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CONTROL IN STEEL

Deliverable 2.2:
Report with classification of issues and topics in the field of advanced control in downstream steel processing

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1 Project Summary and purpose of the present document

The project ControlInSteel is a dissemination activity. Focus of the dissemination are advanced control and automation concepts in the downstream process chain of the European steel production.
Today, knowledge engineering is a mature tool for analyzing problem solutions paths chosen by research projects as functions of impact, effort and problems. In ControlInSteel, controlled vocabularies will be developed, extended to taxonomies and ontologies to describe the interplay between chosen method, targeted problem and impact. Outcome of the project will be a systematic analysis which methods have been the most effective ones for reaching the desired impact. At the center of any dissemination project is the distribution of results. On the one hand by discussing the results found by the ControlInSteel evaluation. On the other hand. by broadening the knowledge about those former project results that are evaluated by the project.
A list of projects that were selected for evaluation is presented in Deliverable 3.

The goal of this deliverable is to illustrate how relevant data were derived from the various projects in order to highlight results potentially transferable and applicable to other industrial contexts, avoiding overlapping, duplications and irrelevant aspects.

Thus, it will be necessary to aggregate a large variety of results coming from the projects in a limited number of classes.
From the defined final list of projects, the results considered of interest will be organised in sub-topics, each representing a general issue (e.g. the specific control technique, IMC, ILC, MPC or other), a production process or process chain or one topic out the group of: improved yield, improved product quality, reduced production costs, reduced environmental impact.
For each class a few significant results will be selected which are easily recognizable for people not involved in the original project.

2 General approach

In order to provide a systematic assessment of the selected projects' results, we first need to classify the used automation methods and the impact. Additionally, we must consider the encountered problems during the projects, especially those that led to a reduced applicability and utilization of the corresponding method.

To do this, we built up controlled vocabularies. These vocabularies represent a common base of terminology that can be used to unify all approaches in the project. Let us provide a simple example from the steel application: the variable roll force is used for different control purposes. But there are different terms and naming conventions. In most simple cases, the variable is abbreviated "F" as it is common in physics. In the data acquisition systems, we find diverse language related variations and strange abbreviations "Presskraft" (for the German terms) or "WK" (for Walzkraft, again a German term), all of which are unsuited for comparisons. Extending this simple example, the same effect is found in the terminology for methods and solutions, for aggregates and processes.

Taxonomies can be set upon such a controlled vocabulary. Different ways to structure, categorize and relate semantic information. Source: A. Warner, Taxonomies. Figure 1 shows the different types of vocabularies (based on A. Warner, Meta-data and taxonomies for more flexible architectures) and illustrates their ability to describe relationships: Synonyms represent equivalence of terminology – the words can be interchanged. Contrarily, ontologies can describe classes and their interdependency, which is suited to describe more complex systems. They are a whole scientific branch on its own, helping us to find the appropriate domains and terms to systematically describe relationships.

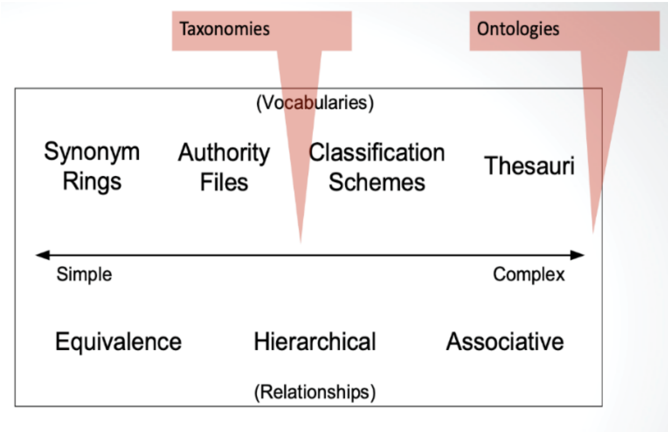

Figure 1 Different ways to structure, categorize and relate semantic information. Source: A. Warner, Taxonomies.

ControlInSteel uses different taxonomies: first a taxonomy (T1) of the problem space, defining the steel production chain and its processes and the physical modes of interaction. Second, a taxonomy (T2) will cover control solutions, building the dimensions of the solution space. A third taxonomy (T3) identifies the impact dimensions, the base of the impact space: e.g. product quality, process quality, throughput, safety and ecologic footprint, which will have to be worked out in more detail by the project. There will also be a separate taxonomy (T4) that identifies issues and boundaries, problems and challenges.

This approach will allow to structure the different methods and to establish a mapping among methods, the aggregates these methods are applied to and lastly what type of impact was achieved by the corresponding technique.

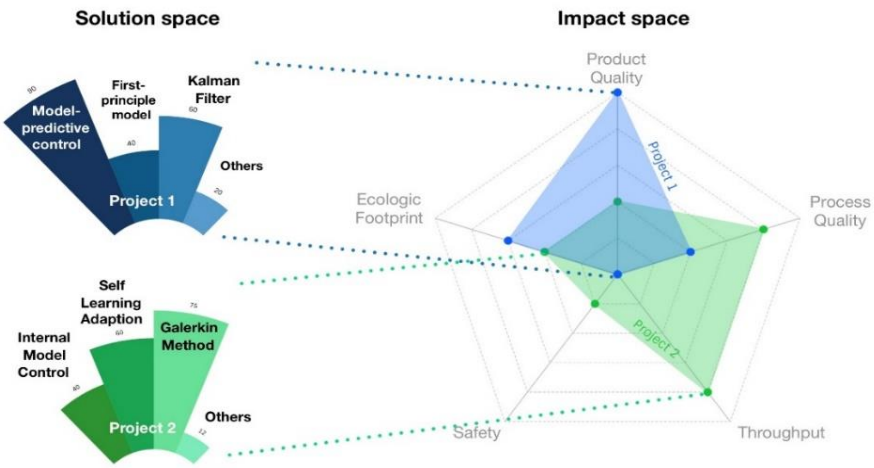

Figure 2 Idea of the mapping between solution portfolios in project 1 and 2, residing in (T2) and achieved impact (T3) projected onto its impact

Project teams often use a specific set of vocabulary to describe their research works and sometimes these vocabularies are difficult to compare. Already the term "control" is used in very different ways throughout several projects. Therefore, a semantic technique called vocabulary alignment will be applied to map the vocabularies onto common standard set of terms Assuming i.e., an exemplary application case in (T1) was already selected, the idea of the mapping, e.g. between (T2) and (T3) illustrating the relationship between method and impact is illustrated in Figure 2.
Given a problem defined in terms of (T1), a specific method portfolio from (T2) was used per project to achieve the impact in (T3). The interrelationships of the three spaces will now be used to construct an ontology, conserving the knowledge worked out during the evaluation. This ontology can be concisely parsed with respect to problem, method or impact space, and will be made available via the project website:

- What are the most important process characteristics, to successfully apply internal model control?
- What system identification strategy proved successful for hot rolling mills?
- How can ecological impact be generated at the hot rolling mill?

The adoption of this approach also allows structuring our dissemination activities in a systematic way as shown below: The dimensions in the problem space (T1) identify the dissemination target audience of the technical problems, which need to know how solutions look like as answered by (T2) and what impact can be generated (T3). Consequently, audience from the method domain (T2) can be informed on the technical problem areas (T1) and expected impact (T3), for which their methodology can be applied. Finally, our dissemination can aim at stakeholders interested in impact (T3) to provide information about the technical field to attack (T1) and the methodology that can be used (T2). Of course, the approach also fosters our objective to transfer solutions.

From the defined final list of projects, the results considered of interest are organised in sub-topics according to the four taxonomies identified. For including or excluding new or ongoing projects some issues should be considered. For instance, an ongoing project, which did not yet provide results, might be included in this deliverable, because its scope and aim are promising. However, later on, the project outcome might not be of interest to our scope. On the other hand, very recent projects initially excluded, as they are not foreseen to provide relevant results during the project, could later on show to be of relevance for the project. In addition, some projects, for instance developed by other industrial sectors, may be unknown to us currently even though they could be of interest. For this reason, they could be included in the dissemination actions of the ControlInSteel project.

The analysis of the identified projects leads to the following classification list for the four taxonomies.

Table 1 Problem space

Aggregate	**Type**	**Product**
Furnace	Furnace	Slab
Roughing mill	Rolling	Slab
Finishing mill	Rolling	Strip
Reverser	Rolling	Slab
Cooling	Cooling	Slab, Strip
Cold rolling	Rolling	Strip
Hot dip galvanization	Refinement	Strip
Pickling mill	Refinement	Strip
Foiling	Refinement	Strip
Energy management		Any

Table 2 Solution space

Aggregate	Type	Loop Type
PID	Control	Closed
Model-predictive control	Control; Optimization	Closed; Open
Iterative learning control	Control	Closed; Open
Internal model control	Control; Model	Closed
System identification	Model	Closed; Open
Convex optimization	Optimization	Open
Multi-agent system	Optimization	Open
Hybrid control	Control	Closed
Machine learning	Model	Open
Data analytics	Model	Open
Evolutionary approaches	Optimization	Open
Statistical method	Model	Closed; Open

Table 3 Issues and barriers

Aggregate	Type	Reason	Counter measures
Acceptance at plant	Social	Misunderstanding	Documentation; Training
Partial Failure	Impact	Scope of work	Transfer
Partial Failure	Technical	Force majeure	Project prolongation
Delay	Technical	Force majeure	Project prolongation
Delay	Logistical	Scheduling	Rescheduling
Communication	Project	Management	Strengthen team
Dissemination	Project	Scope of work	Publications

Table 4 Impacts

Aggregate	**Type**
Quality improvement	Quality
Defect root cause	Economic
Cost reduction	Economic
Yield improvement	Economic
Throuput improvement	Economic
Power consumption	Environmental; Economic
Waste reduction	Environmental; Economic
Emission reduction	Environmental
Worker performance	Economic
Customer satisfaction	Quality
Enabling technologies	Scientific
Novel approach	Scientific