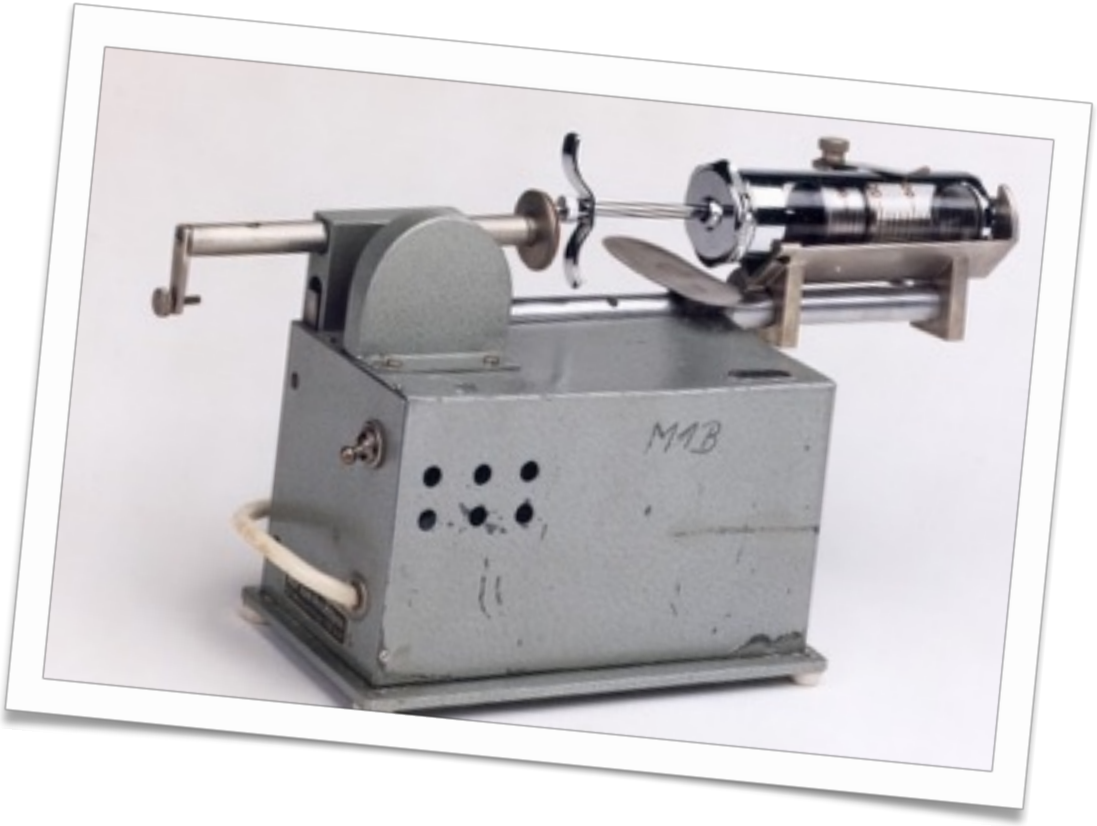
Efficient Modelling and Analysis of User Interfaces in High-Assurance Systems



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Overview of Agenda

Introduction

- Introduction.
- Focus of the research.
- Definitions.
- Motivation.

Context

- Approaches to formal modelling and analysis of human machine interaction.
  - Analysis of usability and safety properties of user interface design.
  - Analysis of user interface design against task models.
  - Analysis of user interface design against human behaviour.

Research

- Objective.
- Tools to support the research.
  - PVSio-web.
  - CIRCUS.
- Ongoing work.
- Future work.

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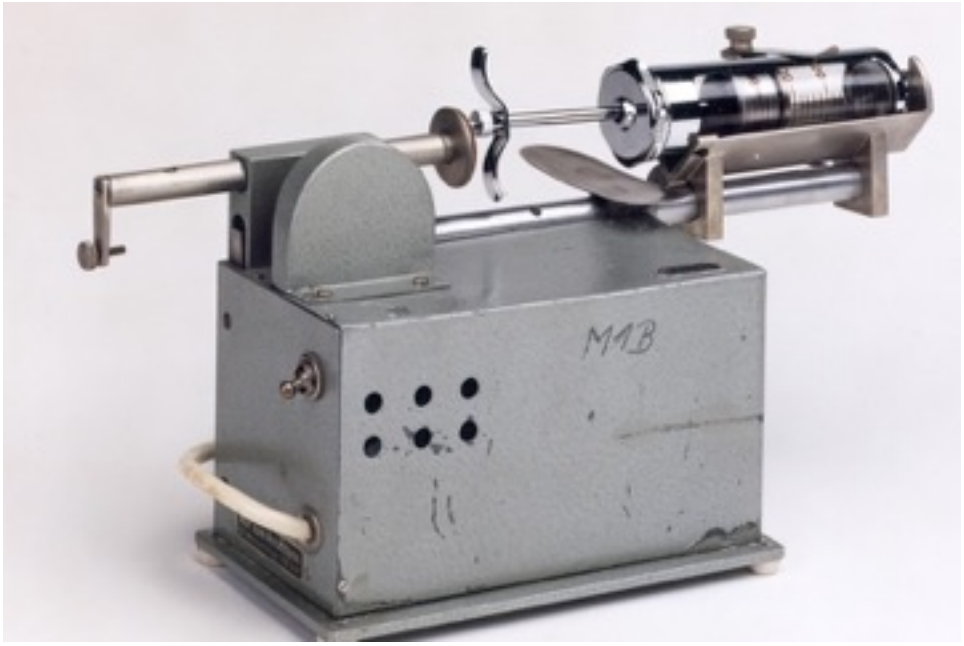
Introduction

- Early user interface in injection pump



Mechanical injection pump (1951).

Focus of the research

Formal Modelling and Analysis of Human-Machine Systems

Infusion Pump.

Airplane cockpit

Definitions

Interactive human-machine systems

Represent systems that interact with humans.

Interactive system model

Defines how the system responds to user actions.

Motivation

Unpredicted situations can happen due to problems in user interfaces

- Mode confusion;
- Lack of visibility of system state;
- Lack of consistency of controls;
- …

Motivation

Aircraft ran out of fuel (1985)

- Mode confusion when refuelling the aircraft[1]

Boeing 767-233 after forced landing.

[1]Lockwood. *Investigating the Circumstances of an Accident Involving the Air Canada Boeing 767 Aircraft*. 1985.

Motivation

Overdose of radiation accidentally given to patients (1985)

- High energy dosage given due to user Interface bug[1]

Therac 25.

[1]Leveson and Clark. "An investigation of the Therac-25 accidents." *Computer* 26, no. 7 (1993): 18-41.

Motivation

Superheating misdiagnosed (1979)

– Design flaw in the control room[1]

Three Mile Island control room.

[1]United States. President's Commission on the Accident at Three Mile Island. *The need for change, the legacy of TMI: report of the President's Commission on the Accident at Three Mile Island*. The Commission, 1979.

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Approaches to formal modelling and analysis of human machine interaction

1) Analysis of usability and safety properties.

2) Analysis against task models.

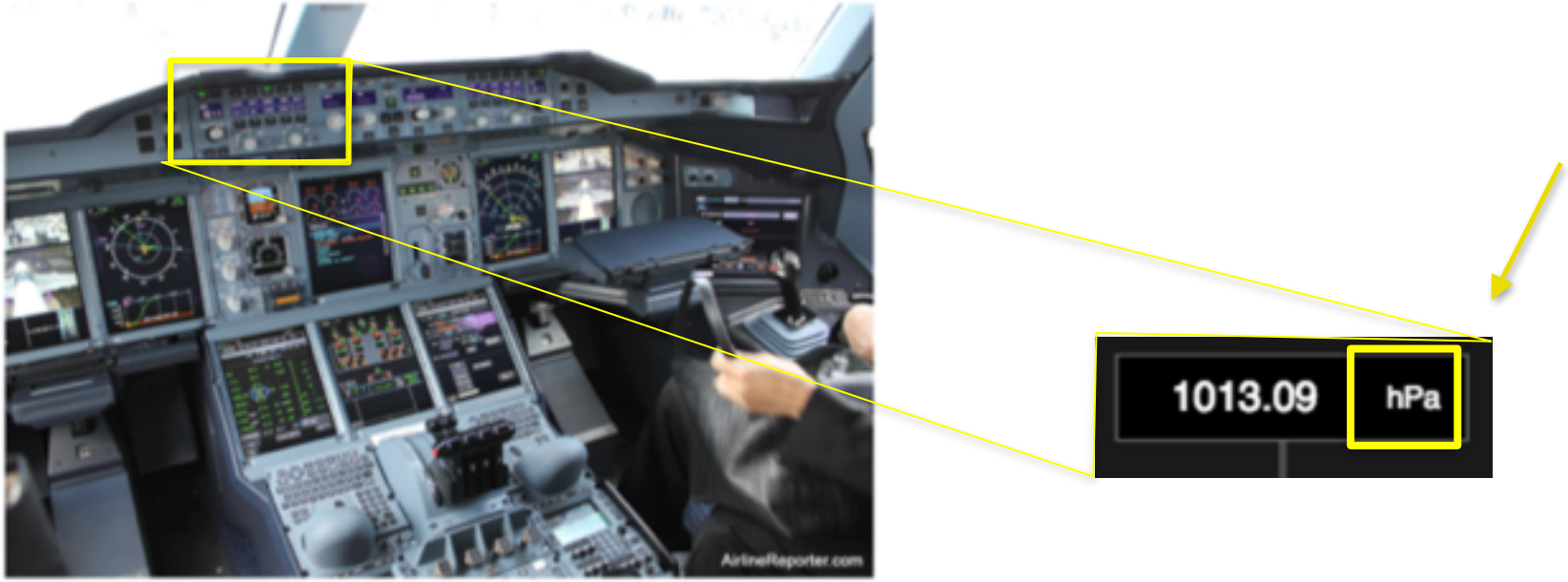
3) Analysis against cognitive models.

1) Analysis of usability and safety properties

Example: Visibility of operational modes of an infusion pump.

1) Analysis of usability and safety properties

Ex.: visibility of data-entry mode in the Flight Control Unit (FCU).

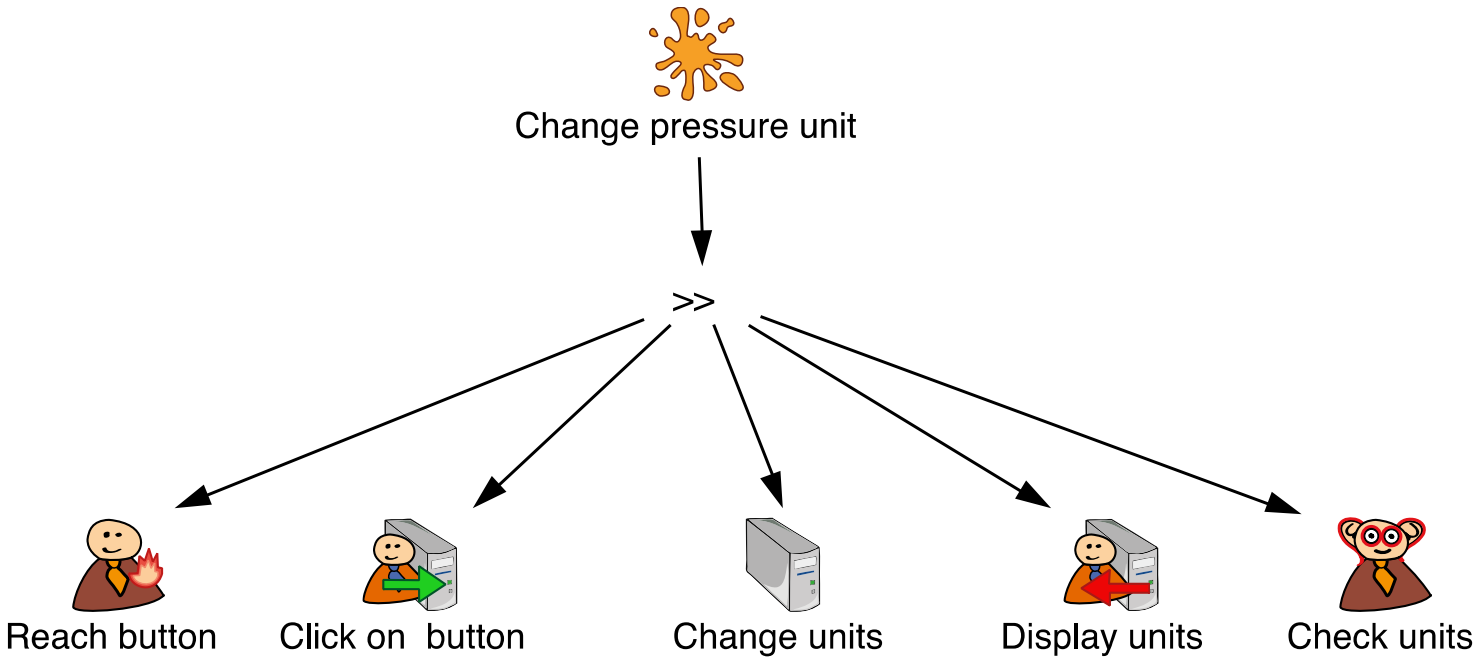


1) Analysis of usability and safety properties

Challenges:

- the scalability of the analysis;
- the relevance of counter-examples produced by the analysis.

2) Analysis against task models.

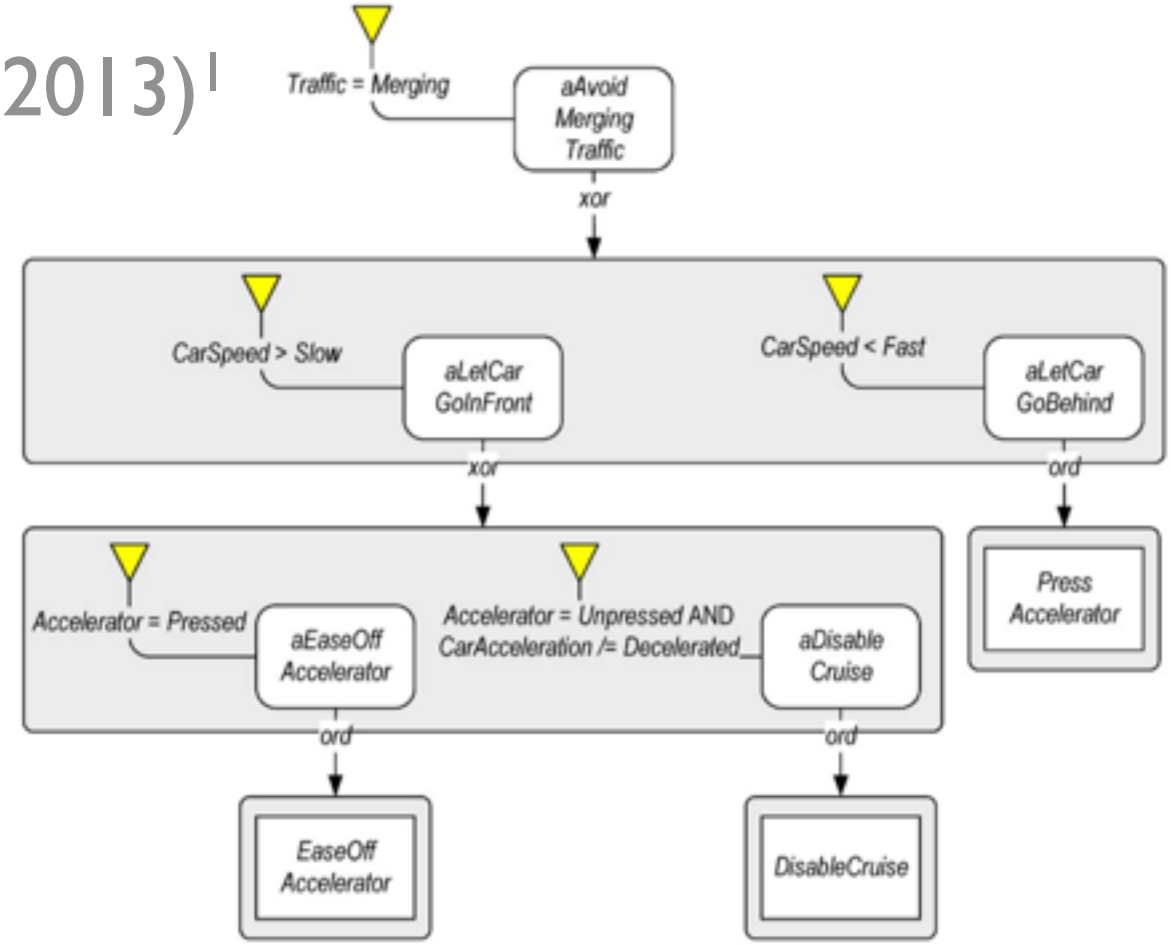


2) Analysis against task models.

- Ex.: approaches based on
  - Verification of system models and the task model
  - Co-execution, simulation and test and the task model

Analysis: Verification

- Bolton et al (2013)[1]



EOFM task model.

[1]Bolton, M. L. (2013). Automatic validation and failure diagnosis of human-device interfaces using task analytic models and model checking. *Computational and Mathematical Organization Theory*, *19*(3), 288-312.

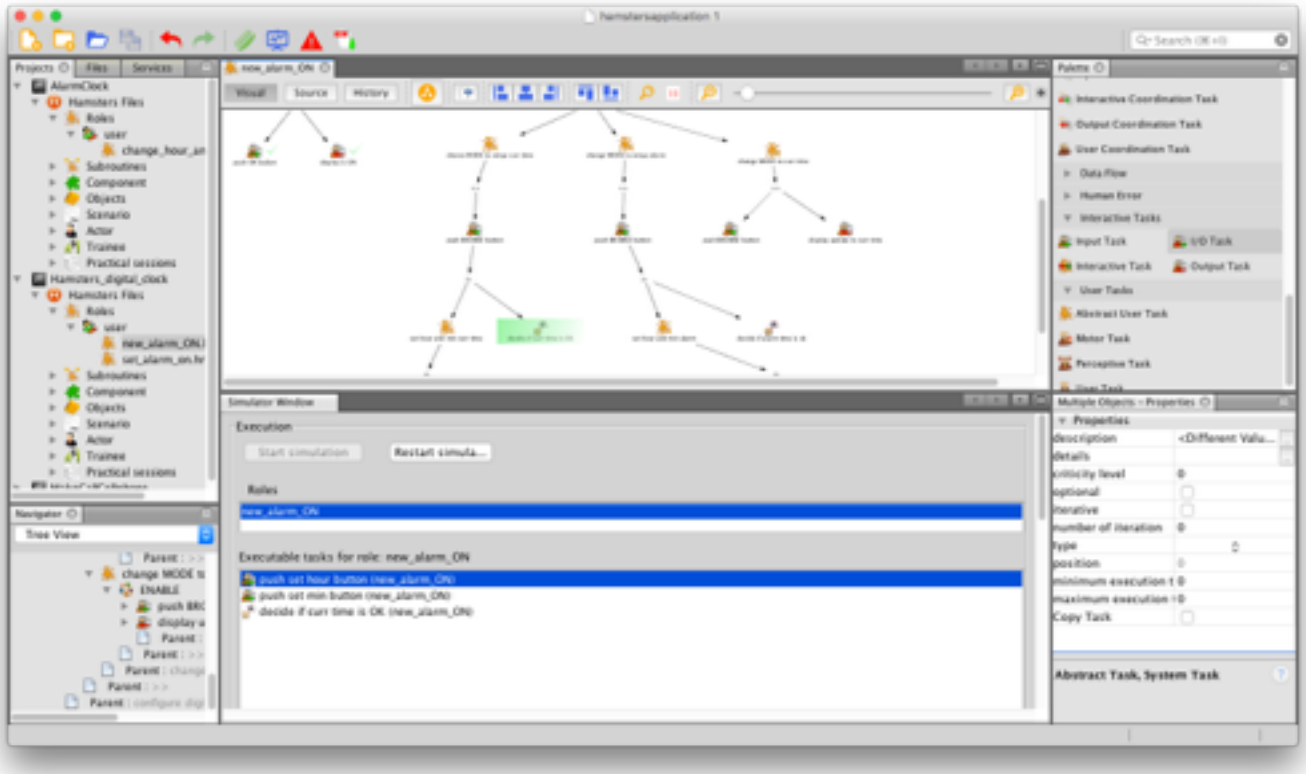
Analysis: Verification

- Campos (2003)[1]
  - Task model and system model: described as interactors
    - Expressed in Modal Action Logic (MAL)
  - Analysis: using IVY tool
    - Automatic translation of the interactors models in NuSMV models and properties.

[1]Campos, J. C. (2003, June). Using task knowledge to guide interactor specifications analysis. In *International Workshop on Design, Specification, and Verification of Interactive Systems*.

Analysis: Simulation/Co-execution

- Palanque et al (2010)[1]



CIRCUS component for Task Models.

[1]Barboni, E., Ladry, J. F., Navarre, D., Palanque, P., & Winckler, M. (2010, June). Beyond modelling: an integrated environment supporting co-execution of tasks and systems models. ACM.

2) Analysis against task models.

Challenges:

- how to analyse systematically non-normative behaviours?
- how to take into account strategies to optimise task operations?
- Simulation and test are not as exhaustive as verification!

3) Analysis against cognitive models.

3) Analysis against cognitive models.

Example:

Rushby (2002)[1] work on mental models for tackling automation surprises

[1]Rushby, J. (2002). Using model checking to help discover mode confusions and other automation surprises. *Reliability Engineering & System Safety*, *75*(2), 167-177.

3) Analysis against cognitive models.

Challenges:

how to validate the cognitive assumptions incorporated in the user model.

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Objective of this research

Explore how to combine two analysis methods:

- verification of usability and safety properties;
- verification against task models.

Expected outcome:

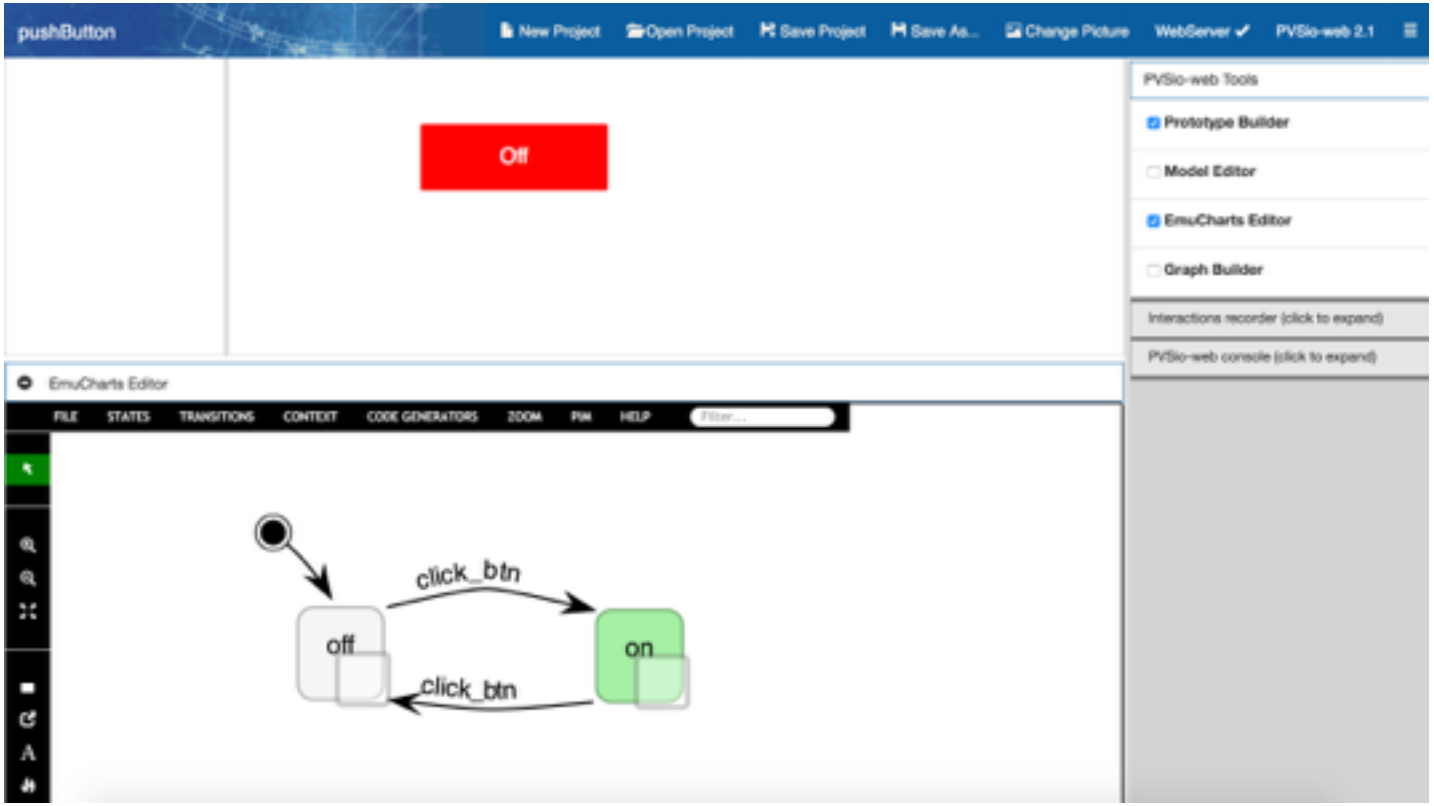
- Set of design patterns presenting efficient solutions to combine these two approaches.

Tools for analysis of system and task models

- PVSio-web
- CIRCUS

PVSio-web

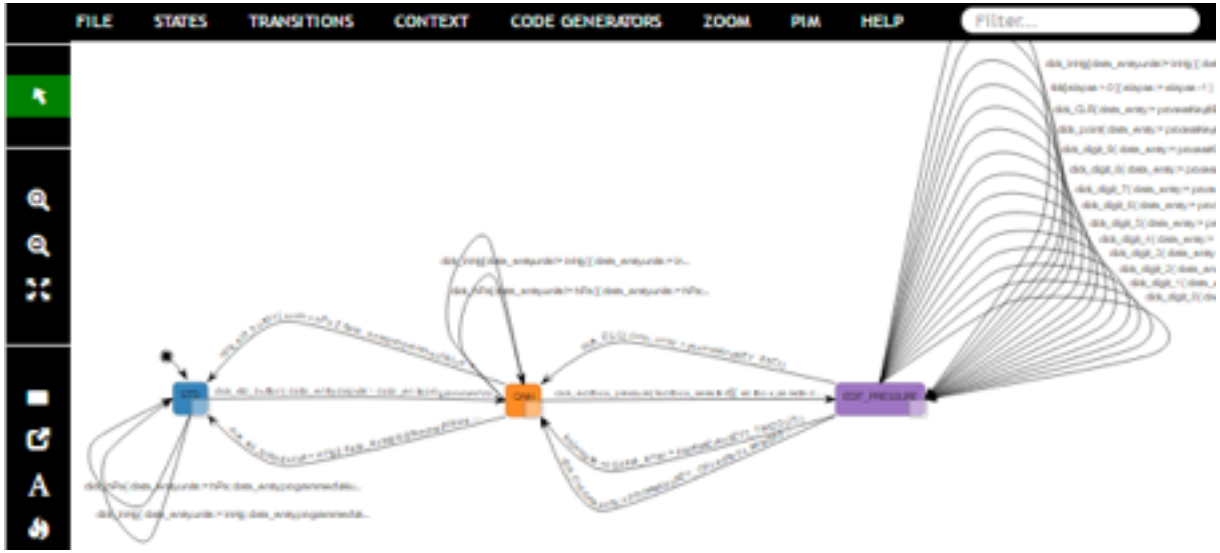
- Ex.: modelling a push button



PVSio-web modules: visual appearance and behaviour of prototype

PVSio-web

- Description of the system model in emucharts (FCU Software)[1]



Emucharts editor describing system's states and transitions

[1]Fayollas et al. Evaluation of formal IDEs for human-machine interface design and analysis: the case of CIRCUS and PVSio-web. Submitted to F-IDE 2016 / 21st International Symposium on Formal Methods (FM2016).

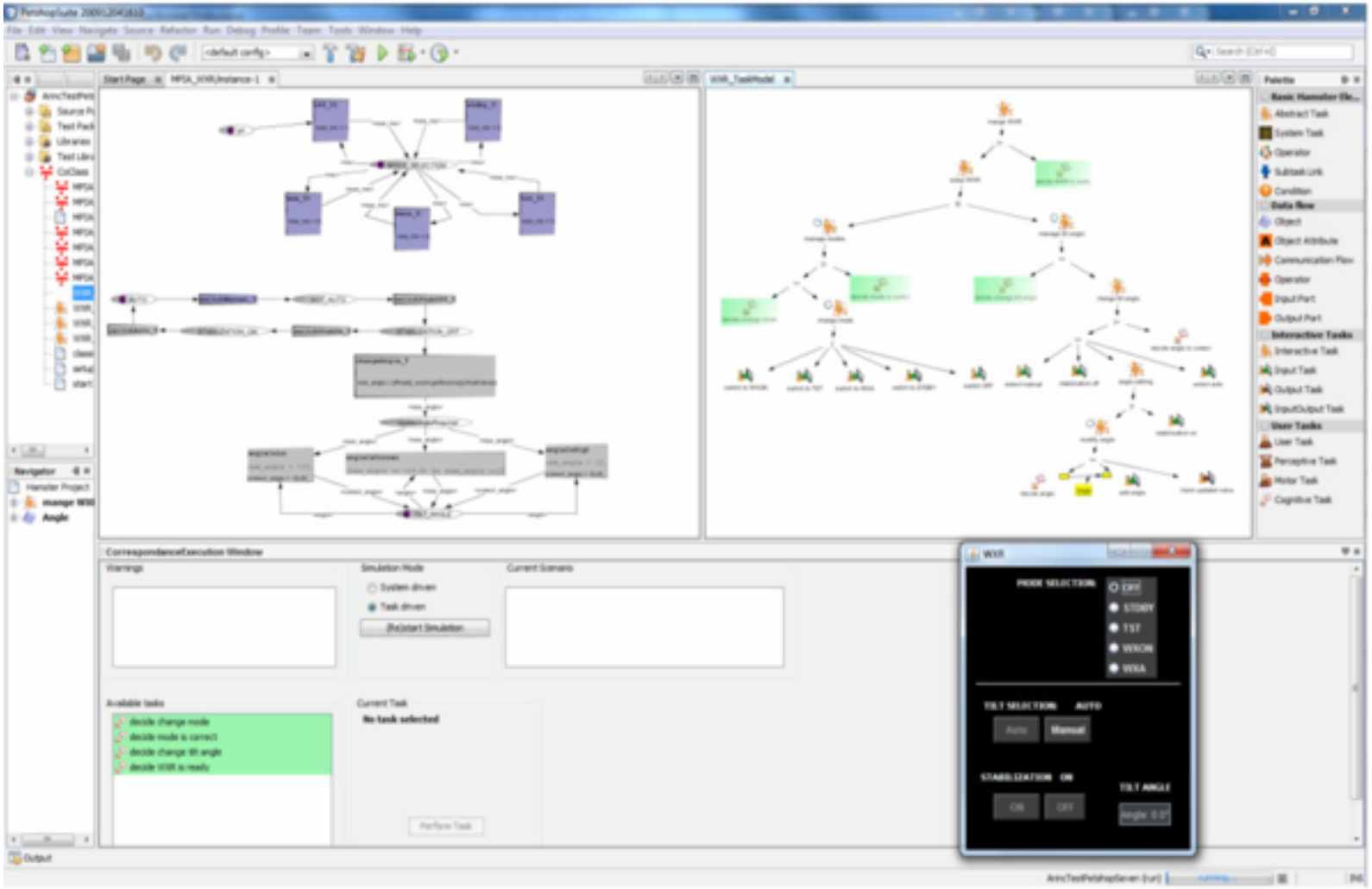
CIRCUS toolset

- Ex.: task model (FCU software)[1]

HAMSTERS task model

[1]Fayollas et al. Evaluation of formal IDEs for human-machine interface design and analysis: the case of CIRCUS and PVSio-web. Submitted to F-IDE 2016 / 21st International Symposium on Formal Methods (FM2016).

CIRCUS



CIRCUS co-execution of system and task models

Specific reasons to justify the tools

- **PVSio-web**
  - can represent system models in the notation of statecharts;
  - analysis is made using theorem proving;
  - does not support explicit task modelling;
  - does not suffer with incompleteness of the analysis.

- CIRCUS
  - can translate task models into a notation compatible with that used for modelling the system.

Ongoing work

- Early stage of this research;
- Two formal tools are currently being used;
- Allows to investigate the definition of efficient modelling patterns (combining task models and system models).

Future work

- Moving to a realistic case study
  - Medical domain
  - Avionics domain

Thanks for listening!

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Acknowledgements

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