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Bachelor in Computer Science

Accelerating SQL with Complex Visual Querying

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ABSTRACT

The dissertation must contain two versions of the abstract, one in the same language as the main text, another in a different language. The package assumes that the two languages under consideration are always Portuguese and English.

The package will sort the abstracts in the appropriate order. This means that the first abstract will be in the same language as the main text, followed by the abstract in the other language, and then followed by the main text. For example, if the dissertation is written in Portuguese, first will come the summary in Portuguese and then in English, followed by the main text in Portuguese. If the dissertation is written in English, first will come the summary in English and then in Portuguese, followed by the main text in English.

The abstract should not exceed one page and should answer the following questions:

- What's the problem?
- Why is it interesting?
- What's the solution?
- What follows from the solution?

Keywords: Keywords (in English) ...

RESUMO

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O *template* colocará automaticamente em primeiro lugar o resumo na língua do texto principal e depois o resumo na outra língua. Por exemplo, se a dissertação está escrita em Português, primeiro aparecerá o resumo em Português, depois em Inglês, seguido do texto principal em Português. Se a dissertação está escrita em Inglês, primeiro aparecerá o resumo em Inglês, depois em Português, seguido do texto principal em Inglês.

O resumo não deve exceder uma página e deve responder às seguintes questões:

- Qual é o problema?
- Porque é que ele é interessante?
- Qual é a solução?
- O que resulta (implicações) da solução?

E agora vamos fazer um teste com uma quebra de linha no hífen a ver se a \LaTeX duplica o hífen na linha seguinte...

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Sim! Funciona! :)

Palavras-chave: Palavras-chave (em Português) ...

CONTENTS

1	Introduction	1
1.1	Context	1
1.2	Motivation	2
1.3	Problem Description	3
1.4	Research Questions	3
1.5	Main Expected Contributions	4
1.6	Structure	4
2	Background	7
2.1	Human-Computer Interaction	7
2.1.1	Interaction Models	7
2.1.2	Main Concepts	8
2.1.3	User-centered Design	10
2.2	OutSystems Background	14
2.2.1	Platform Overview	14
2.2.2	Previous Work	14
3	Related Work	15
3.1	Data Visualization	15
3.2	Visual Queries	15
3.3	Data User Experience and Expressiveness	15
3.4	Technologies and Commercial Applications	15
4	Proposed Solution	17
4.1	Requirements Analysis	17
4.2	Proposed Implementation	17
4.3	Scope Definition	17
5	Work Plan	19
	Bibliography	21

INTRODUCTION

This chapter will introduce this thesis, starting with a brief contextualization about the actual technological framework, followed by a description of the motivation behind it. In addition, will be presented an overview of the problem, such as expected contributions and the structure of the document.

1.1 Context

Nowadays, Information and Computer Systems have been dominating data processing. These fields are genrators of positive impact for personal and business areas presenting a prominent place on any information system. However, well before any electronic system, since people started to count or write, they have needed to store pieces of information. [4] Thenceforth, for many years, people have used physical information, like paper, to store data, however, with the digital transformation, these resources are less and less used.

In the decades of the 1960s, Database Management Systems (DBMS) arose, and later at 1970s new management systems that use relational models, designated as Relational Database Management Systems (RDBMS). Moreover, the first Data Query Languages (DQL) appeared, like SQL [7] which was considered by the ANSI ¹ and ISO ² as the standard query language [10]. These technological evolutions have improved the effectiveness and the efficiency of the querying process. However, to find more specific and complex information on databases a higher degree of DQL understanding was required. Thus, if from one side the technological evolution and the digital transformation have optimized the data querying process, only a subset of people could use these powerful querying technologies.

¹American National Standards Institute

²International Organization for Standardization

Visual Query Systems (VQSs), defined by Catarci, *et. al.* [5] as “systems for querying databases that use a visual representation to depict the domain of interest and express related requests”, are used to mitigate some problems already referred. These systems use different visual representations and interaction strategies to make database queries, using a more intuitive visual approaches, instead of using textual languages, which are more difficult to learn mainly for people without programming base knowledge. In addition, even if it is not mandatory to be considered a VQS, some systems have also data visualization features which can be useful to view the query result, or even the possibility to manage the database schema in a visual way too.

However, usually, these visual languages are associated as more useful to naive users, while textual languages are associated to more expert users. Conversely, some studies have revealed that visual languages might be convenient to the expert users too. For example, the comparison made by Catarci and Santucci [6] concludes that diagrammatic languages can reduce the error rate of the queries, in comparison with those made in a textual language by expert users. These results imply that even expert users make mistakes in simple queries (e.g. they may not remember the name of the tables or the precise syntax of some language expressions). Thus, it is important to analyse how those languages could be used to optimize the querying process not only to the users with a low experience level but also for highly experienced users.

Nonetheless, the widely users’ background and the diversity of the data domain made that a lot of these systems need to be modelled to a specific domain. So, it is very difficult to find an global integrated solution that covers necessities of all users on all domains being this personal or professional.

1.2 Motivation

Low-Code Development is a recent development paradigm which seeks to reduce the time and effort spent in tasks that will not have a significant impact on the final product outcome. Just as the rise of high-level languages, APIs, and third-party infrastructures have provided to developers to be more productive and spend more effort on the most valuable sections of the software they produce. Also, the goal of the Low-Code is to extend this reasoning, using visual IDEs, connectors between components and lifecycle managers, to put away some concerns as infrastructure and re-implementation of patterns and free up people to think better on things that could be more relevant to their objectives [19].

The goal of this project is to analyse and improve the OutSystems Platform data querying component that can be used to create relational database queries through drag and drop interactions and simple configurations beyond visual components and multiple drag and drop features. This platform aim is to provide a complete application development environment where users with different development backgrounds can build,

deploy and manage their applications following good practices and using state-of-the-art technologies even without having to worry about those details.

However, conversely of No-Code approaches, the development through low-code systems give the possibility to use low-level code, written in textual languages like Java, .NET or SQL, in order to increase the extensibility and the power of low-code solutions [20]. Therefore, it is provided to users an alternative to perform their requests that are not supported by the low-code visual approaches. However, if the visual languages of low-code platforms are more robust, responding more thoroughly to users' requirements, there is a diminished demand to resort on these textual programming languages which are high error-prone and have a worse learning curve, requiring also, on multiple situations, previous coding experience.

Furthermore, as mentioned by Amaral *et. al.*, web and mobile applications produced on OutSystems' technology, have proven not only an increase on quality [11], but also allowed developers to increase 10.9x on productivity, when compared with IT Industry standards that do not use these rapid software development solutions [18]. These results reinforces the importance of this matter, the improvement of visual languages used on this platform.

1.3 Problem Description

The OutSystems platform provides a visual query language that allows users to retrieve data from databases by simple processes. Besides, with this language, it is possible to perform some operations that are usually supported by textual Data Querying Languages (DQL), namely join, filter, sort and group operations.

Currently, the OutSystems' solutions have been applied on digital transformation processes in multiple industries that lead with high quantities of data, in order to accelerate the application development processes, unlocking its value and growth.

To this extent, the already implemented querying tool is not able to deal with a set of scenarios, because it might be not accurate when the domain has a lot of tables involved, or does not support essential advanced constructors. Are part of these constructors not supported clauses like IN, NOT IN, EXISTS, NOT EXISTS, DISTINCT, UNION and the possibility to use subqueries.

Under the above mentioned circumstances, the goal of this project is to design and evaluate a new and more powerful Language and User Experience that allows developers to do all these complex data queries in a very easy way without using SQL.

1.4 Research Questions

- What query features are supported by the existing OutSystems visual query language?

- Why do OutSystems developers often use SQL to perform database queries?
- Why are some queries that can be built visually written though SQL instead?
- What are the main causes that users point out to use SQL?
- What users are more unsatisfied with the current provided approach to retrieve data?
- Can we enable OutSystems developers to easily do all kinds of database queries without ever using SQL?

1.5 Main Expected Contributions

This work aims to provide a set of contributions not only as a scientific research, but also with a perspective of creating the most value added to OutSystems. Thus, are presented below a summary of the main expected contributions for this project:

- A synthesization of the design concepts, including relevant interaction and conceptual models, usability definitions, guidelines and principles, and a description of the processes to evaluate the human-computer interaction in the context of a software analysis;
- Provide a state-of-the art about what are the most significant Visual Query Systems, presenting also a comparison of visual representation techniques and interaction strategies used, as well as other important features proper for this study;
- A description of the analysis made to identify what are the most impactful problems regarding the existing visual query language, which includes user interviews and data analysis;
- Design and implementation of a new graphical user interface prototype that tries to improve the existing solution to make queries visually. This prototype expects to fix some predominant problems selected as the most relevant to solve;
- An usability evaluation of the prototype developed through the use of user tests, confronting these results with the first obtained.

1.6 Structure

The remaining chapters of this thesis are organized as follows:

- Chapter 2 - [Related Work](#): presents a short description of the OutSystems Platform, as well as a description of the existing techniques that already exist on the context of the main topic of this thesis - data visualization and visual querying. Besides,

other commercial applications will be enumerated which can have relevant content for this study;

- Chapter 3 - **Proposed Solution**: describes the proposed solution, starting with a requirement analysis, followed by a more detailed explanation about the problem, and finally with a definition of the development scope to understand what problem will be tackled on detail;
- Chapter 4 - **Work Plan**: includes a planning of the inherent total work. Thus, will be presented an overview of the tasks that were done on this dissertation plan, together with the preview of the work which will be the focus of the second phase of the thesis, the elaboration.

CHAPTER 2

BACKGROUND

After the presentation of the problem and the motivations behind it, in this chapter will be introduced key concepts of Human-Computer Interaction, as well as, a briefly contextualization of the OutSystems Platform Background that are indispensable for the comprehension and progression of this study.

2.1 Human-Computer Interaction

Since the goal of this project is to improve and extend the visual language that gives to the user the possibility to construct queries through manipulation of visual components of graphical user interface. Human-computer interaction concepts, rules and techniques are fundamental to design and evaluate any possible solution to this problem. Thus, following, will be presented a summary of human-computer interaction topics taken into account throughout the design and development of this project.

Although computer systems have been designed by humans, these two parts of human-computer interaction do not communicate through the same language. Nonetheless, these type of systems were created to support, in a transparent way, human's tasks and requirements, forgiving careless mistakes. [9] Thus, human-computer interaction fields aim to study the relationship of users and computer systems, in the context of the users' desired tasks, in order to "unfold and reveal challenges and insights, and to instrument appropriate solutions for alleviating the current obstacles to the access and use of advanced information technologies" [21].

2.1.1 Interaction Models

Therefore, have been proposed interaction models to represent the intention of a user to perform a certain task on a system. One of the most influential is Norman's model,

that characterize the interaction of a user with a system beyond execution-evaluation cycles. [9] Thereby, the execution is a flow when the user interacts with the system, and the evaluation phase comprise the presentation and the interpretation of the system output. However, this model only represents the interaction from the users' point of view. Thereupon, Abowd and Beale [1] proposed an extension of this model where it is possible to view how the system communicates through the interface.

In this approach, represented in Figure 2.1, after the user has defined his goal and respective tasks to achieve it, he transmits his intention (articulation) through input language, and after this, that information is translated to system language (performance), ending the execution phase. Secondly, the result of the action executed by the system is presented (presentation) and the user observes it (observation), ending the evaluation phase.

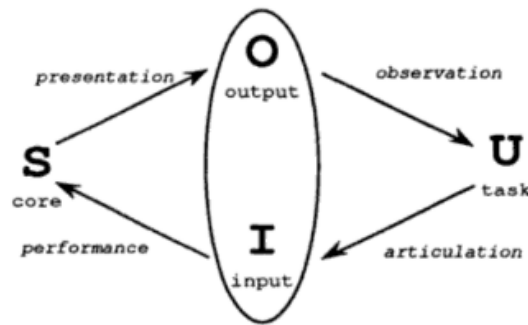


Figure 2.1: Interaction Model proposed by Abowd and Beale [21] (Based on Norman's Model)

These models are useful to understand two concepts that cannot be forgotten when a system is being designed, since these are two effects that designers want to reduce as much as possible, in order to optimize the effectiveness of the human-computer dialogue. Following, these concepts will be described respecting *Dix et al.* [9] definition:

- **Gulf of execution:** "Difference between the user's formulation of the actions to reach the goal and the actions allowed by the system. If the actions allowed by the system correspond to those intended by the user, the interaction will be effective."
- **Gulfs of evaluation:** "Distance between the physical representation of the system state and the expectation of the user. If the user can readily evaluate the presentation in terms of his goal, the gulf of evaluation is small."

2.1.2 Main Concepts

The **Usability** of a system is one of the most important concepts in human-computer interaction, that can not be forgotten on the design process, since its attributes must be taken into account performing also a guidance function through all this process. This

concept was standardized in ISO-9241 [12] as “extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”.

However, usability is not a single-dimensional property, being always associated with its attributes, that characterize the user accessibility when is using the system into five different points, such as referred by Nielsen [16]:

- **Learnability:** How easy is the learning process until a novice user (has not used the system before) has some high-level of proficiency using the system [22]. The learnability is higher as the learning process is faster, and the user has to spend less effort to reach his goal. Also, it depends on tutorials and training provided to users. A system that requires less training has a higher learnability than a system that requires more training. The time that a novice user requires to perform some specific tasks can be used to measure learnability. Learnability can be improved using tips while a novice user explores the system doing his first tasks.
- **Efficiency:** Refers to the productivity level of a user which have already learnt how to use the system. Efficiency can be measured analysing the time that expert users spent to do specific tasks on the system. This attribute can be improved, for example, adding shortcuts to accelerate the interaction process.
- **Memorability:** Defines how easy is for a user, that was using a system before but did not use it for a time period, to do his desired tasks on the system. So it's related to how many time the user has not used the system and the time that the user needs to remember how the system works. Therefore, if a system has a good memorability the user does not need many time to remember it, even if it has stopped use it for a long period of time. Memorability can be measured, for example, analysing the interaction process of a user who has been away from the system, while he uses the system again. The use of visual components and metaphors with real-life objects helps, sometimes, the users in this process.
- **Errors:** A system not only must have a low error-rate but only if an error occurs, the user should be able to recover from that. Since there are multiple types of error with different severity levels, it is important that catastrophic errors must not occur. This attribute can be measured evaluating the error-rate, taking into account the severity levels of the errors. Furthermore, if a system has errors, that can be reverted and do not have a negative impact on the final result, cannot be forgotten that these errors also harm the efficiency of the system.
- **Satisfaction:** The most subjective attribute of the usability that is related to the overall satisfaction of the user when uses the system. Could be measured by asking the users about the experience while they are using the system, always searching for subjective answers.

Nonetheless, as mentioned by Nielsen [16]:

“it is not always possible to achieve optimal scores for all usability attributes simultaneously”.

Thus, when a system is designed it is necessary to prioritize what are the most important attributes for the users and the domain where the system will be used and applied. These trade-offs are one of the most challenging tasks of the design processes because it depends on user expectations and their backgrounds, as well as, the problem domain and what are the main focus of the system use.

Accordingly, it is fundamental that the design process can focus on target users of the systems. Therefore, following will be described some main concepts, processes and techniques for a design process centered on the users.

2.1.3 User-centered Design

Before user-centered design principles and methodologies were adopted, the Waterfall model was commonly adopted as a software development process. This model comprises five sequential phases, from the requirements specification phase to the operation and maintenance phase, and has a good quality control since documentation and planning are a major concern of this methodology.[2] However, the stages of this model are not overlapping stages, so other development methodologies and philosophies arose to mitigate this problem and include the user on the design process, due to their impact on the usability of the system.

Consequently, it was necessary a new model that has the users included on the development process to verify, along the development, if the approaches adopted are positive and what is the users' acceptability. Nielsen [15] reinforces this saying that “user interfaces should be designed iteratively in almost all cases because it is virtually impossible to design a user interface that has no usability problems from the start. Even the best usability experts cannot design perfect user interfaces in a single attempt, so a usability engineering lifecycle should be built around the concept of iteration”.

The Spiral model of iterative design arose as an iteration through design, implementation and evaluation phases where the cost and accuracy increase on each iteration, since first iterations should use low-cost resources, like paper prototypes, and when the results are positive the accuracy is incremented, changing to computer prototypes, for example. [13] An overview of this model is represented in Figure 2.2.

2.1.3.1 User and Task Analysis

Regarding the concept of usability presented above and the importance of the users on the design process, it is important to define the users and their desired tasks of the system in order to find the best solution as possible to the usability attributes trade-offs. Just a

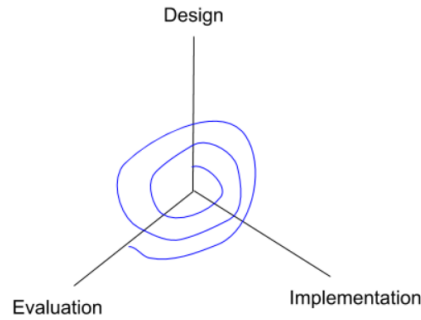


Figure 2.2: Sprial model of Iterative Design (adapted from [13])

good description of the users and the tasks of the system leads the designers to the best choice of what are the usability attributes most important for the system.

Accordingly, it is important to make a **User Analysis** to understand all users' characteristics that could have an impact on the acceptability of the system. The expected result of this analysis should be a set of structured information that characterize the users of the system in terms of technological expertise, knowledge of business domain, application experience, educational background, gender and age, as other aspects that might be useful to comprehend, depending on the system's users and domain. [8] The more traditional process to gather this information is through questionnaires or interviews, but that can also be obtained by conducting a market analyses or observational studies. [16]

Furthermore, it is essential to enumerate and analyse the tasks the users should perform using the system. The **Task Analysis** process aims to aggregate information about the tasks that should be performed on the system, starting from the system overall goals and break down these to obtain individual tasks. [16] Moreover, the goal of this analysing process is to obtain more structured information about: how the tasks are performed using the existing systems, what are the pre-conditions and the requirements of each task, why the users need to perform this tasks, and others that might be useful to characterize the tasks of the system.

The techniques used, to extract information to this analysis, tries that users specify how the tasks should be done instead of how they would perform them, resorting on examples as well as possible, in order to understand what type of strategies are used, what type of exceptions from their normal workflow are occurring, and other aspects that can be observed where the communication with users is on a concrete level. [16] In addition, Nielsen [16] points out that "The users' model of the task should also be identified, since it can be used as a source for metaphors for the user interface", which reinforces that these dialogues with users to obtain analysis content, can be useful also to find relevant solutions to latter design process phases.

Therefore, the outcome of this analysis should contain a list of the entire tasks that users what to perform in the system, the information that is required to complete them, the steps and the dependencies between tasks, all the outputs that must be generated,

and how is the communication process between the users associated with the system's tasks. [16]

2.1.3.2 Sketching and Prototyping

After the user and task analysis process, designers must start sketching and prototyping ideas and approaches, in order to think about how can they solve the problems. Nevertheless, this phase of the design process should start with sketching techniques, as these are not only a good and inexpensive starting point to communicate ideas, but also help to develop structure and enrich the reasoning, leading to the perception of other details as well as of other approaches to solve the related problems.

While sketching techniques are more plentiful, and have a low detail level, being mainly based on suggesting and exploring, rather than retrieving results, the prototyping phases, have more refinement approaches and are used to test the design choices made.

However, there are prototypes with different thoroughness degrees, presenting different advantages and disadvantages. Thus, it is important to start the prototyping process with low fidelity prototypes, as paper prototypes, since the objective of these is to evaluate the conceptual model (if the users understand the system), the functionalities presented, the navigation, the screen components distribution, and the terminology used. After the evaluation of these prototypes presents good results, high fidelity prototypes should be used, like computer prototypes. There are a set of available tools to assist in the building process of these prototypes, such as Balsamiq [3] and Mockingbird [14]. These different prototype types can detect different issues when tested with users, so it is very important to test prototypes with different granularity levels.

Furthermore, there is another relevant aspect of the prototype designing, that is the scope definition of the prototype. It is important to define what features the prototype undertakes and what is the inherent detail level. Nielsen [16] describe this as two dimensions of prototyping: horizontal prototyping and vertical prototyping, as demonstrated in Figure 2.3. A vertical prototype is characterized as a prototype to test a restricted part of the system but with real users and circumstances. A horizontal prototype is presented as suitable for test the entire system but in a less realistic approach.

Finally, regarding the methodology about how to use the prototypes built, Dix et al. [9] refer that are three main approaches:

- **Throw-away:** After the prototype is built and tested, it is used on the final system development, but after that, the prototype is discarded and the rest of the design process continues without relaying on the prototype previously built;
- **Incremental:** First, the system is separated into different parts, and each part is built, one at a time. So the prototypes are developed separately, regarding its correspondent part, and finally are combined together to build the final system;

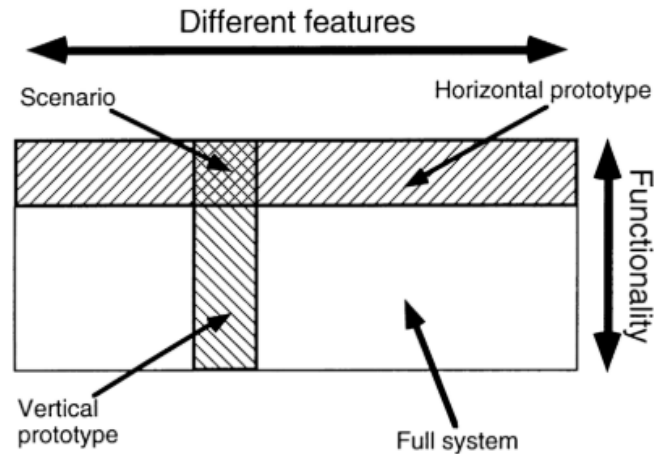


Figure 2.3: The two dimensions of prototyping: Horizontal prototyping keeps the features but eliminates depth of functionality, and vertical prototyping gives full functionality for a few features (extracted from [16])

- **Evolutionary:** Contrary to the throw-away approach, the prototypes developed are used as the basis for the next iteration of design.

2.1.3.3 Evaluation Techniques

2.1.3.4 Errors Classification

The errors occurred when a users interacts with a system are an excellent indicator to designers. Thus, what reason led the user to reach the error, is a good strategy to understand and classify them. Therefore, errors can be classified as slips and mistakes, as will be presented below according to Dix *et al.* [9]:

- **Slips:** in these type of errors, the user knows how to do the pretended task on the system, however, he presses a wrong button or closes one window accidentally. So, he understands the action, but a misaction does not allow that he reaches his goal;
- **Mistakes:** these errors occur when the user does not understand the system, formulating a wrong goal. An example of an Mistake is when the user does not understand the action associated with an icon, performing a not pretended action.

Therefore, the strategy to mitigate the problems associated with these two types of errors could be different, as mentioned by Dix *et. al.* [9]: “Slips may be corrected by, for instance, better screen design, perhaps putting more space between buttons. However, mistakes need users to have a better understanding of the systems, so will require far more radical redesign or improved training, perhaps a totally different metaphor for use.”

2.2 OutSystems Background

2.2.1 Platform Overview

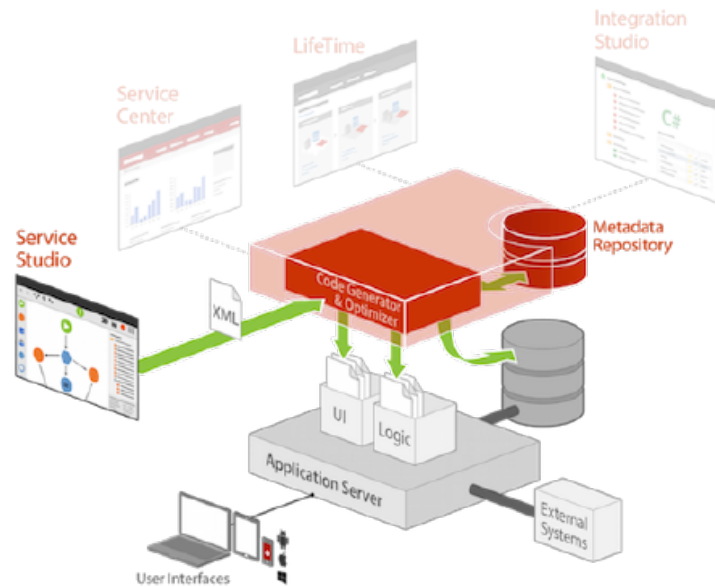


Figure 2.4: OutSystems Platform Overview [17]

2.2.2 Previous Work

RELATED WORK

On this thesis, it is pretended to apply Human-computer interaction (HCI), Data Visualization and Visual Querying concepts, techniques and technologies to improve a Visual Querying Feature of the OutSystems Low-code Development Platform. Thus, in this chapter, will be presented the results of a study that analysed what is the Low-code development platform background and its actual situation, as well as what are the techniques and technologies which already exist, including some comparison between them. Finally, will be enumerated what products, technologies and tools exist on other commercial applications which can be related with the topics of this thesis.

[The next sections depend on the research done.](#)

3.1 Data Visualization

3.2 Visual Queries

3.3 Data User Experience and Expressiveness

3.4 Technologies and Commercial Applications

Such as the techniques research, it is also very important to search what are the technologies related with the subjects of this thesis that already exist, as this knowledge can be very important to the concept of a solution proposal.

Furthermore, in any research, the academic content should not be the only taken into account, because sometimes the knowledge does not evolve only in the research centres but also in the companies. Since this thesis is made to improve a company product, the latter assertion has additional strength, so also, will be introduced commercial applications

which can be useful to all the entirety of this process.

PROPOSED SOLUTION

This chapter presents the solution proposed to the problems presented, that includes a description of the process realized to understand why the people use SQL to made queries instead of Aggregates, such as Personal Interviews and a Quantitative Analysis of the queries which customers ran on the cloud. Furthermore, this chapter presents what is the scope of the project, so it will be explained what problems will be tacked in detail.

4.1 Requirements Analysis

As referred above, this section presents the results of the analysis made to understand why developers use SQL to make queries instead of Aggregates through its Visual Querying Features.

4.2 Proposed Implementation

Following, will be detailed the pretended project, indicating all the problems identified and all the approached that will be adopted.

4.3 Scope Definition

In this section, will be presented what were the decisions made of which problems will be addressed in this thesis, once the initial problem presentation had a wide scope and it was concluded that it's not possible to resolve all the Aggregates expressiveness and experience problems in this project.

WORK PLAN

This chapter includes a planning of the total work from beginning to end. Thus, will be presented in a chronological way all the work realized in the preparation phase. Furthermore, after all the analysis realized on this dissertation plan, will be presented an expected plan to the remaining time until the final of this thesis.

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