Deliverable 3.1

Case Study Implementation Strategy

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[1] **R**=Report, **DEC**= Websites, patents filling, etc., **O**=Other

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Table of Contents

Executive Summary

1 Introduction

This document explains the goals for the work to be conducted under WP3 (Case Studies) for Road2CPS and provides plans for executing the work.

Under WP3, Road2CPS will produce a set of case studies. These will be aimed at practitioners who are not familiar with CPS technologies and "CPS thinking". The collection of case studies can be used as a tool to help practitioners answer the following questions:

1) What is a CPS?
2) Why should I be interested in applying CPS thinking to my own work?
3) How do I apply lessons from other case studies?

The rest of this document is structured as follows. Section introduces the case studies work, including aims and minimum criteria for case study selection. Section 3 presents one example case study, which is used as a pilot to demonstrate the proposed presentation format. Section 4 presents some brief conclusions.

2 Introduction to Case Studies

2.1 Background and added value of the document

This document outlines the strategy for collecting and documenting a set of case studies for WP3. The collected case studies will become a useful tool, targeted at CPS practitioners and stakeholders who do not already have high awareness of CPS challenges or potential solutions. Together the case studies will be used to introduce CPSs and explain the value of addressing these challenges using available tools and techniques.

2.2 Target audience for case studies

The planned target audience for the case study deliverables will be existing practitioners. These could be industrial players (particularly SMEs, but also larger businesses) or they could be public sector operators with responsibility for delivering value-for-money services, such as civil infrastructure and smart cities. The target audience will be those who are not already very familiar with CPSs, or perhaps familiar with the term but unaware of the business case for engaging with "CPS thinking" in their own work. The collected case studies will serve to inform this audience about CPSs.

2.3 Goals of the case study deliverables

The goal of WP3 is to deliver a set of case studies that will illustrate, in an accessible way, a fairly simple message:

1) What is a CPS?
2) Why should I be interested cyber-physical systems?
3) How do I apply lessons from other case studies?

The aim of the deliverable is to ensure that businesses and similar stakeholders begin to self-identify as CPS practitioners, that they are aware of some of the challenges in the field and how various domains have begun to tackle those challenges, and what lessons (e.g. recommendations, tools and techniques) are currently available.

2.4 Planned structure for case studies deliverables

Case studies will be presented in one document that fuses together two deliverables, D3.2 and D3.3. These two deliverables will be merged, with D3.3 forming a separate chapter appended to D3.2.

The planned structure of the document is as follows:

A. Introductory material

B. What is a CPS? In this section we will provide one or two case studies which are designed to illustrate what a CPS is and why it differs from other existing fields (such as embedded systems)

C. Why should you be interested in cyber-physical systems? In this section we will provide 6-8 case studies that will illustrate various aspects of CPS design. Each case study will provide one illustrative challenge or problem, showing how this challenge presents a problem or an obstacle, and, in some cases, explain how it was tackled and perhaps solved (or partially solved). As far as possible, each case study will present the business benefits achieved. Examples of challenges could include (illustrative examples only):

   - Dealing with big data
   - Modelling techniques to reduce time to market
   - Working with autonomous and independent partners
   - Internet of things platforms

D. How to identify opportunities to apply CPS technologies in your own work. In this section we will summarise the lessons learned in Part 2, and in addition provide 1-2 case studies that illustrate how these lessons could be applied to some newly-emerging domains.

Sections A-C of the document will provide content for Deliverable D3.2. Section D will present some suggestions for “How to identify opportunities in your business”. This content replaces D3.3.

2.5 Proposed selection criteria for case studies

Case studies will be contributed from all partners, and our goal is to ensure that they represent a wide spectrum of application domains. Here are some minimal selection criteria that will be used:

- Case studies should have, as far as possible, a commercial context, e.g., case studies from businesses or from a public sector interested in value-for-money. A small number of case studies may be from non-commercial contexts
- For case studies in Section C, we should be able to identify a technical or business challenge within the case study. Challenges do not need to have been solved yet – we can present some open challenges
- For case studies in Section C, we should be able to identify some “lessons learned” or unsolved challenges
- Some case studies may be employing EU-funded ICT CPS engineering platforms, but this is not mandatory

Case studies will also intentionally consider a wide range of aspects of CPS case studies, including technical challenges and business cases. This can include technical aspects and challenges as well as consideration of market challenges and business cases for identifying products as CPSs.

We consider that 800-1200 words is the appropriate length for a case study; this is sufficient to provide a brief description of a domain and any challenges being tackled, but is short enough that it is appealing to read.

2.6 Proposed timetable for case study collection

Each Road2CPS partner will be supplying at least one case study. The following dates indicate planned deadlines for completion of major milestones for WP3.

- April 2016. Identify case studies and allocate to the appropriate Sections.
- August 2016. Partners write case studies and submit to UNEW for integration.
- September 2016. UNEW integrate and produce deliverable.
- October 2016. Internal review.
- November 2016. Submit deliverable.

2.7 Minimum data to be collected

The minimum information for each case study will be:

- Case study title
- Brief summary
- Case study supplier
- Domain
- Case study scope
- CPS aspects of the case study
- Case study challenge
- Tools/platforms/methods employed (only for case studies in Section C)
- Outcomes of the case study (only for case studies in Section C)
- Key Lessons (only for case studies in Section C)
- Further information

Section 3 of this document provides a pilot case study, which is collected and presented via a template. The template is designed to collect the minimum data.

3 Pilot Case Study

In this section we present an example of a case study. The purpose of this pilot case study is to develop and test the planned minimum data to be collected about each case study (explained in Section 2.7). Each case study collected under WP3 will follow a similar format, demonstrated with an example case study presented below. This case study is considered suitable for inclusion in Section C of the proposed Deliverable D3.2.

Collaborative Design for a Complex Embedded System

Case study source

This case study is a summary of a previously published report. It is taken from [1].

Brief summary

Neopost is a company based in Drachten, the Netherlands, and is one of the world's leading manufacturers of small-to-middle-range equipment for mail handling. This includes equipment for flexible packing of documents and automated processing of high volume mail. Neopost's products therefore involve software and highly precise hardware components. The company wished to improve the quality and speed of their design process, and so they investigated a technique for collaborative modelling ("co-modelling") that permits engineers working on hardware design, and software engineers working on design of the control logic, to collaborate early in the design process. Although the case study illustrates aspects of embedded systems design, similar principles can be applied to CPS design.

Company

Neopost manufactures equipment for mail handling and employs around 75 R&D engineers. Engineers are roughly 50% software engineers by training, and 50% mechanical engineers by training.

Domain

Neopost products include equipment for flexible packing of documents and automated processing of high volume mail. These involve embedded systems, incorporating both highly precise hardware for picking up and manipulating paper items at high speed as well as software control logic.

Case study scope

The case study presented here focusses on the model-based design of a system that can fold sheets of paper, arrange them in the correct sequence and insert them into an envelope. The system has a number of bins containing sheets of paper (e.g., separate printed pages for a multi-page document) and also a bin to hold empty envelopes. The system is configurable, picking up separate documents from the bins in a given order, folding them in correct sequence, inserting them into waiting envelopes, sealing the envelopes and depositing them into an output bin, at speed.

CPS aspects of the case study

The case study focusses on embedded systems, incorporating sensors and actuators that will interact with the environment, and software to provide control logic. Like embedded systems, CPSs involve elements to interact with the real world as well as complex software. A key challenge for CPS engineers can be found in the question of how to tackle design teams working in different disciplines, with incompatible design tools. Allowing them to share design ideas and assumptions at an early stage in the design process can be beneficial.

Case study challenge

Neopost wished to study causes of paper misalignment. Paper misalignments can lead to collisions between documents and/or envelopes, creating paper jams and resulting in a less productive system. Neopost wished to develop an understanding of how the different causes of misalignment contribute to a collision. This would allow available design effort to be allocated to appropriate improvement activities.

Tools/platforms employed

Co-modelling ("collaborative modelling") techniques can be used to facilitate multi-disciplinary design teams. Neopost chose to evaluate the use of a co-modelling tool called Crescendo [1]. Crescendo is a "co-simulation engine", developed by the EU-funded FP7 project DESTECS for the collaborative development of embedded systems.

Modelling is much faster and cheaper than building and testing physical prototypes, allowing for a larger number of proposed designs to be trialled and a better-quality system to be built. As a result, modelling is a key part of modern engineering design. A fairly common scenario sees the hardware aspects of a system modelled and designed separately from the control software. This is partly because of the separate development of engineering and computer science disciplines; each has developed its own tools, terminology and design techniques, which are sometimes incompatible. For example, engineers working on a hardware-oriented system typically model the finished system using continuous-time mathematics to describe and analyse the system and its environment, whilst software engineers model software systems using notations based on discrete mathematics. Models created using these different types of notation are difficult to integrate. In particular, software modelling techniques offer notably poor support for capturing and reasoning about "real-time" requirements and behaviours. Real-time systems are systems where the correct functioning of the system is at least partially dependent on meeting some time-driven deadline, and it is commonly required for accurate modelling of aspects of hardware. This incompatibility between continuous-time (CT) and discrete-event (DE) modelling approaches tends to enforce a separation between design teams, leading to a high risk of misunderstandings and inappropriate assumptions. These types of problems will probably not be uncovered until the two components are brought together at a late stage in the design process.

Crescendo tackles this problem by supporting collaborative design. Each design team – the CT designers responsible for designing hardware, and the DE designers responsible for designing software – can develop a model using a notation which is natural to them. Then the two models can be executed in a joint, collaborative simulation using Crescendo as the "engine". Neopost developed co-models using Crescendo to study the problem of misalignment of paper as it is manipulated by the paper-folding and envelope-stuffing system.

Outcomes of the case study

Neopost's modelling activities are not available due to confidentiality reasons. Fortunately, the modelling activities for Neopost's system have some similarity to a public example, the paper path control for a digital printer that has been studied in the BODERC project [2].

Co-simulations conducted for this BODERC system exposed some misunderstandings between the separate design teams. In one example, each team assumed different approaches for measurement. In another example, CT designers assumed that the time allocated for aligning a sheet of paper includes the time needed for deceleration of the sheet of paper but DE designers interpreted the requirement differently and did not include this time. These types of misunderstanding are relatively easy to uncover during the co-simulation phase using Crescendo; it would be much more time-consuming to identify such a problem had it not been uncovered until the first prototype.

Neopost's case study confirms these findings from the BODERC study as representative examples of design misunderstandings, as explained in [1]. Neopost themselves identified and solved several flaws in the design due to co-modelling work, before the physical prototypes were built. This saved much development effort and cost. In fact, Neopost engineers estimated that significant effort was saved due to the early ability to analyse the complete system.

Key Lessons

Techniques allowing engineers and software designers to collaborate early in the design process can reduce the development effort, particularly in the design of complex interactions between hardware and control logic.

Further information about the case study

More information about Crescendo and this case study is available from [1].

References

[1] Fitzgerald, J., Larsen, P.G., Verhoef, M. (2014). Collaborative Design for Embedded Systems: Co-modelling and co-simulation. Springer-Verlag, Berlin.

[2] Verhoef, M. (2009). Modelling and validating distributed embedded real-time control systems. PhD thesis, Radboud University Nijmegen.

4 Conclusion

This deliverable presents a plan for collecting together a series of case studies, including one example case study. In Deliverable D3.2 a collection of case studies gathered from all Road2CPS partners will be presented. Case studies can cover a variety of topics, including technical subjects, market needs economic aspects. The finished collection will become a useful tool for educating practitioners who do not currently self-identify as CPS engineers about the tools and techniques that are available to help them.