Prototyping Data Management Model and Tasks

Kalinka Kaloyanova[1], Ioannis Patias[1], Boris Robev[1]

[1]Faculty of Mathematics and Informatics
University of Sofia St. Kliment Ohridski“
5 James Bourchier blvd., 1164, Sofia, Bulgaria

kkaloyanova@fmi.uni-sofia.bg

Abstract. When new products are introduced, the ability to deploy them quickly on the market is the key to their success. In this paper, we discuss an approach for data modeling used in the Laboratory Intelligent Urban Environment – IUE-Lab (Center for Competence in Mechatronics and Clean Technologies). The main design goal was that any prototyping procedure elaborated in IUE-Lab should not set up a new database. Instead, a predefined data management model could be used as a data repository for all prototypes. This model is based on a generic data presentation adequate for both observational and real-time data for experiments, devices or prototypes.

Keywords: Prototyping, Data Model, Data Repository, Data Management.

1 Introduction

Prototyping is widely accepted in different projects in the IT area. The prototyping concept has been actively used in the Intelligent Urban Environment Laboratory (IUE-Lab) to address the needs of the MIRACle project: Mechatronics, Innovation, Robotics, Automation, Clean technologies – for the establishment and development of a Center for Competence in Mechatronics and Clean Technologies. IUE-Lab aims to develop three parallels, namely Intelligent Home Environment (IHE), Intelligent Public Environment (IPE), and Intelligent Personal Assistant (IPA). The main idea is to develop the required infrastructure, in terms both of hardware and of software, able to support the observational and real-time data collection, storage, and analysis. This is important for the development of the laboratory and its activities (see fig.1), namely:

- iVille – mobile (incl. flight) autonomous hub of data and control signals for the urban environment;
- iVac – a mobile autonomous hub of data and control signals for the home environment;
- iÉcole – a mobile autonomous hub of data and control signals for a public structured environment – for example in education and administrative

services. Within the IUE-Lab, it will be prototyped for the purposes of the educational environment, and

- iChien – an electronic guide for blind people, based on a smartphone and integration into the IUE-Lab.

The process of prototype management covers several different tasks, including database and reporting templates design, for both observational and real-time data collection, storage, and analysis. The aim is to cover various application fields from smart city, and e-government [1], smart home, smart school, even more specific ones related to devices to support vulnerable groups, medical devices and other services [8]. Essential features for our lab activities include the following:

- prototyping end-users support: we aim in building autonomous management of the users without having to work with our experts.
- multiple platforms support: able to work with various configurations of hardware and operating system.
- generic analysis platform: able to support the data collection, storage, and various types of analysis [12].

The present paper discusses the role of prototypes in product development and presents the IUE-Lab prototyping observational and real-time model of data management system. The prototyping database characteristics will be presented. The proposed generic data model fits to the requirements for reusability.

2 Prototypes and product development

Prototypes are very important for the product development process [2]. They affect the entrepreneurship and management of innovation. The companies that wish to be counted in the innovators group invest with R&D expenses that often get up to a double-digit percentage of their sales. Although the expenses get that significant the product development either, do not get to the market or do not get the expected sales.

The development of prototypes including complicated software and hardware systems, embedded or embedding other subsystems, represents a significant cost for the companies our days and it is important to be successful. We need to look at prototype development as a business-oriented process, but also as an engineering-oriented process, and try to identify the corresponding approaches that will help us in the efficient application of those approaches [3].

Applying a business-oriented approach we evaluate all those components, which are related to the development of the product in terms of market needs a response. However, we also need to take into consideration the realization of the product in the market, meaning we need to manage all of the logistics, timing, and budget-related issues, as well as the whole project coordination itself. Those components apart in prototype development projects are also present in many other kinds of product realization projects.

In an engineering-oriented approach, we need to focus on the creation of the physical product. This includes the establishment of the processes for effective development supported with the use of appropriate methods and tools.

Finally, the successful method is the one that can incorporate both the business-oriented and the engineering-oriented approaches.

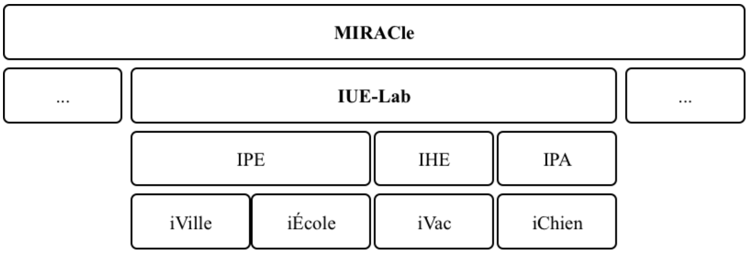

Fig. 1. IUE-Lab activities under the MIRACle project.

For the project purposes, we need to bring together people with different backgrounds. On the one side, the ones with the business orientation defining the requirements, and on the other the engineers, which are requested to transform those requirements into product prototypes.

The successful combination and the implementation of this method is the tool for the successful prototype development and product delivery efforts. This method helps us avoid projects time overdue, or projects over gone in the budget. This method secures successful products on time to the market.

Trying to outline the importance of prototyping in the frame of the IUE-Lab design process we may also study the effects on both the process and the people involved in it.

First, we can compare engineering and the positive impact on management. The idea is that we can use agile prototyping, or re-use previous prototypes, and build in a scalable manner. So, by creating some tangible prototypes, usually at low-cost, the developers become rapidly able to get end-user evaluations. This helps evaluate the product but also helps to understand any existing trends regarding user acceptance. The earliest stage in the development process, you have the end-user feedback, the better you can react and get the benefit of this feedback. In other words, such fast prototypes are beneficial to the product design, and to the people involved in it. The designers gain majorly that:

- early critics from end-users are an opportunity for faster and successful release to the market;
- the progress of product's development step-by-step, and
- the feeling of creativity.

Second, we can compare the effect of working in a real–physical environment versus working in a virtual environment on the people involved in product development. Even if we divide into two groups the people involved, meaning non-designers, non-engineering, and non-informatics, and designers, engineers, or informatics specialists, we can see the differences when we have real environments instead of virtual environments. All involved people get better results when they have direct access to physical prototyping and testing environment, with a real, or at least real-like testing platform.

In other words, the availability, and access to real physical prototyping and testing environments are important for the faster and better product development. However, it is also important for the people involved, because support direct communication with the end users, systematic product development progress follow up, and creativity.

In the case of more specialized quality management systems (QMS) like ISO 13485, for quality management in medical devices [5,6,7] the provided processes standardization clarifies the difference between some of the terms that will be used here: monitoring, measuring, analyzing, and evaluating a process [9] (see fig. 2):

- monitoring – of process performance through inspection or observation and by keeping records of those observations;
- measurement – of quality and quantity;
- analysis – of trends and tendencies;
- evaluation – against criteria, able to confirm the performance or conformity of the process and the output;
- improving – based on the analysis and evaluation.

Applying the plan, do, check, act discipline (PDCA cycle) is an efficient way of implementing the improvement of processes. The aim is to develop records of accomplishment for all process performance monitoring activities, the results captured in terms of quality and quality, the examined trends and tendencies, and finally the comparison results of those, against pre-defined expected process outcomes. Those records can be used to secure the systems predictability, accuracy, and reliability. All those are prerequisites for sensitive systems, like medical devices.

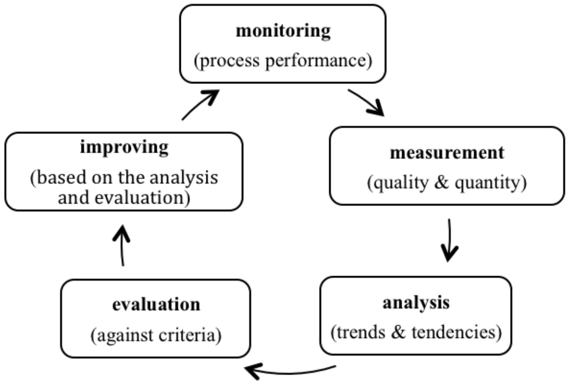

Fig. 2. QMS processes based on ISO 13485.

3 Prototyping database and generic data model

In order to design a generic data model, we need to define how the mapping of the different prototyping variables, defined on the reporting templates, will be done into the database tables.

The most convenient for our case model is the Entity–Attribute–Value model (EAV) [13], also known as Object–attribute–value model, vertical database model, and open schema. The model is used in similar applications for clinical trials [14]. The difference is that it enables encoding in a more efficient way regarding space. Entities and the respective number of attributes describing them, like properties, or parameters are many, and differ to each next experiment, device, or prototype. At the same time, the amount of times that those concrete attributes will be used is small. By using an EAV data model, we will have attribute-value pairs as facts describing the entities, and each row will store one so described fact [15].

In the EAV data model, we have data recorded as three columns:

- entity: describing the item, or in our case the experiment, device, or prototype;
- attribute: describing entity properties or parameters. The tables for the definitions of the attributes usually contain at least: attribute ID, attribute name, attribute description, data type, and
- value: of the concrete attribute.

In our concrete case, the EAV design will represent every single entity – experiment, device or prototype, and its data as multi-rows in a single table structure. The following elements can be combined to form our data model (see fig. 3):

- form: the templates used to collect data, which map data for a set of assigned in it measurements for the concrete experiment, device or prototype;

- version: different versions for each form, the various filled with observational and/or real-time data copies of the used forms;
- data field: the concrete variable on a form;
- variables: the concrete ones for which experiment, device or prototype data are collected;
- variable category: the category of variables, for which experiment, device or prototype data may be collected;
- place-keeper: the associated with a particular variable place-keeper in the form of standard elements like input field, combo box, etc;,
- unit: representing the distinct variables;
- unit category: with which the unit variables are associated;
- prototype: each experiment, device, or prototype is related to a respective collection of documents;
- experiment: a concrete record for an experiment, device, or prototype, associating it with a set of related documents;
- document: the forms become documents when stored;
- value: one data field.

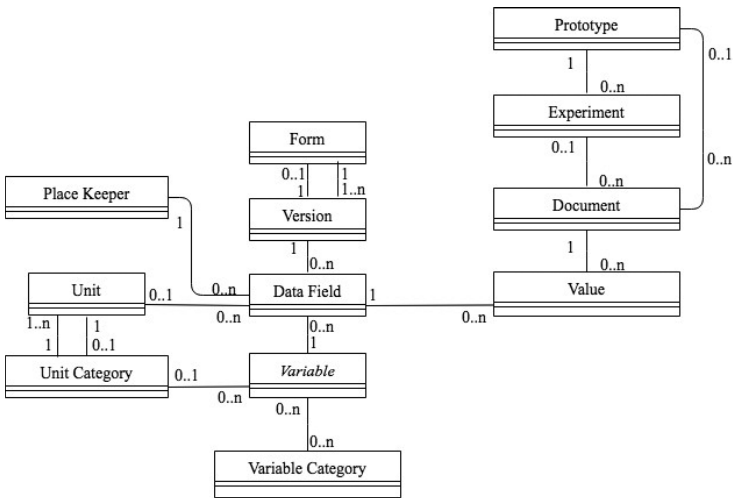

Fig. 3. Prototyping generic data model.

Finally yet importantly, regarding the EAV model, it is worth noting that Resource Description Framework (RDF) is being employed as the basis of Semantic-Web-related ontology work. RDF, intended to be a general method of representing information, is a form of EAV, as an RDF triple comprises an object, a property, and a value, even given their limitations [10]. In our case, this is important also for further development of the semantic representation of the prototyping results in terms of ontologies [4, 11].

4 IUE-Lab prototyping data management system model

The following three data management tasks (see fig. 4) are usually performed in the course of experiment, device, or prototype testing: (1) reporting templates design, (2) observational and real-time data collection, and storage, and (3) data analysis. Those three cover the above-mentioned QMS activities (processes) and results (products). In the following sections, we will discuss how each of these steps is supported by the modeled system.

Fig. 4. IUE-Lab prototyping data management tasks.

4.1 Reporting templates design

The purpose of the reporting templates design component is to support the process of new templates construction. End users should be able to create their templates and directly relate them to the database. The required functionality concerns:

- component reusability, using a repository with elaborated components such as different variables,
- design automation, by using existing templates and variables,
- observational and real-time data incorporation in templates, by adding standardized elements, and
- remote accessibility, all templates should be stored and accessed remotely.

4.2 Data collection and storage

Either Prototyping observational and real-time data are recorded by filling in reporting form or with real-time data flow stored directly in the respective pre-defined elements. In both cases, data is stored in the database. The data collection process could be customized in different ways. For example, by using concrete templates automatically loaded and displayed for concrete users, or using real-time data that is automatically stored in predefined elements.

4.3 Data analysis

The analysis component should be open to different statistics, analytics, and other research methods. For the analysis component, the system should use different formats, like the ones used to store data.

6 Conclusions

In this paper, the concept prototype and the role of prototypes in product development were discussed. It was reported the IUE-Lab prototyping observational and real-time data management system model, and the characteristics of the prototyping database and the underlying generic data model. The proposed data management model serves the needs of MIRACle project: Mechatronics, Innovation, Robotics, Automation, Clean technologies – Establishment and development of a Center for Competence in Mechatronics and Clean Technologies, and more specifically for the Laboratory Intelligent Urban Environment. The design goal that the prototyping procedure should not have to design and set up a new database for each new experiment, device, or prototype was met. The described generic data model is suitable for the storage of any experiment, device, or prototype observational and real-time data the IUE-Lab is able to support the prototyping procedure, in order to ensure the ability to support the race for new products in the market.

6 Acknowledgment

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