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A practical example of a software factory

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Context

- Road2CPS project, a 2-year Co-ordination and Support Action within the EU-funded Horizon 2020 R&D programme;
- Partners: 5 institutions in 4 countries;
- Early deliverable Month 6 -
- A comprehensive State of the Art Report;
- Actvity lead by Loughborough University with a part time Research Associate.

The need for speed

- The Challenge:
  - 6 months (really 5 months) to review 53 technical projects and produce a 'State of the Art Report';
- The Contributors:
  - Expertise distributed across 5 Institutions in 4 countries;
- The Method:
  - A Rapid Evidence Assessment approach offered a suitable method to collate information.
- And we had to hit the ground running….

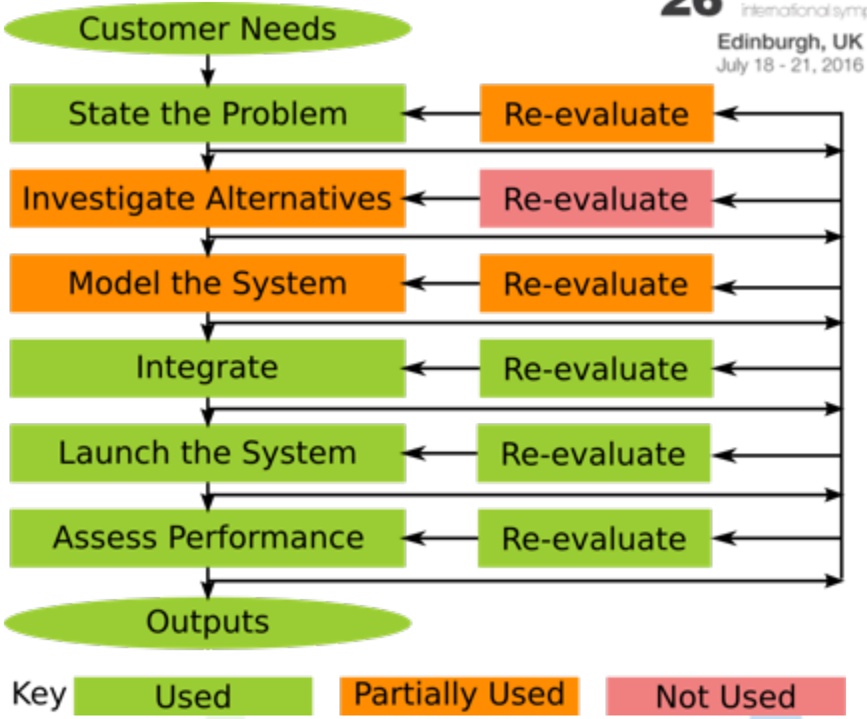
A Custom Tool

- Developed a custom tool
- Tool used a mixture of off-line and Internet facing components
- Collated information on the 53 projects as 'Snippets' of data annotated with suitable meta-data
- Used meta-data already used by the broader CPS community

This Paper is a retrospective analysis of why the overall approach worked

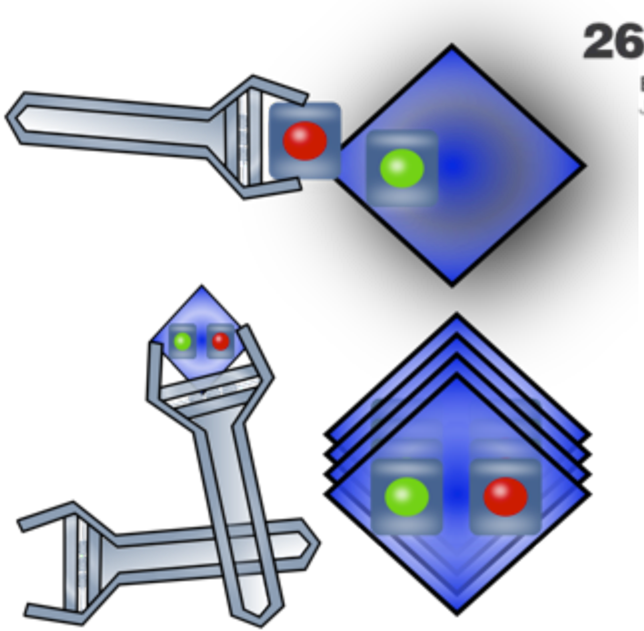
Was this a systems approach ?

- The SIMILAR model is a good way to describe the overall approach.
- The process was very parallel rather than sequential.
- The working system was the model.
- All the components, including the skills of the consortium members, were necessary in the delivery of the output.
- Yes, it was a systems inspired approach.

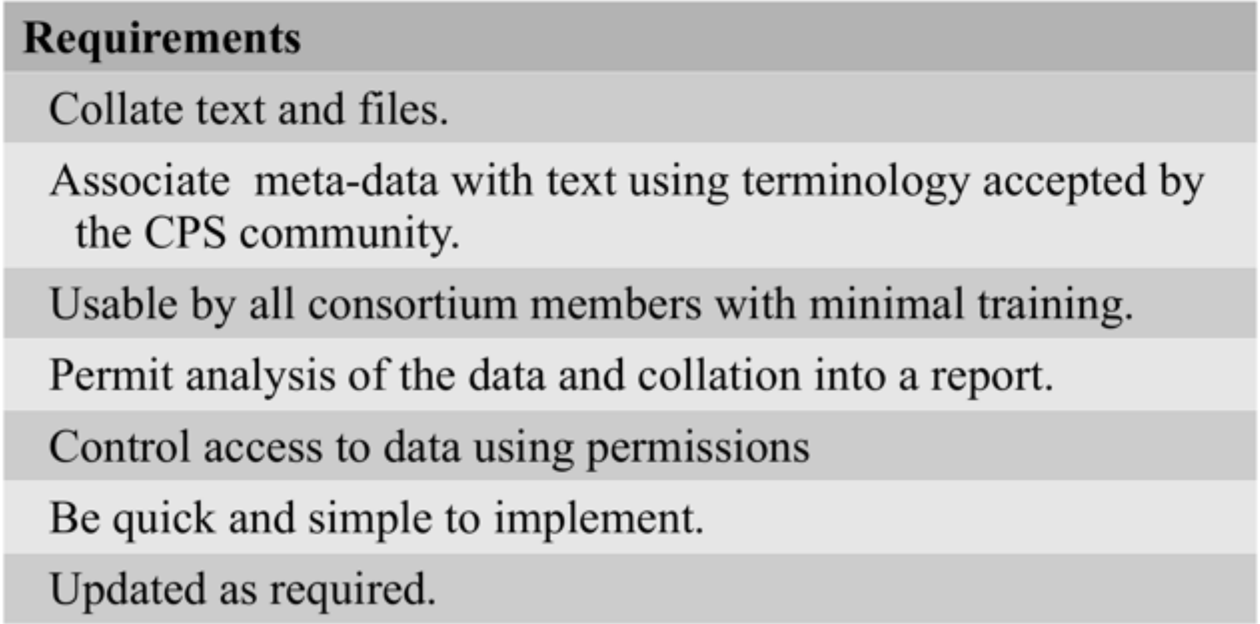


Why A Software Factory?

- The approach was general purpose
- All parts of the final tool were regarded as components including the Internet facing web and mySQL servers
- The same approach could be used to build many other software tools
- The same tool could have been built in many other configurations such as stand alone hardware

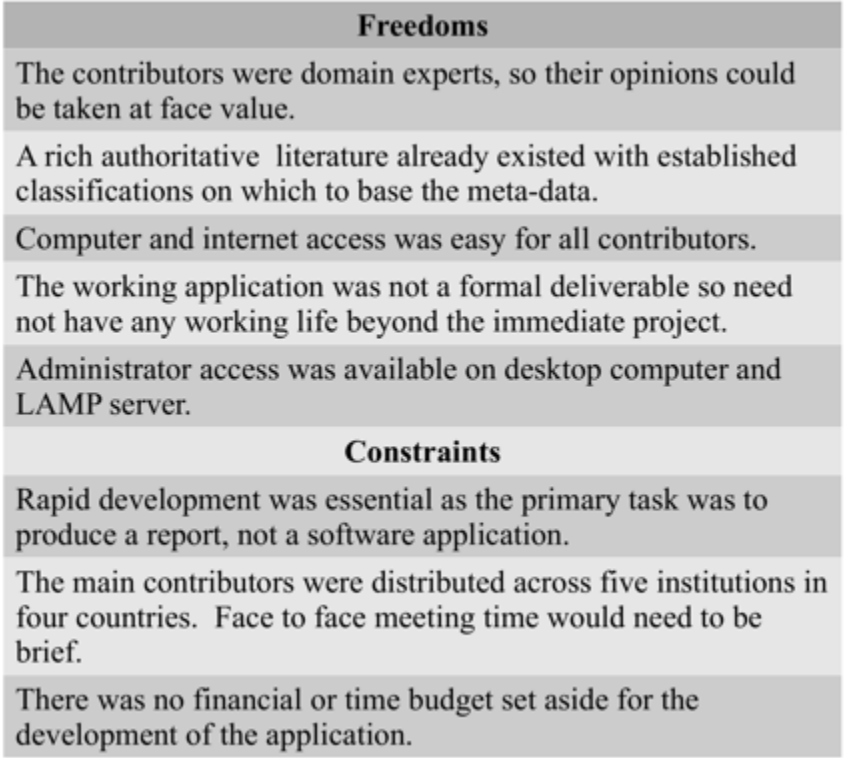


The Requirements



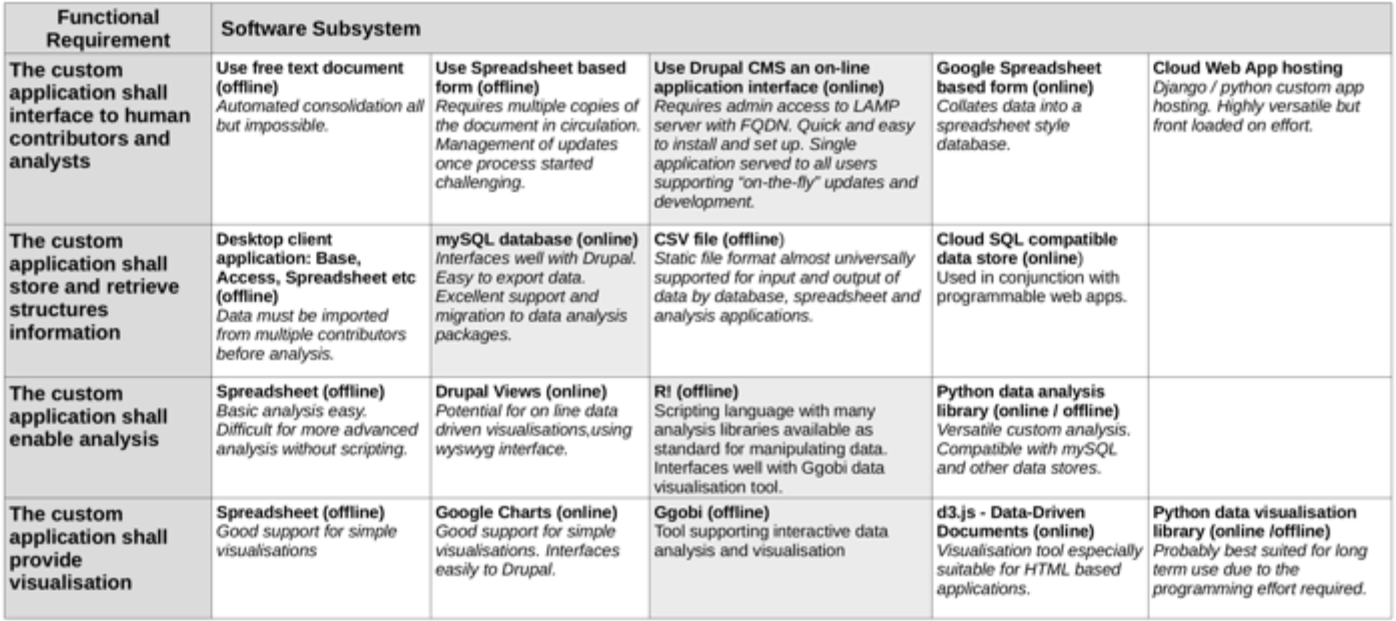
Requirements
Collate text and files.
Associate meta-data with text using terminology accepted by the CPS community.
Usable by all consortium members with minimal training.
Permit analysis of the data and collation into a report.
Control access to data using permissions
Be quick and simple to implement.
Updated as required.

Freedoms and Constraints



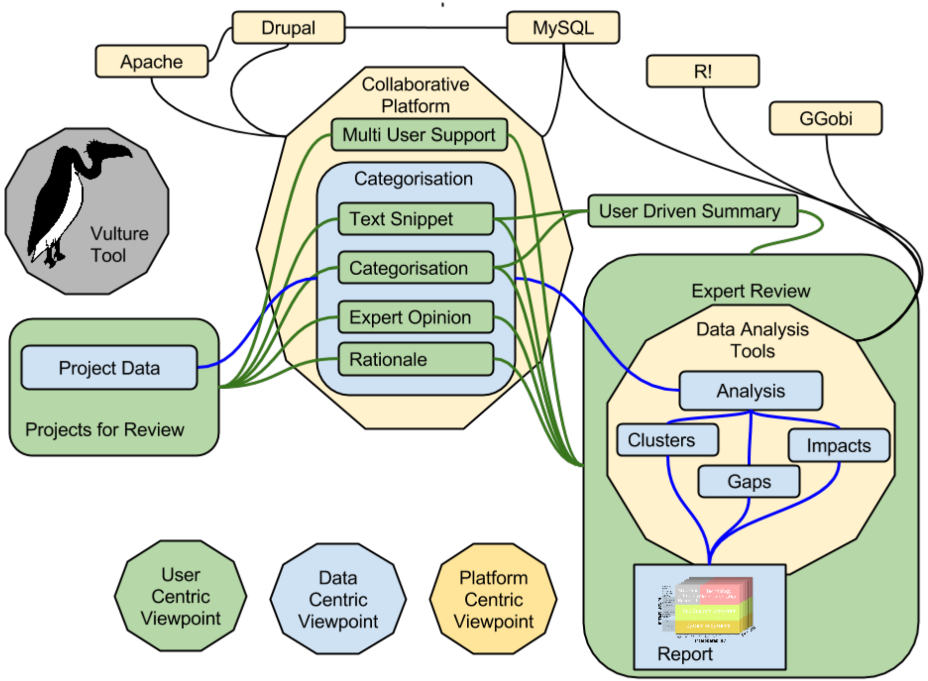
Freedoms
The contributors were domain experts, so their opinions could be taken at face value.
A rich authoritative literature already existed with established classifications on which to base the meta-data.
Computer and internet access was easy for all contributors.
The working application was not a formal deliverable so need not have any working life beyond the immediate project.
Administrator access was available on desktop computer and LAMP server.
Constraints
Rapid development was essential as the primary task was to produce a report, not a software application.
The main contributors were distributed across five institutions in four countries. Face to face meeting time would need to be brief.
There was no financial or time budget set aside for the development of the application.

Potential Solutions (Matrix)



Functional Requirement	**Software Subsystem**				
The custom application shall interface to human contributors and analysts	**Use free text document (offline)** *Automated consolidation all but impossible.*	**Use Spreadsheet based form (offline)** *Requires multiple copies of the document in circulation. Management of updates once process started challenging.*	**Use Drupal CMS an on-line application interface (online)** *Requires admin access to LAMP server with FQDN. Quick and easy to install and set up. Single application served to all users supporting "on-the-fly" updates and development.*	**Google Spreadsheet based form (online)** *Collates data into a spreadsheet style database.*	**Cloud Web App hosting** *Django / python custom app hosting. Highly versatile but front loaded on effort.*
The custom application shall store and retrieve structures information	**Desktop client application: Base, Access, Spreadsheet etc (offline)** *Data must be imported from multiple contributors before analysis.*	**mySQL database (online)** *Interfaces well with Drupal. Easy to export data. Excellent support and migration to data analysis packages.*	**CSV file (offline)** *Static file format almost universally supported for input and output of data by database, spreadsheet and analysis applications.*	**Cloud SQL compatible data store (online)** Used in conjunction with programmable web apps.	
The custom application shall enable analysis	**Spreadsheet (offline)** *Basic analysis easy. Difficult for more advanced analysis without scripting.*	**Drupal Views (online)** *Potential for on line data driven visualisations,using wyswyg interface.*	**R! (offline)** Scripting language with many analysis libraries available as standard for manipulating data. Interfaces well with Ggobi data visualisation tool.	**Python data analysis library (online / offline)** *Versatile custom analysis. Compatible with mySQL and other data stores.*	
The custom application shall provide visualisation	**Spreadsheet (offline)** *Good support for simple visualisations*	**Google Charts (online)** *Good support for simple visualisations. Interfaces easily to Drupal.*	**Ggobi (offline)** Tool supporting interactive data analysis and visualisation	**d3.js - Data-Driven Documents (online)** *Visualisation tool especially suitable for HTML based applications.*	**Python data visualisation library (online /offline)** *Probably best suited for long term use due to the programming effort required.*

The Vulture Tool

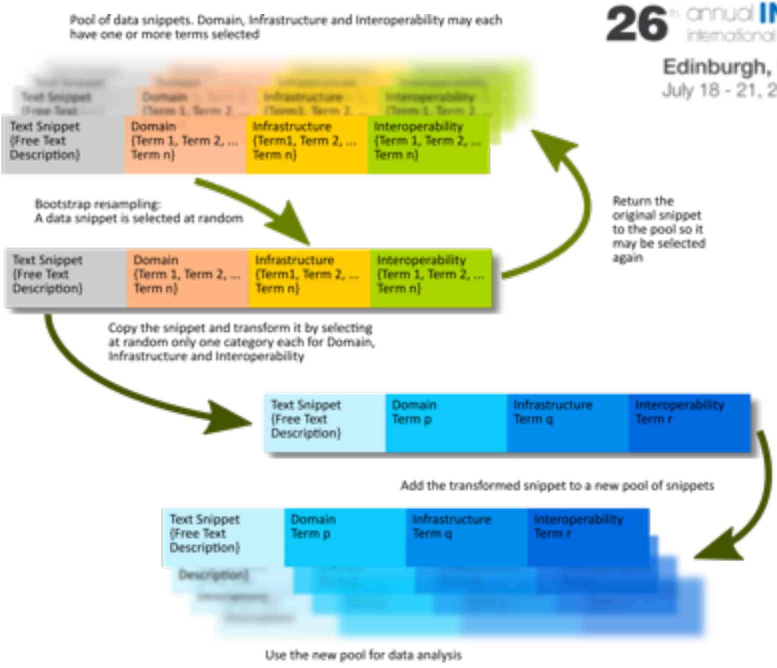


Collating the Data

- Meta-Data terms were taken from those already used to describe the domain
- All terminolgy added to the tool to try to ensure consistency of definition
- Video instructions produced for contributors and added to the tool
- All users had their own accounts and could edit their own contributions

Analysing the Data

- The data was downloaded as csv files for the analysis process
- Scripts to help analyse the data were written **before** the data collation was complete. The helped to decouple software scripting effort from data collection effort
- The results were converted to graphics to help visualise the data



Pool of data snippets. Domain, Infrastructure and Interoperability may each have one or more terms selected

Text Snippet (Free Text Description)	Domain (Term 1, Term 2, ... Term n)	Infrastructure (Term1, Term 2, ... Term n)	Interoperability (Term 1, Term 2, ... Term n)

Bootstrap resampling:
A data snippet is selected at random

Text Snippet (Free Text Description)	Domain (Term 1, Term 2, ... Term n)	Infrastructure (Term1, Term 2, ... Term n)	Interoperability (Term 1, Term 2, ... Term n)

Return the original snippet to the pool so it may be selected again

Copy the snippet and transform it by selecting at random only one category each for Domain, Infrastructure and Interoperability

Text Snippet (Free Text Description)	Domain Term p	Infrastructure Term q	Interoperability Term r

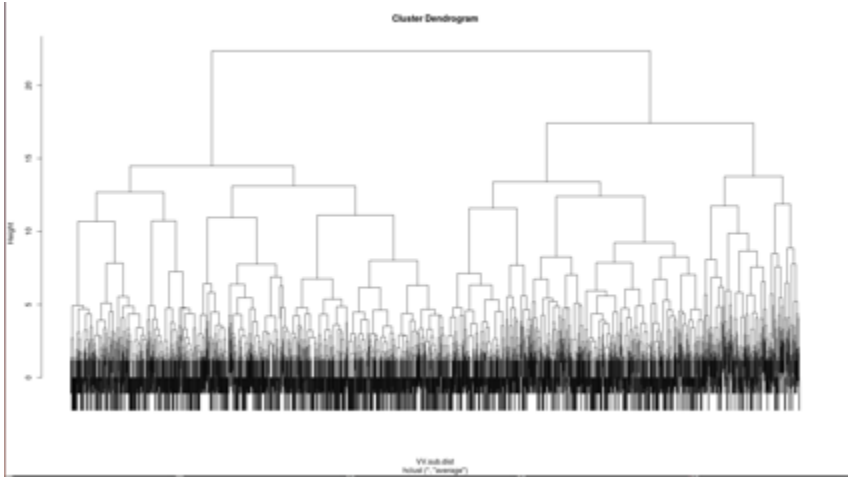
Add the transformed snippet to a new pool of snippets

Text Snippet (Free Text Description)	Domain Term p	Infrastructure Term q	Interoperability Term r

Use the new pool for data analysis

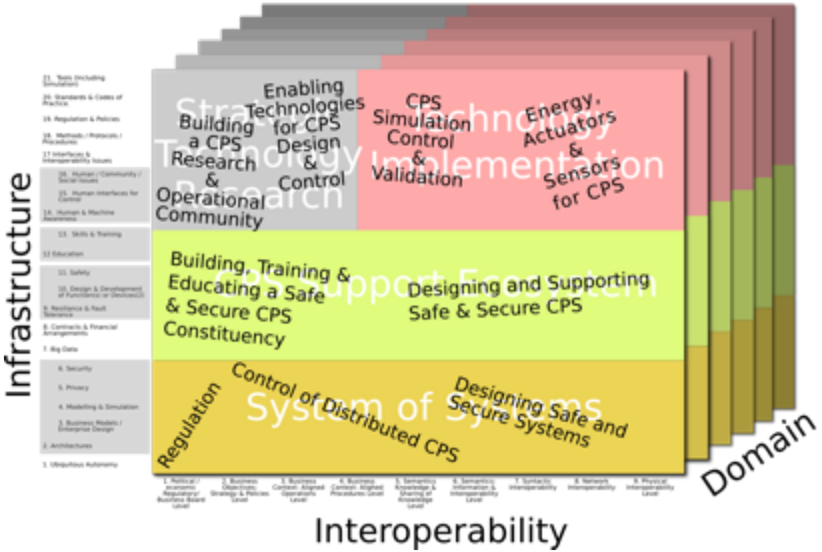
Analysing the Data

- Initially we expected to see clsuters of activity so had set oup the analysis to search for clusters
- Because we used an alogorithm to search for clusters the results were not strongly influenced by contributor bias. No individual could see the impact of their data as they added it
- We were suprised to find that **Domain** did not appear to be a significant factor in discriminating clusters



The State of the Art Report

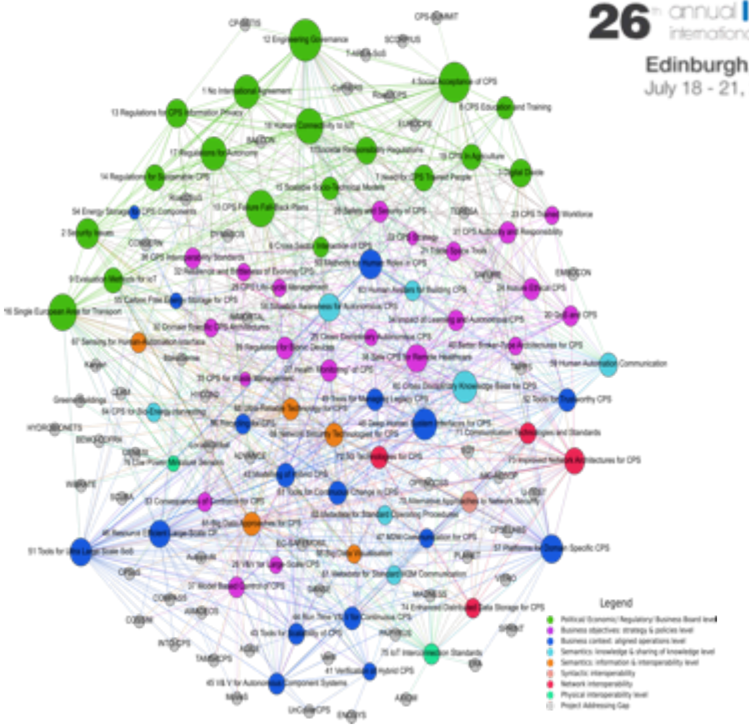
- Delivered on time.
- Report underpinned by 337 'snippets' of information annotated with meta data.
- Commentary on the projects reviewed.
- A highly successful outcome.


Infrastructure
21. Tools (including Simulation)
20. Standards & Codes of Practice
19. Regulation & Policies
18. Methods / Protocols / Procedures
17 Interfaces & Interoperability Issues
16. Human / Community / Social Issues
15. Human Interfaces for Control
14. Human & Machine Awareness
13. Skills & Training
12 Education
11. Safety
10. Design & Development of Functions(s) or Devices(s)
9. Resilience & Fault Tolerance
8. Contracts & Financial Arrangements
7. Big Data
6. Security
5. Privacy
4. Modelling & Simulation
3. Business Models / Enterprise Design
2. Architectures
1. Ubiquitous Autonomy
Strategic Technology Research
Building a CPS Research & Operational Community
Enabling Technologies for CPS Design & Control
Technology Implementation
CPS Simulation Control & Validation
Energy, Actuators & Sensors for CPS
CPS Support Ecosystem
Building, Training & Educating a Safe & Secure CPS Constituency
Designing and Supporting Safe & Secure CPS
System of Systems
Regulation
Control of Distributed CPS
Designing Safe and Secure Systems
1. Political / economic Regulatory/ Business Board Level
2. Business Objectives, Strategy & Policies Level
3. Business Context: Aligned Operations Level
4. Business Context: Aligned Procedures Level
5. Semantics: Knowledge & Sharing of Knowledge Level
6. Semantics: Information & Interoperability Level
7. Syntactic Interoperability
8. Network Interoperability
9. Physical Interoperability Level
Interoperability
Domain

This paper is a retrospective analysis of why the overall approach worked

Ongoing Work

- The work so far has been very well recieved by the EU project reviewers
- We have expanded the annotated data to cover Gaps and Impacts and their relationships to each other. This has enabled the production of network like views to help describe the space
- A second similar tool “Magpie” has been created for the TAMS4CPS project


Legend
🟢 Political/Economic/Regulatory/Business Board level
🟣 Business objectives: strategy & policies level
🔵 Business context: aligned operations level
● Semantics: knowledge & sharing of knowledge level
🟠 Semantics: information & interoperability level
● Syntactic interoperability
🔴 Network interoperability
● Physical interoperability level
○ Project Addressing Gap

Why Did It Work?

- Building a custom tool
  - Adopting an informal 'box of bits' approach as in a 'scrap heap challenge'.
  - Availability of the expertise in the consortium.
  - Using Open Source components to minimise financial constraints

In Retrospect

- The Vulture tool
  - Adopting an informal 'box of bits' approach as in a 'scrap heap challenge'
  - We had access to the technology we required
  - Using Open Source components to minimise financial constraints

- The People
  - Access to technical skills we required
  - Availability of the experts within the consortium
  - Experts willingly made their contributions into the tool when asked

Thank You

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