Using a visual language to create better spreadsheets

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ABSTRACT
It is known that spreadsheets are error-prone. It is very difficult for users to get an overview of the design of the spreadsheet, and this is causing errors. Furthermore users are not always aware of the best way to structure a spreadsheet and just start modeling. To address this we will build a visual language to develop spreadsheet models. This enables users to visualize the design of their spreadsheets. A spreadsheet generator will create the spreadsheet based on the specifications made with our visual language. During this process, best practices for structuring spreadsheets are automatically incorporated. There will be a bidirectional link between the model and the associated spreadsheet.

1. INTRODUCTION
Spreadsheets are extensively used by companies. Information embedded in these spreadsheets often forms the basis for business decisions [7]. The quality of these spreadsheets impacts the quality of the decisions. It is known that spreadsheets are error-prone [9]. A poorly structured spreadsheet is often the cause of errors. Because of the nature of the spreadsheet user interface it is difficult to keep an overview of the underlying design. And without a clear design the structure of the spreadsheet gets messy. Also users do not always possess the knowledge to structure a spreadsheet properly.

In order to address this, we present a research plan to develop an alternative user interface that enables the user to design a spreadsheet using a visual language. Based on the instructions made with this language the spreadsheet is generated automatically. The transformation between the model represented in the visual language and the automatically generated spreadsheet is bidirectional. Changes in the model are propagated to the spreadsheet and vice versa. The visual language will help the user to keep an overall overview of the spreadsheet design. And even more important, because the spreadsheet is generated automatically, well-known design patterns can be incorporated to structure the spreadsheet.

2. PROBLEM DEFINITION
The success of spreadsheets can be partially explained by their easy-to-use interface. However, it is this same interface that is responsible for some of the problems that are associated with spreadsheets. If you write a document or a program you can scroll up and down to get an overall overview of the object you are creating. Also you can use tools (like an outline view, table of contents generator, or dependency graph) within the software to get a better overview. In Excel users can easily enter data and formulas in cells, but as soon as they hit the enter-button a spreadsheet will only show the result of the formula and not the formula itself. In a formula, references are made to other cells in the spreadsheet. It is not possible to immediately see these references. You could say the underlying design of the spreadsheet is hidden ‘behind’ the spreadsheet itself. The hidden design makes it difficult to understand a spreadsheet and to get an overview of the design. This is causing errors [8].

A part of the design of a spreadsheet is the way the information is structured within the sheet. There are best practices for the structure of a spreadsheet that can be found in literature. A commonly found model is to split input, model and output. This works quite well for some of the problems that people want to solve with spreadsheets. However, it is not the best model in every situation. Spreadsheets are also often used for what-if questions: “What is going to happen if I change this?” In this situation it would be better to have input and output closely together. Putting input and output closely together will lead to a completely different structure of the spreadsheet than implementation of the input, model, output principle. The optimal way to structure a spreadsheet depends on the kind of problem that you want to solve with the spreadsheet.

In practice, users are not making a conscious choice of how they structure their spreadsheets. They want to solve a problem as quickly as possible and just start entering the data and formulas without giving the structure a lot of thought. When the complexity of spreadsheets increases over time they end up with a messy model. At that point it is difficult to change the underlying structure and the risk of errors is imminent.

This brings us to the two problems we want to focus on in our research:

1. The design of a spreadsheet is hidden behind the spread-
Figure 1: Model and associated spreadsheet

sheet itself, making it very difficult for an user to get an overview of the design.

2. Users are not aware of the best way to structure a spreadsheet and just start modeling. The model works, but is poorly structured and error-prone.

3. PROPOSED SOLUTION
To address the above mentioned problems, we will develop an alternative user interface for the development of a spreadsheet. The basis for this user interface is a visual language (see also Figure 1). One of the success factors of spreadsheets is their flexibility and ease of use. If users have to learn a specific programming language before they can start developing a spreadsheet, we expect that the adoption of this alternative user interface will be very low. However, if we can develop a visual language that is easy to understand, works intuitively and at the same time makes use of a drag and drop interface, we expect a higher adoption.

It will be possible for the user to develop a spreadsheet with the visual language in one screen and seeing the associated spreadsheet in another screen. The link between the model and the associated spreadsheet should be bidirectional. Changes made in the model should be propagated to the associated spreadsheet and vice versa.

To implement this solution we face many challenges. It is not in the scope of this paper to address them all, but we would like to highlight two of them in more detail. First of all, we face the challenge of the scalability of a visual language. Real-life spreadsheets are often complex models and it is difficult to present such a model visually in a clear way. Careful attention should be paid to the level of details that are presented in the visual language. Second, if we want to make the link between the model on the spreadsheet bidirectional, we have to think about what kind of operations are allowed in the spreadsheet. How should we, for example, handle a change in the spreadsheet that violates the model?

4. HYPOTHESIS
There are several hypotheses underpinning the proposed solution that will be evaluated during the research:

1. Users are more likely to use a visual language than a written language as an alternative to develop a spreadsheet.
2. The representation of a spreadsheet in the visual language will help users to get an overall overview of the spreadsheet.
3. If the user has a better overall overview of the spreadsheet, the spreadsheet will contain fewer errors.
4. The automatic spreadsheet generator will use common design patterns to structure the data in a spreadsheet. This will improve the underlying design of the spreadsheets.
5. A better structured spreadsheet contains fewer errors.

5. APPROACH
A spreadsheet model consists of formulas and operations on data. These formulas and operations are the constructs of our visual language. To develop this visual language we have to research what constructs should be included. With our language it is possible to model the majority of questions that are solved with spreadsheets. This implies that we need to get an understanding of the different questions that users try to solve with spreadsheets. Finally we will also explore if the constructs we find are depending on the domain in which the spreadsheet is used or if they are used regardless of the domain.

To answer these questions we will use the EUSES spreadsheet corpus [6]. This corpus contains over 4000 real world spreadsheets from domains such as finance, biology, and education. We will analyze what kind of formulas are used in spreadsheets and how they are combined. This will be translated to the constructs that are needed to build the visual language. The spreadsheets from the EUSES corpus will be complemented with real-life spreadsheets collected from our industrial partners.

To automatically generate a spreadsheet and to structure it in the most optimal way, we will inventory the best practices in spreadsheet design. Besides, we will research if additional design patterns are needed to cover the majority of questions. We will carry out a literature study to get an overview of the commonly used and known design patterns. Furthermore, we will search for additional design patterns by analyzing the spreadsheets in the EUSES corpus and the spreadsheets collected from our industrial partners.

Based on the knowledge gained about the required constructs for the visual language and the best practices to structure a spreadsheet, we develop a prototype of a ‘graphical spreadsheet generator’. The spreadsheet generator will generate the spreadsheet based on the specifications made.
with the visual language and uses a suitable design pattern
to structure the data. At this point, we also investigate if
it is possible to automatically generate a graphical repre-
sentation (using the syntax of the visual language) from an
existing spreadsheet. This is needed to synchronize the vi-
sual model with the spreadsheet and allow the users to make
changes in both the model and the spreadsheet.

6. EVALUATION
To validate our hypotheses, we carry out two different kinds
evaluations. First, we will evaluate the impact of the visual
language on the behavior of the users. Is it true that they
have a better overall overview of the spreadsheet and
do they prefer a visual language over a written language?
These two questions can be answered with case studies [11].
In the case studies we will ask users to develop a real-life
spreadsheet with the new interface and afterwards interview
them about their experiences.

Furthermore, we want to know if the spreadsheets that are
developed with our visual language contain less errors and
if this is caused by a better structure or because the end-
user has a better overview/understanding of the spreadsheet
or both. To evaluate this, controlled experiments will be
performed. Two sets of participants are asked to develop a
certain spreadsheet model. One group will use the visual
language, the other group the classical spreadsheet interface.
The two resulting sets of spreadsheets will be compared with
each other concerning the number of errors and development
time. Besides the experiments, we interview the participants
to get a better insight of the users experience with the visual
language.

7. RELATED WORK
Already in 2001 Burnett et al [2] developed Forms/3, a gen-
eral purpose visual programming language. Main rationale
to develop this language was to remove spreadsheet limi-
tations without sacrificing consistency with the spreadsheet
paradigm. Two principles in particular guided the develop-
ment process: directness and immediate visual feedback.

In our approach we are less concerned with the limitations
of modern spreadsheet languages. We want to improve the
overall quality of spreadsheets by introducing a visual lan-
guage that supports users by visualizing the design of their
spreadsheet and help them to better structure their data. How-
ever, directness and especially immediate visual feed-
back are also two valuable guiding principles in our research.

Engels and Erwig [5] have described an automatic transfor-
mation process to generate a spreadsheet from a so called
ClassSheet. The development of ClassSheets is a further
elaboration of the work on spreadsheet templates [1]. With
ClassSheets, it is possible to model spreadsheets according to
domain-related business object structures. The ClassSheet
represents both the structure and relationships of the in-
volved (business) objects and classes and the computational
details of how attributes are related and derived from each
other. ClassSheets help to reduce the semantic distance be-
tween a problem domain and a spreadsheet application.

Cunha et al. [4] have further improved the concept of Class-
Sheets. They have embedded the ClassSheets spreadsheet
models in spreadsheets themselves. Because of this, users do
not have to familiarize themselves with a new programming
environment. Furthermore, the authors have presented a
technique to perform co-evolution of the ClassSheet model
and the related spreadsheet. Modifications to the model are
automatically propagated to the spreadsheet.

The main difference between the ClassSheet approach and
ours is the introduction of a visual language that does not
use the tabular two-dimensional layout of spreadsheet de-
sign. We agree that users should not be required to fa-
miliarize themselves with a new programming environment
before they can develop a spreadsheet. Therefore the visual
language will be used in the same environment as the asso-
ciated spreadsheet. However, if the model is represented in
a spreadsheet-like layout, it is still difficult for users to get a
good overview of the design of the model. That is the reason
why we develop a language that specifies and visualizes the
model at the same time.

Also, our visual language embraces object-oriented prin-
ciples, but does not expect the users to be aware of these
principles. The overall goal of our research is to apply soft-
ware engineering principles to the design of spreadsheets to
improve the overall quality of spreadsheets. However, the
spreadsheet user - who is not a professional programmer -
should be able to develop the spreadsheet without being re-
quired to have knowledge of these principles.

Furthermore, our visual language can be used to generate
the associated spreadsheet. This does not imply that the
user is restricted in influencing the layout of this spread-
sheet (as is the case with the ClassSheet approach). It was
estimated that 95% of U.S. Firms uses spreadsheets for fi-
ancial reporting [10] and layout is an important factor for
effective reporting.

Finally, the current ClassSheets approach enables the co-
evolution of the spreadsheet model and the spreadsheet data.
At the theoretical level, the evolution of the instance of the
model and the co-evolution of the model itself has been real-
ized [3]. In our research, we focus on bidirectional transfor-
ations and integrate them in the prototype of the spread-
sheet generator.

8. EXPECTED CONTRIBUTION
This research will lead to the following contributions:

1. A classification of the type of questions that end-users
   try to solve with spreadsheets.
2. Better understanding of the kind of formulas that are
   used in spreadsheets and the way these formulas are
   combined to solve questions.
3. Best practices for the design/structure of spreadsheets.
4. A visual language to model spreadsheets.
5. Methods to automatically generate a spreadsheet from
   the visual language.
6. Methods to automatically generate a graphical repre-
   sentation (using the syntax of the visual language) of
   a spreadsheet.
7. A prototype of an alternative user interface for the development of spreadsheets that is based on a visual language.

9. REFERENCES


