Software Technology
Eindhoven University of Technology
PDEng projects 2011
The Software Technology PDEng (Professional Doctorate in Engineering) degree programme is an accredited and challenging two-year doctorate-level engineering degree programme. During this programme trainees focus on strengthening their technical and non-technical competencies related to the effective and efficient design and development of software for resource constrained software intensive systems, such as real-time embedded systems, in an industrial setting. During the programme our PDEng trainees focus on systems architecting and designing software for software intensive systems in multiple application domains for the High Tech Industry.

The programme is provided by the Department of Mathematics and Computer Science of Eindhoven University of Technology in the context of the 3TU.School for Technological Design, Stan Ackermans Institute.

For more information, visit the website: www.3tu.nl/sai/st.
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Seventeen Software Technology candidates graduated in 2011. Seventeen well-trained and much needed professional designers performed their final project in an industrial setting, and subsequently found their way into the High-Tech industry.

From January 2011 until the end of September our candidates have been on their projects at High-Tech companies and research institutes. An overview of the results you find in this booklet. I have characterized them as ‘Visual ICT’, since many of the projects had to do with forms of visualization.

From the medical domain, examples of this include the accurate visualization of blood flows, vessels and artifacts as well as the place of such visualization in the engineering process. A completely different interpretation of ‘visual’ is found in the projects around intelligent lighting and digital media. Also tools were developed to interact with underlying systems in a visual way.

An important class of projects is concerned with the development of software itself, and the tooling supporting that process. Here we see modern software development techniques being examined and implemented. The tools address problems around automated testing, workflow management, interface specification of components and model-driven engineering. Visual feedback is most often obtained through simulation.

Again, the projects had the characteristics we observe every year: there is a real design challenge that requires skill and training and the result is relevant and needed by the organization hosting the project.

The results are here before us and serve as a ‘business card’ for our programme. To all candidates: I wish you all the best and a successful career.

Johan Lukkien
Scientific Director
Challenges
The first challenge was to learn the new clinical domain of cardiovascular diseases, and medical imaging technologies. The biggest challenge, however, was to design and implement the X-ray IVUS co-registration application integrated with the Interventional Workstation platform of Philips Healthcare, which required a detailed understanding of the complex software platform.

Results
The main result of the project is the working demonstrator of the time-based co-registration which enables useful discussions and feedback from clinicians. Firstly, a communication interface for the time-based co-registration of these two imaging systems was designed and implemented. Secondly, images of these systems are co-registered based on their timestamp information. Thirdly, a prototype is developed to visualize these coregistered images. Lastly, the clinical accuracy claim of this solution is investigated by using empirical data.

Benefits
The X-ray IVUS Co-registration project is one of the pioneering projects at Philips Healthcare that apply in the domain of coronary artery disease. The developed prototype enables Philips Healthcare to get valuable feedback from clinical users. The key concepts in this application will be the basis for potential future product development. The application has a generic architectural solution that can be extended for other intravascular modalities as well as allowing easy maintenance for future changes.
Cardiovascular disease (CVD) is the leading cause of death in the developed world. Coronary artery disease (CAD), which is a subgroup of CVD, is typically caused by a narrowed vascular section. A large part of the world population dies each year due to this disease. In the USA alone, 17.5% of the people die because of CAD, and over 600,000 Percutaneous Coronary Interventions (PCI) with stent placement are performed in the USA on a yearly basis. It is therefore important that an interventional cardiologist can assess the disease in detail to select the right stent and the right location for deployment to treat the narrowing. This task is challenging because the cardiologist needs to combine information from many sources to diagnose the patient and decide on the treatment plan. Philips Healthcare initiated this novel project to address this clinical need.

X-ray and IVUS systems
During the diagnosis and treatment phases of PCI, two imaging techniques are commonly in use: X-ray angiography, providing an external view of the coronary arteries and IntraVascular UltraSound (IVUS), allowing the visualization of the coronary arteries from inside the body. Although these technologies are commonly used during PCI, there is no direct relation between the information these two imaging techniques provide, thus the correlation of the IVUS image data to the X-ray data (i.e. co-registration) becomes a challenging job for a cardiologist. It is expected that displaying a synchronized view of an X-ray image and the corresponding IVUS image will be beneficial.

Time-based coregistration
It is proposed that the synchronized view of X-ray and IVUS can be achieved by using the time information of these images. This project aims to provide the proof-of-concept for the time-based co-registration of X-ray and IVUS systems. A demonstrator is designed and implemented which can be integrated with an in-house IVUS simulator, co-registers X-ray data with the simulated IVUS data by using timestamps, and visualizes the co-registered information. Additionally, a generic co-registration interface is designed that can be used by multiple intravascular modalities whose information can be co-registered with X-ray angiography. An initial assessment for the accuracy of the envisioned solution is also made in order to foresee the acceptability of the solution from the clinical domain.
Challenges
Accessing data that resides on the grid can be achieved in multiple ways. Most of the times it can be done by making use of various tools that are unique to grid computing and hence unfamiliar to inexperienced users. The utilization of these tools proves to be difficult and in some cases rather inefficient. The main challenge is to provide to the users an easy-to-use and efficient method to access data.

Results
A secure WebDAV interface that is accessible from any operating system without requiring any difficult-to-install grid-specific tools has been developed. Moreover the project implements a transparent distributed cache system that stands between the users and the storage elements, in order to increase the efficiency and to decrease the grid’s resource consumption.

Benefits
The results show that by providing the WebDAV interface to the user, no grid-specific tools need to be installed up front, except a Firefox plugin that is used to delegate the credentials. The execution time of the jobs that run on the grid can be highly improved by using this project due to its distributed cache mechanism.
C.T. Cirstea PDEng

Grid Data Access: Proxy Caches and User Views

“The National Institute for Subatomic Physics (Nikhef) focuses on research in area of (astro) particle physics. Apart from physics research, the institute provides data storage and computing facilities as part of the Worldwide LHC Computing Grid, which is mostly used by the CERN (European Organization for Nuclear Research) experiments, but also for other research domains such as biomedicine or bioinformatics. The goal of “Grid Data Access: Proxy Caches and User Views” project is to determine and to integrate a standard communication protocol that would ease the access to data stored on the Grid. Moreover, the project needs to be scalable and it needs to optimize the data traffic between users and storage elements by implementing a distributed cache system.

A standard interface to access data
Although there are various methods to access data, they are considered difficult by inexperienced users. In order to ease the access to data, several research groups were surveyed to determine a method that would be considered easy to use and in the same time to add value to their work. It turned out that using a WebDAV interface would allow users to access data from any operating systems without requiring any special knowledge or tools. Furthermore, the Worker Nodes can make use of the new interface in order to access data.

Reducing the resource utilization
A brief analysis of the data utilization pattern that resides on a storage element revealed that more than 30% of the files are utilized more than once. The overhead introduced by the components of the grid is rather high, in order of seconds. By implementing a transparent, efficient and (almost) overhead-free caching mechanism, the user would pay the overhead only first time when the files are accessed. Next times they would be delivered directly from the efficient cache. Tests of the system at scale show that the file access time is only marginally increased by the cache system for a first access of a file; the times for subsequent accesses to that file are in general greatly reduced.

“Cristian … did an outstanding job in discovering the true requirements, constructing a prototype, testing it at scale, and answering many of the questions we had.”

Dr. J. Templon
Nikhef
Challenges
The goal of this project was to identify a mechanism to link various information sources, services and servers together and think how to give a user a meaningful link towards their lighting. One of the biggest challenges was to design and implement a generic framework that enables the integration of the web information with consumer lighting systems. In addition, the framework must handle the information-gathering and information-processing part in such a way that both can be vary independently without affecting each other.

Results
A comprehensive analysis shows various web technologies and their pros and cons, their interesting association and feasibility in the consumer lighting domain. A prototype demonstrates the web information gathering and later transforming it to light effect based on the user preferences. The prototype implements use cases that cover areas such as Social Networking, Email, RSS, Stock, Weather and Location based service.

Benefits
The prototype implementation shows the feasibility of the integration of web services with the consumer lighting system. The benchmarking analysis and deployment cost calculation shows that the system architecture is flexible enough to adopt it in a real project. Separation of concerns between information gathering and processing part ensures that the web information gathering part can be used in other application domains.
Internet Lighting: Linking Internet Media to Consumer Lighting

Philips Lighting has rolled out a range of products known as LivingAmbiance, which is a first step towards delivering “connected lighting” to the home. These products include bulbs and luminaires which work seamlessly together as one system allowing consumers to create new ambiences and scenes with easy to use remote controls. The connectivity technology which makes this possible is called SmartLink, a proprietary radio solution based upon Zigbee.

People increasingly spend a large amount of their times online, using the internet to find information, for fun or for staying in contact with friends. With a connection towards IP is established, it is a natural next question to ask, what would it mean to connect lighting to this world? Philips Lighting is investigating the possibility to explore various scenarios where lighting control considers the web as an important input source. This definitely requires a mechanism that connects all the different information sources, services and servers together and gives a user meaningful link towards their lighting.

A web information gathering and processing framework
In this project, several activities were carried out to meet project goals. First, various web information sources and technologies were studied and evaluated to discover the technical feasibility and their practical relationship in the consumer lighting domain. Second, a web information gathering and processing framework was designed and implemented using various state of the art technologies. The framework demonstrates the integration of a consumer lighting system with information areas like Social Networking, Email, RSS, Weather, Stock, and Location. To decouple the information-gathering part from the rest of the system, a separate WEB API was designed. The prototype implementation shows the possibility to link web information with the consumer lighting without changing any infrastructure in the existing LivingAmbience system. The benchmarking analysis shows that the system architecture can guarantee main requirements like scalability, modularity and usability.
Challenges
The main challenge was to gain understanding of the education-and-coaching domain and translate it into software model. Another challenge was to design a service-oriented system with the flexibility to host parts of the system in different locations, together with scalability and performance in mind.

Results
A working prototype was built from scratch, which can offer different education and coaching programs to different patients. Off-the-shelf technologies were used when applicable. A graphical Web Front-End for patients was developed by a colleague from Philips Research.

Benefits
The patients only need an Internet browser to access the program. The prototype provides a means to easily test different education-and-coaching programs to patients; it shows the possibility to add new programs without recompiling the system and patients have a low barrier to use the program.

In addition, the development of the prototype gave valuable learning experience in e.g. Internet and rule-engine technology to both the author and Philips Research. The prototype also demonstrates the trade-offs between flexibility to host parts of the system in different locations and performance.
Chronic diseases such as heart failure and COPD are a major health concern in the 21st century. To improve survival and quality of life, patients with chronic diseases are expected to change their lifestyle and to perform a part of the care themselves. To increase the level of self-care, Philips has developed the Motiva system. Motiva offers education and coaching programs in an interactive way at home via a set-top box and TV.

It is highly desired to also offer education and coaching programs via ubiquitous platforms such as PCs, tablets, and smart phones, making use of Internet technology. This eliminates the need for a dedicated device and installation process, and facilitates the reuse of off-the-shelf components. The main focus of this project was to develop a Web-based education and coaching system.

In the process of developing the education-and-coaching programs, it is necessary to be able to test the impact of different programs on the patients. This introduces the need for an education-and-coaching system that can offer different programs to different patients and that can easily be altered to accept a new program. Moreover, each of the programs may consist of different program flows. Each of the patients may have a different program flow depending on e.g. his/her health condition.

The result of the project is a Web-based system that is split into a Back-End and several Front-Ends. The Back-End is a service-oriented system implemented using Web-service technology. Two education-and-coaching programs were created to demonstrate the system. The demo proves that the system fulfills the above requirements.
Challenges
The biggest challenge was the hardware and software integration. Even though the system seemed running in debug mode, the deployment stage suffered from unknown bugs. The second challenge was to figure out the detailed data flow and for processing the data in real-time. The third challenge was the collaboration with the software and hardware providers and working with components that are still in the test phase.

Results
A real-time distributed system is constructed and the infrastructure for the system-wide decision mechanism is provided. A prototype is designed with a protocol that determines the system setting based on available resources (processing, bandwidth). The design provides network reservation for the system nodes and scheduling for the tasks comprising the distributed video processing application. The decision mechanism is tested with one camera platform.

Benefits
The redesigned distributed real-time system provides a better quality of service for the video processing application in the surveillance domain including a reduction of latency. With the proposed design and the implementation, the specifications of the video frames are adjusted based on the network capacity. The possible data loss on the network is therefore reduced.
This project has redesigned a system of a distributed video processing application by including a system-wide decision mechanism with admission control of the network. The project was done as a part of the Optimization of Modular Embedded Computer Vision Architectures (OMECA) project at the Software Architecture and Networking (SAN) Group in Eindhoven University of Technology.

The goal of the project was to design the software to deal with the distributed system as a single system, thus minimizing the delays while keeping the predictability. The SAN Group provided prepared camera platforms with a Real Time (RT) Kernel, a PC, and video processing application as an example which can be distributed on the given hardware. At the start of the project, the real time operating system was investigated for the PC and two camera platforms were connected to the PC via a network switch. Then the video processing application was run on this setup. Basically, a user requested a connection to the camera platform and camera platform provided video streaming to the user.

In order to solve resource conflicts an admission control application was designed and installed on the PC and the original video processing application was redesigned on the camera platform in order to include this admission control. The idea was to control the distributed system as a single system. The admission control evaluates the frame that would be sent by the camera platform, and decides whether or not the camera platform can stream that frame based on the network availability. It also can change the specifications of the frame on the camera platform and adjust the camera platform to the network. It schedules the network access of the second camera platform connection in order to prevent a possible network overload.
Challenges
The first challenge is to learn and inter-relate the new fields of the live automated test, flexible-schema data modeling, and data visualization. The biggest challenge, however, was to design and implement the data model for the automated test execution data, integrated within the live automated test environment. In addition, non-functional requirements such as extensibility, reliability, performance, and deployment had to be met.

Results
First, the new design of the test execution data offers flexibility to allow the schema evolution and extension in an easy way for the dynamic changes. Second, it offers simple and efficient queries such that the performance of the prototyped visualization charts is over 100 times faster than the views which were accessed through the old website. Third, it keeps the relevant test data from the past while satisfying the performance requirements.

Benefits
The newly designed system provides the foundation to carry out further extensions and evolutions. It provides a long-term solution to the problems of inflexibility in the database design, inefficiency and slow performance of the views, and the removal of the test data from the past. It allows the stakeholders to migrate the live automated system to the newly designed system in time without downtime and data loss. Furthermore, it allows the stakeholders to monitor the performance of the live automated test environment.
During the automated test of the printer’s controller software in Océ, large amounts of test data are required to configure the test (such as testcase data) and are produced as a result of test execution (such as test results). The Framework Automated Testing (FAT) stores these test execution data in a database. The FAT system uses these test data to provide several views of the stored test data.

Due to the strong dependencies and inflexible schema of the current database system, the data model has failed to keep pace with the dynamic changes required by the FAT stakeholders. This has three drawbacks. The first is that the inflexible design of the current database does not allow for smooth extension and evolution in order to perform further development and innovation. The second is that the tight coupling of the current database does not allow keeping pace with the changes required by the FAT stakeholders. Finally, the performance of the views is a key non-functional requirement not met by the current system that has enforced purging the relevant test data from the past.

The main focus of this project was to remove the drawbacks by providing a flexible data model design for the test execution data so that it can keep pace with the dynamic changes required of FAT system in order to meet the FAT stakeholders’ needs. The designed system has been split into three components: the flexible database design for the test execution data to allow smooth schema extension and evolution based on the changes required, the consumer application to facilitate the loose coupling of the test execution database, and the prototype portal application consisting of two data visualization charts that serves as a proof of concept for the designed system.

“We are now at a point where we feel confident to start migrating to the newly developed system and can plan extending it based on the guidelines Yogesh has provided us.”

Ing. J.A.P. Janssen
Océ Technologies B.V.
Challenges
One of the main project’s challenges was to find out ways of describing behaviour of interfaces and components, and possible usage of those descriptions within phases of the software design and development process. The solution space was narrowed by the actual state of the ASML software, which has been depicted by analyzing the software and by interviewing the software architects about current problems related with the concept of dynamic behavior of interfaces.

Results
The study, which has been conveyed in order to find out possible options for describing behavior and its practical usage, recommends using adapted UML state machine formalism and generating mocks for testing purposes respectively. Following these proposals, two Domain Specific Languages (DSLs), namely BDL and IDP, together with two test-double generators, and state machine execution environment were created. In order to show the applicability in the ASML software, this prototype was used in existing test cases of ASML TWINSCAN software within an ASML software testing environment.

Benefits
Behavior description of interfaces and components can be used for different purposes within different phases of the software design and development process. This powerful toolset can boost the software quality: it provides code generation for mocks, which means that the coding effort is reduced; it enables software validation, i.e., it facilitates discovering of incorrect usage of interfaces during earlier stages of the software design and development process, and reduces the overall costs in fixing software bugs. Moreover it improves the communication between engineers because behavioural aspects of the interfaces are described in a unified and unambiguous way.
ASML is a company that designs, develops and produces photolithography machines, called wafer scanners, used in the process of manufacturing chips and integrated circuits. ASML wafer scanner is a highly complex machine, both in hardware and software complexity. Its software, known as TWINSCAN software, controls the entire work of the wafer scanner i.e., it controls the electronic and mechanical parts of the machine. The high-level static architecture of the ultra-sized TWINSCAN software is described with a proprietary Architecture Description Language (ADL), used to describe the architecture of the software. Although this language is mature in describing the software structure i.e., static architecture, the dynamic aspects of the software cannot be expressed with this ADL. Namely, when we discuss the dynamic aspects of the architecture we mean the expected behavior of the interfaces and the components (e.g., expected order of events, data-dependencies between events), which constitutes the main focus of this project.

**DSLs for describing behavior and their practical usage**

A research has been conveyed in order to find out what are the suitable formalisms to describe behavior of interfaces and components, and to find out ways of practical usage of those descriptions during some phases of the software design and development process. Using adapted UML state machines and generating mocks intended for testing purposes, are chosen as solution directions.

We created Behavior Description Language (BDL), based on adapted UML state machine, which is used to describe dynamic behavior of interfaces. Although BDL references ASML Interface Description Language (AMSL IDL is a part of ASML ADL), IDL models stay intact and decoupled from the BDL models that are further used to generate Python server mocks applied within the testing process.

Regarding the testing process, a component to-be-tested usually requires multiple interfaces and there are dependencies between them. Thus, another language called IDP (Interfaces DePendency), also based on adapted UML state machines, was built: A Java-based generator takes IDP models as input, and generates a Python class that verifies the dependencies between the interfaces, and moreover it checks and enforces the described response order of the function calls during run-time.

— Niko Lazovski PDEng

*Component Interface Specification in Architecture Description Languages (ADLs) for Behavioral Validation*

Erik Holleboom,
ASML
Challenges
The main challenge was the design of a graphic specification tool that allows warehouse designers to develop WMCSs in a user-friendly and effective manner. The tool must be based on an existing reference architecture for decentralized WMCSs. It must capture the warehouse designers’ specification without exposing the implementation details of the reference architecture. Furthermore, it must support generation and execution of the specified WMCSs.

Results
The effort resulted in a prototype for the WST. The tool comprises a specification language that describes the system components, the interconnections, the component behaviors including a large variety of warehouse business rules, and the corresponding graphical editor. The WST allows warehouse designers to describe WMCSs without detailed knowledge of the underlying specification language and supports automatic generation and execution of the specified WMCSs. The tool also provides Gantt charts for visualization of the task execution.

Benefits
The WST provides warehouse designers a user-friendly way to describe WMCSs. The tool can drastically reduce the WMCS development effort, in particular the configuration of WMCSs. Moreover, the tool reduces the occurrence of manual errors during WMCS definition process by supporting automatic generation of the WMCSs. The design of the WST ensures that it is extensible for additional functionality.
Warehouse Management and Control Systems

The operations in a warehouse are controlled by a warehouse management and control system (WMCS). For a warehouse to achieve high performance, the responsible WMCS must make use of a warehouse’s limited resources in an efficient manner. These systems are inherently complex due to the size of modern warehouses and the fact that these systems are tailored to fulfill very specific needs of different warehouse customers. The specificity of the delivery requirements drastically reduces the potential of reusing the same warehouse management and control functionality for different warehouses. This implies that the WMCS design process is time consuming.

In order to reduce the WMCS development effort, there is a need to design a user-friendly method to describe WMCSs at the level that precisely captures the variation that is needed for constructing the customer systems. The solution must allow the description of a warehouse’s component structure, the relationships between the components, and component behaviors.

Model-Based Warehouse Design

This challenge was met by a prototype for the Warehouse Specification Tool (WST). The tool consists of a warehouse-control specification language which was defined according to the developed WMCS reference architecture that allows reusability of system components and component behaviors. It allows warehouse designers to describe the system components and the communication between them through the graphical editor. Configuration of WMCSs does not require detailed knowledge of the implementation of the underlying reference architecture nor the underlying specification language. The tool supports automatic configuration and generation of WMCSs from a warehouse designer’s specification. It also provides automatic execution of the specified WMCSs and a visualization of task execution.

In addition, the prototype WST demonstrated that model-based warehouse design can improve the efficiency of WMCS design process. It achieved the goal of providing the warehouse designers in Vanderlande Industries a user-friendly way to describe or configure WMCSs.
Challenges

Functional programming is very different from traditional imperative programming style. Workflow handling within the controller software of a printer system is very complex. The major challenge was understanding the functional programming concepts, and applying them to realize a stateless workflow handling. In addition, the focus was also to keep the performance high and memory consumption low.

Results

A part of the workflow handling functionality, which is based on a pipe-and-filter architecture pattern, was developed using F#. The prototype developed showed how it can be realized using functional programming concepts such that it is stateless. An insight into the performance and memory usage behaviour was also provided.

Benefits

**Performance:** Since the filters don’t contain state information, it would be possible to parallelize certain computationally expensive transformations more easily.

**No extensive locking:** Even in a multi-threaded environment, we don’t have the additional overhead of using locks.

**Testing:** The functionality of each filter can be tested standalone easily because the filters are stateless.

**Readability:** Due to the high-level constructs provided by functional languages, the filter functions are concise and more intuitive to read.
The workflow handling of a printer system is very complex and is currently designed and developed using object-oriented programming paradigm. A functional approach was not tried before at Océ to realize this part of the workflow handling. Some software designers at Océ had the idea of approaching workflow handling using the functional programming paradigm, which led to this feasibility study.

Why functional programming paradigm
One of the major bottlenecks in complex multi-threaded environments is state. In order to access state information such as a global variable, some form of synchronization mechanism such as locks should be used. If a synchronization mechanism is not used, then correct functioning of the software cannot be guaranteed. Locking is an expensive operation. In the functional programming paradigm there are no mutable variables and hence in theory multi-threaded applications can be developed using functional programming constructs without locking.

Stateless functional design and implementation
This feasibility analysis focused on investigating the possibility of eliminating state in a pipe-and-filter architecture pattern based software systems. Insight into the feasibility had to be provided by implementing several prototypes incrementally and analysing their performance and memory consumption behaviour. The prototype developed using the functional programming language F# showed that a stateless functional design and implementation of the workflow handling is feasible.
Challenges
To identify essential features of data processing pipelines that are required for simulation, realistic cases have been modeled. Identifying common factors of these systems and incorporating them into a design that uses clear-cut concepts to represent the domain well was an interesting challenge that required extensive cooperation with stakeholders. In order to be useful, the simulation should execute fast because it is used interactively. Besides taking care of simulator performance, managing complexity by using clear concepts in the design as well as the implementation played an important role to enable future maintenance and extensions.

Results
The created tooling enables data processing pipeline designers to identify likely performance bottlenecks in a proposed system design. The approach takes into account dynamic execution aspects such as resource usage and scheduling. Simulation results can be evaluated in detail using trace analysis tooling that is able to visualize task execution and the usage of individual resources.

Benefits
The created simulator supports data processing pipeline designers in identifying the impact of their design decisions by estimating the performance of proposed designs in early product design stages. Estimation takes into account concrete usage scenarios and dynamic behavior without depending on actual hardware. Simulation executes fast enough to interactively examine the impact of design changes interactively even for fairly large models. Because the model is used directly for analysis, changes to the model can be directly evaluated. This new approach improves on many traditional, spreadsheet-based throughput analysis methods that often require separate maintenance after model changes and do not take into account dynamic behavior such as resource interaction.
High performance printers are complex mechatronic systems capable of printing high-resolution images onto paper at very high speeds. An important part of the software and hardware design of printers is about preparing the data that is required for printing. Preparing this data consists of a series of computationally intensive image processing steps that operate on high-resolution images. Data Processing Systems such as the ones found in printers are often realized using hybrid software/hardware systems to provide sufficient performance. During development of such systems, many performance-affecting decisions can be made in the software as well as the hardware design. Estimating performance in a data processing system design and identifying likely bottlenecks without building prototypes is important, especially in early design stages.

**Data processing pipeline analysis**

Traditionally, models often only exist to provide a visual overview and analysis is done using spreadsheets that are maintained separately from the model. Calculations in the spreadsheets often assume a worst case scenario in which all components run simultaneously and ignore interaction with resources. This simple approach provides good results for some types of systems, but as data processing pipelines grow more complex, methods that take into account concrete usage scenarios and dynamic aspects such as interactions with resources become more important.

**Data processing pipeline simulation**

The analysis challenges were met by the creation of a simulator that is able to execute concrete usage scenarios and take into account interaction with resources. Using execution trace visualization tooling allows observation of behavior and performance of a proposed data processing pipeline design. The simulation is able to directly use design models and executes fast, allowing users to observe the impact of design changes interactively.
Challenges
The major challenges were learning to work with the complexity of the code-base comprising the ViewForum platform and the Flow4D application. The procedures and mathematics in published experimental studies of the cardiovascular system had to be translated to an automated implementation in the application. Maintaining good performance was an increasing challenge with more visualization and quantification features being added.

Results
The existing Flow4D application using only velocity data was enhanced with derived quantifications such as pressure, acceleration, vorticity and pulse-wave velocity among others. Display of visualizations showing blood-flow were overlaid with vessel anatomy rendering for more intuitive visuals. Particle trace animation was visualized in 3D and vessel longitudinal section (2D) visualization enhanced to match it with the cross-section visuals. Rendering performance was raised by integrating better rendering modules and some dependent graphics hardware upgrade.

Benefits
Clinicians can gain a better understanding of the blood-flow pattern by viewing its visualizations associated with the vessel anatomy overlay. The quantifications provide insight in the blood-flow dynamics; the tedious computations mainly done by experimental researchers have now been made accessible to a wider audience. Quantities such as pressure and pulse-wave velocity have been related to cardiovascular functioning by well-established results. The Flow4D application will help research and evaluation of useful functionalities through clinical use.
Cardiovascular diseases are the leading cause of mortality in the developed world. Their diagnosis, choice of treatment and monitoring during and after treatment, can be greatly aided by QFlow (Quantitative flow) imaging technology depicting blood flow in the vessels. QFlow MRI (Magnetic Resonance Imaging) represents such a technique that can be used coupled with scanning protocols that acquire data about entire 3D volumes rather than slices through the body. The data is acquired at different time instances spread across the cardiac-cycle. The vast amount of velocity data is hard to analyze by clinicians.

Clinical usefulness
Clinicians have been using a 2D analysis of QFlow MRI data, hence visualizations have been targeted to show slices through the volume acquisition, in order to maintain compatibility. Volume data has problems with occlusion of details, some visualizations, such as streamlines and particle animation, solve this problem and illustrate the flow-pattern through vessels over time. Typical cardiovascular diseases affect the pattern of blood-flow, such as, narrowing (stenosis) or widening (aneurysm) of the vessel, affects the velocity of blood flowing through the afflicted region. Researchers have been investigating the patterns and their correlation to such abnormalities. The goal of the Flow4D analysis tool is to facilitate this research in discovering clinical applications.

Flow4D analysis results
There are two key aspects to the analysis of blood-flow patterns: quantification of different parameters from the data and their visualization. Continued development on the Flow4D analysis application enriches it with 3D visualizations, such as particle traces and provides quantification of velocity-derived parameters such as pressure and pulse wave velocity. The Flow4D application can derive various measures from the velocity data, while allowing the user to interactively select the location of the analysis plane in the volume, based on vessel outlines. The vessel anatomy is also depicted overlaid with 3D visuals such as particle animation and streamlines, in order to provide the clinicians with all relevant details associated with each other. Multiple views linked to display the same analysis data, such as cross and long-section and volumetric visuals, allow fast exploration of the vast data set.

“The result is a mature prototype that can now both visualize and numerically characterize many aspects of blood flow. The next step is the clinical evaluation of this prototype.”

Prof.dr.ir. M. Breeuwer
Philips Healthcare
Challenges
The main challenge during this project was to enable modularization and reuse of modules in an existing DSL (Domain Specific Language) without changing that DSL, in order to have a backward compatible behavior of the models.

Results
Modularization concepts and reuse of modules are added to the DSL. Using the DSL, model fragments such as APA and AUR can be specified (see Figure 2). These model fragments are composed into a complete model, according to the composition model. The resulting model APA+AUR conforms to the DSL. This approach has been implemented in the development process of the wafer handler router and proofed to be compatible with the actual engine running on the ASML scanners.

Benefits
The introduction of modularization and model reuse reduces the maintenance effort and development time of new wafer handler’s routers. Instead of a single monolithic model of the router, we now have multiple models (fragments), which enable parallel development. The approach followed is generic enough to be used for the modularization of arbitrary DSLs.
Enabling Modularization for the ASML Wafer Handler Router DSL

ASML is the world’s leading provider of wafer scanners for the semiconductor industry. Such wafer scanners consist of, amongst others, a wafer handler which is responsible for moving wafers in the scanner. The hardware of the wafer handler is controlled by a software component called wafer handler router. This component is developed using Model Driven Engineering (MDE) principles and techniques. The component’s behavior is modeled using WR-DSL, a Domain Specific Language (DSL) developed by ASML, and its models are compiled to executable code.

Current situation: Monolithic models
The routing of the wafers is modeled using the WR-DSL language. These models are compiled to a GPL (General Purpose Language) in order to be executed on a scanner. Both the WR-DSL language and its modeling environment do not facilitate the reuse of (parts of) models, or a way to specify modules and interfaces between them. This led to monolithic models, one for each different scanner product, and to the duplication of the models.

New situation: Modular models
By means of the Reuseware framework, concepts of modularization and reuse are added to the WR-DSL language. For this purpose, 1) the WR-DSL language has been formalized in a Ecore model (Eclipse Modeling Framework (EMF)), and a concrete textual syntax has been defined; 2) modularization concepts, such as Module, Interface, Connection are defined and mapped to the WR-DSL; 3) the framework was extended with a Composition DSL called WRC-DSL in order to specify textual composition models; and 4) a Model-to-Text transformation (Acceleo) from WR-DSL to a GPL has been defined. The router of the wafer handler has been remodeled in terms of model fragments (modules), such as APA, ALR, WHRouterA (see Figure 1); and composition models, such as Sys1 and Sys2, have been developed. Using the previously described approach, code has been generated that was successfully tested on a wafer scanner.

"The project has delivered a method and tools which enable fragment models to be composed into a specific model. The resulting model has been transformed into code using current ASML tooling. The presented method enables software developers to apply the copy/share concepts on a smaller model granularity than today."

L. Raulea ASML
Challenges
The main challenge of this project was to align different (multidisciplinary) stakeholders with different backgrounds and ways of working. Furthermore, there was no established tool or methodology for system level timing specification and validation. Also, in such a setting requirements tend to be more volatile: as soon as a requirement was ‘captured’ it changed. This inherent nature of the project brought more flexibility in terms of design but also more difficulties in aligning and implementing a solution.

Results
A proof of concept for an integrated environment was built. This proof of concept contains a domain specific language with the necessary modeling concepts to specify and refine system behavior. In turn, this specification can be executed using a simulator and visualized using a Gantt chart. The proof of concept has not only been accepted by the various stakeholders but seemed to be re-useable for other departments within ASML as well.

Benefits
The proof of concept is the starting point for the creation of a unified environment that can be used to specify, execute, analyze, and validate (timed) sequences of lithography systems. In addition, the cases performed to validate the environment already showed (i) a reduction of the gap between system and software design, (ii) increased detection of software implementation gaps, and (iii) disambiguation of the communication between system engineers and software architects and designers.
ASML provides semiconductor manufacturers with advanced lithography systems. The main business differentiating aspects of ASML lithography systems are their ability to print layers of small patterns with the smallest possible ‘Critical Dimension’ (line width), at high speed (productivity), exactly on top of each other (overlay accuracy).

Problem statement
For productivity, system engineers focus on the number of good wafers per hour that a machine can produce (throughput). They specify the machine’s behavior at system level using timed sequences in the form of Gantt charts. Currently, there is no established design (modeling) environment to construct these charts and analyzing the throughput is difficult, especially when considering different scenarios and machine configurations. It is also hard to maintain these charts and adapt them. Currently, system design specifications are not written in a processable and reusable manner resulting in a gap (i) between the system and software design, and (ii) between specification and implementation which is typically detected after implementation (during integration).

Solution direction
In order to specify, execute, visualize, and analyze timing sequences a model-driven environment has been designed and implemented. The environment contains a modeling language to create the sequence specifications, which in turn can be executed and visualized. In this way, the sequences are specified in a processable and unambiguous way.

With this environment, system engineers can define more optimal throughput sequences and make all the requirements and dependencies more explicit. Then, the system level specifications can be refined and reused in the same environment by e.g. software designers who can immediately validate their designs against system design specifications. This process helps to detect problems during the system design rather than implementation, which should facilitate the reduction of development lead-time and testing costs by early integration.
Challenges
The project required quite some knowledge about the medical domain. It was a challenge to get familiar with endovascular surgery procedures, workflows, X-ray and CT systems and the data these systems produce. However, the biggest challenge during the project was to work with the viewing architecture that is used as basis for new multimodality imaging applications. This toolkit is in an early development stage, which means that certain parts of the architecture are still missing and several parts were constantly changing. A close collaboration with the developers of the toolkit provided the opportunity to work on the development of a new Vessel Navigator prototype and, at the same time, help to improve the toolkit.

Results
In this project a new, fast, and intuitive manner of defining a vessel network was developed. A framework was set up in such a way that existing algorithms for automatically finding the vessel-center and -wall could be easily integrated. The framework also provides the tools to easily interact with the vessel network and improve results. Elements of the network can simply be dragged and dropped and undo and redo functionality provides the user with the option to explore possibilities without losing previous results.

Benefits
Clinicians using Vessel Navigator can reduce radiation exposure time and minimize the use of contrast agent. This can lower the risk of post-operative complications significantly. Furthermore, the preparation steps of Vessel Navigator result in less surgery time, which saves money for the hospitals. With the contribution of this project, endovascular clinicians can do the vessel segmentation much faster, with more convenient user interaction, and without having to know the exact behavior of complex segmentation algorithms.
Vessel Navigator is a multimodality imaging application of Philips Healthcare. It combines information from 3D-data, such as a CT-scan, with a live X-ray image stream to allow the clinicians to orientate and navigate easier and faster during endovascular procedures. One frequently occurring procedure is endovascular aortic repair (EVAR), which is a minimally invasive operation to prevent further expansion and rupture of an abdominal aortic aneurysm (AAA). During the treatment, a graft stent is placed inside the aorta such that it covers the dilated aortic wall. Live X-ray is used to navigate the catheters and guidewires inside the vessels. The vessels themselves, however, are often only temporary visible on the X-ray due to the use of a contrast agent. Vessel Navigator provides an overlay with the vessel structure from the 3D-data such that, amongst other advantages, the contrast agent dose can be minimized.

To attain an accurate overlay, Vessel Navigator guides the clinicians through four tasks. In the first task the vessel structure is extracted from the 3D data. This is called segmentation. Next, the user can select favorable view angles and application settings for during the procedure. In the third task the segmented vessel structure needs to be mapped with some X-ray images from patient. This registration is necessary to calculate the right position and rotation of the overlay. Finally, in the live task the clinicians can do the actual procedure and use live X-ray, taken from any view angle, with a matching overlay.

The goal of the project was to improve the segmentation and to make the possible interaction in this task more user-friendly. The voxel based segmentation algorithms are replaced by algorithms that provide paths through and rings around vessels. These paths and rings are stored in a vessel network, which accurately describes the segmented vessel structure. This vessel network allows the user to edit the results in an easier and more efficient way than the results of voxel based algorithms.
Challenges
Specifying the needs of the future products was a real challenge. Besides, getting the exact performance values of the platforms was also challenging. Quite a considerable amount of time was needed to gather a useful set of information.

Results
The current and near future PLC solutions are introduced to Philips Lighting. Detailed benchmarks are conducted on the development kit of the selected vendor. These results would guide Philips Lighting to switch to this vendor or not. Additionally, the proof-of-concept design would ease the start-up of the next phase.

Benefits
Up-to-date knowledge on PLC modem solutions is gained. This knowledge will help the Philips Lighting system architects on deciding the target hardware platform of the future products.
The Power-line-communication (PLC) technology became cheaper and more reliable with advanced hardware components with reasonable prices. Today, the smart-grid devices, home automation, security and lighting products also benefit from the PLC technology.

Philips Lighting also makes use of the PLC technology. However, there has been a dependency to a single PLC modem supplier. This became a cost disadvantage in time, due to lack of competition. The project presented the performance and the capacity of the available PLC modems and also the comparison of available PLC standards.

The feasibility analysis showed that a software based PLC modem solution is possible, where general purpose processing units are used. Due to software dependency general purpose processing units can be used instead of system-on-chip platforms. The software takes over the hardware components' tasks, so the number of hardware components is reduced.

The strongest target hardware candidate is chosen for further benchmarking. The benchmarking results proved that the illuminator control software and the communication can share the resources of a single processing unit. This would result in a gain in the bill-of-materials.

As a result of having software based solutions, each vendor may introduce different APIs, even for the same PLC standards. In order to introduce flexibility in vendor selection a software framework is designed and implemented. This framework removes the dependency with the proper selection of the interfaces.
Challenges
The main challenge of this project was the identification and specification of good non-nominal scenarios from which maximum test coverage could be achieved. Furthermore, design constraints such as mappability to model checking tools and overall architectural genericity proved to be important decision points in choosing a suitable design for the error injections and persistence.

Results
The wafer-flow simulator has been extended with error injection and persistence. With these extensions, non-nominal scenarios can be specified and executed in the test environment. Moreover, realistic simulations are promoted with the implementation of persistence. A qualification test-suite has also been developed to test the simulator’s language and code generators.

Benefits
The extension of the wafer-flow simulator with error injection promotes reliability and robustness of the software by improving its test coverage. Non-nominal situations that are hard or hazardous to test on real machines can be tested on the simulator. The persistence feature helps test and system engineers in two ways: One, it enables the wafer-flow simulator to be loaded from a previously saved state and two, it enables the simulator to recreate a scenario that occurred with the machine in the field. Together, these features promote early integration testing of the software, greater test coverage, and testability of the software when the hardware is unavailable or at damage risk.
ASML’s lithography machines are driven by complex control software. This control software is tested in environments ranging from the real machine to software simulators. The wafer-flow simulator is a software simulator in which the various actuators and sensors of the real lithography machines are replaced by simulations that realize interactions between various hardware components. Using Model Driven Engineering (MDE) techniques, the simulator code of the wafer-flow is generated from models of the hardware that are specified in a Domain Specific Language (DSL).

The wafer-flow simulator primarily simulates nominal behavior of the lithography machine components. In order to ensure the reliability of the control software, it is important to improve its test coverage by testing its behavior in not only nominal conditions but also in non-nominal conditions. For example, a wafer may be displaced on a hardware component. Another important simulation scenario to address is that the real machine preserves its physical state between system stops and starts unless altered by a manual operator. In order to promote realistic simulations, it is important to maintain the state of the simulator between restarts. Finally, since the DSL used to generate the simulator code is evolving due to the addition of new simulated hardware components and fault situations, it is important to ensure that existing users are not adversely affected by its continuous improvements.

In order to fulfill the aforementioned requirements, the wafer-flow simulator is extended with the following:

*Simulated Error Injections:* Error Injection is the run-time introduction of a fault situation in the wafer-flow simulator. Error injectors are deployed to test the software in non-nominal situations. The fault scenarios are specified dynamically using a configuration file or an API.

*Persistence and Snapshots:* A persistence module may be used to save state information of the simulator so that it can be loaded at the next restart thereby enabling persistence in the simulator.

*Qualification of language and generated code:* A test framework will enable both language creators and software developers to qualify the language as it evolves and also test the resulting generated simulation source code for correctness and regression impact.
Challenges
Getting deep understanding of the three existing systems is one challenge. However, the biggest challenge is to maintain the user friendliness of the home lighting system when extending it with professional sensors and at the same time providing powerful and flexible automated control solution based on resource constraint devices.

Results
A prototype was implemented to link professional sensors to the home lighting system in a user-friendly way. A flexible automated control mechanism was designed and implemented on the existing bridge platform. The API that allows developing lighting control applications in the IP domain and the built-in web application were extended for users to configure the system easily.

Benefits
The developed prototype was based on the existing low-cost hardware platforms and was easy to use. It provided valuable insight into setting up, configuring and designing an automated lighting system. It also enabled explorations on emerging challenges of smart homes such as a self-configuration system.
Home automation solutions have been a hot topic for technology enthusiasts for decades. As technology progresses, cheaper and faster microcontrollers are embedded everywhere in home appliances. This makes home automation more appealing and affordable to people without technical background.

**Automated lighting in the consumer domain**

Philips Lighting has launched ranges of Zigbee-based wireless lighting control products such as the LivingAmbiance and the OccuSwitch Wireless in the consumer and professional domain, respectively. Meanwhile, a low-cost IP-to-Zigbee bridge was investigated to enable devices with web capabilities to control LivingAmbiance products. The bridge not only gives a centralized control gateway for a home Zigbee network, but also enables new applications to manage more complicated interactions with consumers. Therefore, everything is in place to offer a mass market home automation solution by the natural extension of the LivingAmbiance ecosystem with the bridge and sensing elements.

Bringing the professional sensor to the consumer domain is challenging as it requires a deep understanding of three different systems. The link between lighting and sensors is well known in offices but how to make something meaningful for homes is challenging, especially how to make a system which users can easily set up and configure. Moreover, realizing powerful and flexible control mechanisms for automated lighting system based on resource-constraint devices is another major challenge.

**Easily configurable low-cost control system**

When linking the sensor to the home Zigbee network, the same setup approach as the existing home system was adopted in order to keep the user’s mental model consistent and maintain interoperability among devices. The bridge prototype was studied and extended with a flexible and powerful mechanism to support automated lighting based on a multitude of control input and configurations. To keep the system easy to use, the bridge’s external interfaces and embedded web application were extended for monitoring and configuration purposes as well. The resulted system was verified through various use cases, including the setup flow. The system’s response time, resource usage and the sensor’s battery life were also evaluated.

This project proved the feasibility of extending the home lighting system with sensors while still maintaining its user friendliness. The result showed the bridge has the potential to be a centralized home automation gateway based on low-cost hardware platforms.
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