive*	P1. User does not need to have a query in mind. P2. Query is limited to what can be *sensed* in the environment. P3. Unrequested information should not be a distraction from the user's primary task.
Feature 2: *Non-intrusive, yet Accessible*	A1. Information can be ignored, but is still easily accessible. A2. System should allow the user to decide whether to view or ignore information.
Feature 3: *Locally Contextual*	C1. Provide information from a source that may or may not be changing. C2. Local context is the user's spatially local environment. C3. Information provided by the H-SI is not meant to pull a person out of his current context.

6. Evaluation and selection of H-SI features for interactive factory planning

6.1. Approach for scoring the features of the interactive planning methodology

The approach used by this research for scoring the features of the H-SI is represented, in analogy with the aspects previously discussed, in Figure 1.

In Section 4 of this paper we described the use case employed by this research, and extracted a set of requirements from the industrial partner. In Section 5 we described the features of the H-SI based on the JITIR approach.

In the following section we will analyse the answers given by the RTD partner when queried about the H-SI. These answers were then correlated the H-SI features. The answer to the feature specific question is called score. The score can take only two values, 0 – for not requiring the fulfilling of the feature or 1 – for requirement of fully fulfilling the feature. 4. Online license transfer

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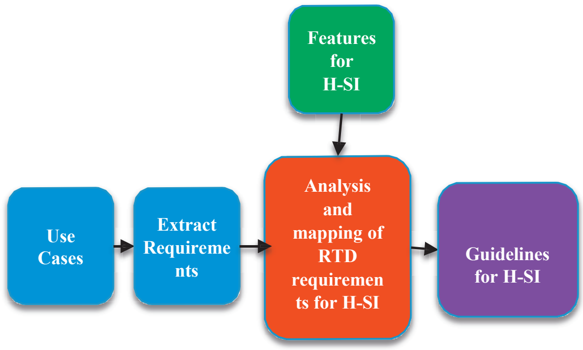

Figure 1: Approach for scoring the features of the interactive planning methodology.

6.2. Analysis and mapping of RTD requirements to H-SI features

The first RTD requirement that was analysed is that the H-SI "should provide means of capturing the logic of the textile machinery manufacturing line, the constraints and the interdependencies between the various resources."

This requirement can be mapped onto the interaction with the local context as an essential requirement. This means that the H-Si must provide the user with the required information at the right time and in the right context depending on his/her current activity. This maps out onto the following HS-I features A1, C1 and C2.

The RTD also stated the "desire to have only non-specialist end users of the platform". During the interviews with the RTD partner it was noted that this requirement was of extreme importance, since they did not want the system to fall into disuse because there were no experts in the system.

Therefore this requirement for the H-Si can be mapped onto the need to cater for different levels of users that may proactively be supported with information feedback. This can also be considered as part of the user's environment as the H-SI should determine the knowledge and expertise of the user and then customize the information provided to that user. This could be achieved by having a database of users with information on their role and experience within the company. This requirement maps onto the HS-I features P2 and C3.

Another important requirement for the RTD partner was for "the user interface to be intuitive in its usage". The H-SI has to facilitate the interaction of the user to the planning process. Therefore in terms of information retrieval that a structured and cascading approach to providing the user with successive layers of detailed information may be required. This means that the H-SI is required to capture and represent a high quantity of information efficiently in a way that it does not overload the user. This maps onto the HS-I features A1 and A2.

6.3. Summary of mapping exercise

The detailed mapping of the RTD requirements onto the H-SI features is summarised in Table 2.

Table 2: Summary of H-SI feature mapping.

H-SI Feature 1: Proactivity	**Scoring**
– *P1: Should the user need to have a query in mind, or even know that information relevant to his situation exists?*	0
– *P2: Should the "query" used to find useful information for the user be limited to what can be sensed in the user's environment?*	1
– *P3: Should the interface be carefully designed so that unrequested information does not become a distraction from the user's primary task?*	1
H-SI Feature 2: Non-intrusive, yet Accessible	**Scoring**
– Q1: Should the information be presented in such a way that it can be ignored, but is still easy to access the information if should be desirable?	1
– Q2: Should the DREAM H-SI allow the user to decide whether to view or ignore a particular piece of information depending on his current task and level of cognitive load in the case this information is whether or not important or urgent?	1
H-SI Feature 3: Locally Contextual	**Scoring**
– Q1: Should the DREAM H-SI provide information from a source that may or may not be changing, based on relevance to a user's rapidly changing local context?	1
– Q2: Should the DREAM H-SI capture the local context of the user's spatially local environment, including his current task?	1
– Q3: Should the DREAM H-SI to add additional information that might be useful to the user within its context, and to not pull a person out of his current context?	1

7. H-SI guidelines

7.1. Proactive

The factory planning and simulation system has to proactively provide information to the user. The user should not need to search or query the system, or even know that information relevant to his situation exists to gather such information. The system should therefore sense the user's environment/activity and provide information thereof.

This may lead to an information overload so it important that the interface be carefully designed so that unrequested information does not become a distraction to the user's primary task.

7.2. Non-intrusive, yet accessible

The H-SI has to the present the information be in such a way that it can be ignored, but is still easy to access the information if should be desirable. The user has to be allowed to decide whether to view or ignore a particular piece of information depending on his current task and level of cognitive load in the case this information is whether or not important or urgent.

7.3. Locally contextual

The H-SI has to provide information from dynamically changing sources, based on relevance to a user's rapidly changing local context/activity. This would require the H-SI to capture the local context of the user's spatially local environment, including his current task. The H-SI should therefore provide the user with additional information that might be useful to the user within its context, but not pull the user out of his current context.

8. Conclusions

This research has contributed towards establishing a set of guidelines for H-SI for factory planning and simulation software. These guidelines are based on the JITIR approach for information retrieval. Future research will further develop the concept for unobtrusive system assistance in planning, supporting the achievement of better planning solutions in daily industrial practice based on the H-SI guidelines portrayed in this research paper.

As the first step is planned the performing of several experiments aiming at exploring the relevance of the H-SI features: 1) Proactive, 2) Non-intrusive and yet Accessible and 3) Locally Contextual at the end-user Balkan and another SME in the field of rapid prototyping.

The results will show how within the digital factory environment the developed concept provide support to the human stakeholders in the system by proactively yet non-intrusively providing the required information at the right time based on the users context. They will represent valuable information for the further development of the DREAM platform, as the vision and the objectives of the project are requiring.

Acknowledgements

Authors including an appendix section should do so before References section. Multiple appendices should all have headings in the style used above. They will automatically be ordered A, B, C etc.

References

[1] G. Chryssolouris, Manufacturing Systems: Theory and Practice. Springer, 2006.
[2] H. Muller and C. Maasdorp, 'The data, information, and knowledge hierarchy and its ability to convince', in 2011 Fifth International Conference on Research Challenges in Information Science (RCIS), 2011, pp. 1–6.
[3] R. Venkata Rao, 'Introduction to Decision Making in the Manufacturing Environment', in Decision Making in the Manufacturing Environment, Springer London, 2007, pp. 3–6.
[4] Westkämper, E., 'New paradigm in manufacturing engineering: Factory life cycle', Prod. Eng., vol. 13, no. Nr.1, pp. 143–146, 2006.
[5] D. Zuehlke, 'SmartFactory—Towards a factory-of-things', Annu. Rev. Control, vol. 34, no. 1, pp. 129–138, Apr. 2010.
[6] J. M. Tien, 'Big Data: Unleashing information', J. Syst. Sci. Syst. Eng., vol. 22, no. 2, pp. 127–151, Jun. 2013.
[7] A. D. Baddeley, Working memory. Oxford [England]; New York: Clarendon Press ; Oxford University Press, 1987.
[8] Meadow C.T., "Text information retrieval system", Academic Press., San Diego, 1992.
[9] B. J. Rhodes and P. Maes, 'Just-in-time information retrieval agents', IBM Syst. J., vol. 39, no. 3.4, pp. 685–704, 2000.
[10] D. C. Engelbart, Augmenting human intellect: A conceptual Framework. Stanford Research Institute, 1962.
[11] R. B. Miller, 'Response Time in Man-computer Conversational Transactions', in Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I, New York, NY, USA, 1968, pp. 267–277.
[12] M. Waite, Paperback Oxford English dictionary. Oxford: Oxford University Press, 2012.
[13] D. Hiemstra, "Term-Specific Smoothing for the Language Modeling Approach to Information Retrieval: The Importance of a Query Term", University of Twente, Centre for Telematics and Information Technology, Sweden.
[14] A. Gao and D. Bridge, 'Using Shallow Natural Language Processing in a Just-In-Time Information Retrieval Assistant for Bloggers', in Artificial Intelligence and Cognitive Science, L. Coyle and J. Freyne, Eds. Springer Berlin Heidelberg, 2010, pp. 103–113.