CONTROL IN STEEL

Deliverable 1.1: Comprehensive Overview

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Former D2
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1. Introduction

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.

ControlInSteel started within the global COVID-19 crisis. The projects initial plan to conduct face-to-face workshops for the dissemination was slightly changed towards digital workshops and on-demand course material. The project team believes, that with this approach, the dissemination work will be even more reusable for the future.

A list of projects that were selected for evaluation is presented in Deliverable 3.

Figure 1 shows the planned timeline with mayor dissemination events planned in the end of 2021 and during the first half of 2022.

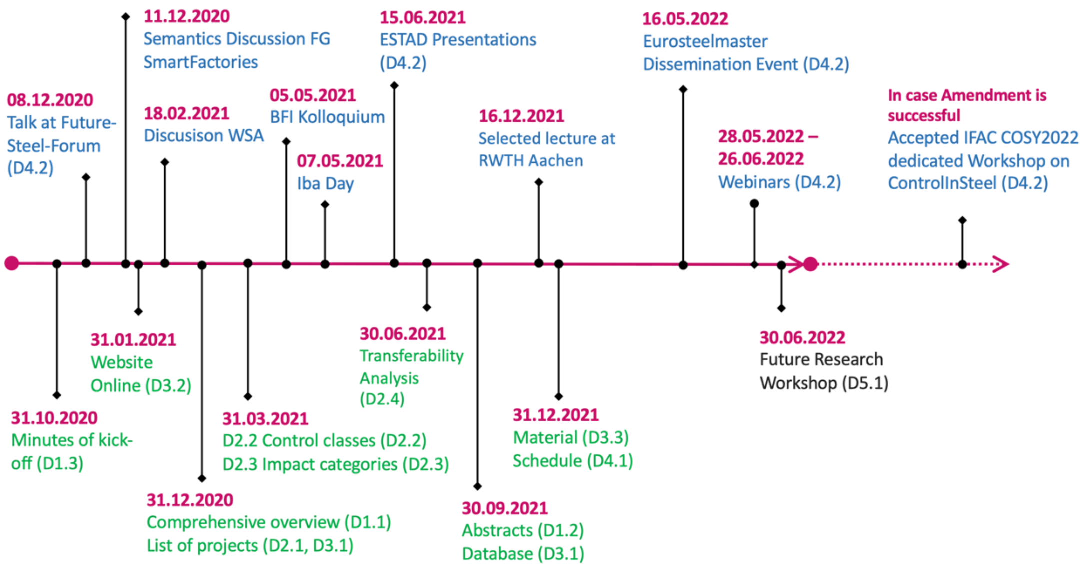

Figure 1. Schedule of the ControlInSteel activities and deliverables. Picture was updated at 06.03.2022 to accommodate potential prolongation of project.

2. Comprehensive overview

RFCS based research projects quickly adopted modern process control for optimizing steel processes. Today, the European Steel Industry can be regarded as a mayor driving factor behind process automation and its continuous improvement. While first activities and results strictly focussed only the optimization of single processes, nowadays also cross-process optimization, decentral automation paradigms and machine learning based control strategies have been covered by projects. All these components are currently driving the Industry 4.0 vision. It also shows, how vital process control is already entangled with Industry 4.0

The proposed dissemination project will analyse research results that feature relevant portions of the design, development, implementation or integration of control solutions in the downstream process chain. That comprises methods for system identification, techniques for designing models tailored to the needs of control applications, online adaptation to unforeseen system behaviour and which type of control approach has been successfully brought to application and how the success was related to the complexity of the method.

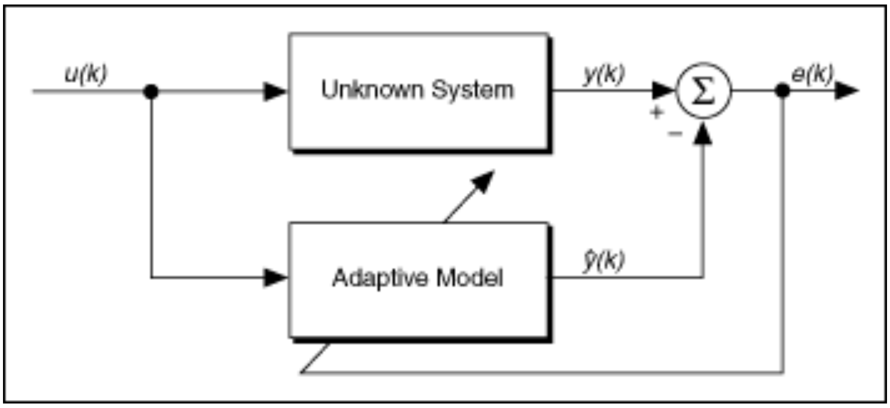

Figure 2. Example of system identification input u and output y are used to minimize the error e between y and model output $\hat{y}$.

Examples of advanced automation and control methods

System identification

Advanced control requires knowledge on the considered dynamical system. Sometimes, a rigorous first-principle modelling – also called white box modelling – can be applied, e.g. describing the intrinsic physical processes by theoretical models known from literature. But often, systems are far too complex to be modelled by ab initio approaches. Then, statistical methods are applied to build the mathematical models based on measurements. Such models are referred to as black box models. Grey box models rely, at least in some part, on system knowledge which is only supported by a set of measurements. Throughout the various RFCS projects, several different approaches of system identification have been used. Additionally, it will be evaluated how model precision and execution speed affect advanced automation and control systems, especially, which types of models can be regarded as the most successful ones.

Iterative Learning Control (ILC)

Repetitive operations such as factory batch processes can sometimes be improved by considering the results of previous batches. In such situations, iterative learning

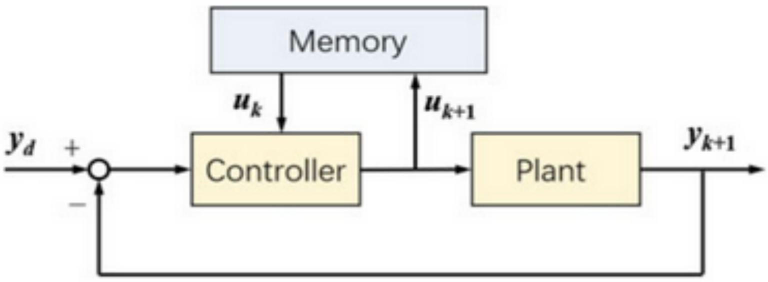

Figure 3. Block diagram of iterative learning control, featuring a memory.

control adapts its control output by learning from previous control outputs. This concept allows good control performance, especially when the model is uncertain or when there is little information about the system structure and its nonlinearities.

Model Predictive Control (MPC)

Model Predictive Control (MPC) uses a system model to predict the future system behaviour during its control loop. The prediction requires a significant computational effort per time step. These high computing times are one reason why MPC has been mainly introduced for large numbers of slowly changing variables. It depends on the quality of the underlying model and on a proper system identification. Novel aspect of the technique was neither the solution of an optimization task nor the inclusion of restrictions, but the principle of a so-called moving horizon, in which the optimization task is solved with restrictions for each time step.

Automatization of logistics: agents and self-organization

With the rise of Industry 4.0, new technologies like intelligent autonomous agents and multi-agent systems have been introduced to control systems. They allow integrated through-process control of the whole process chain. With such methods, new technological paradigms like self-organisation, self-optimization, communicating products and digital twins emerged, which as of today play a predominant role for the future of automation. Thus, disseminating the findings of prior RFCS projects, already researching the impact of these components is of vital interest for the ControlInSteel project.

Implementation and integration

A specific question concerning advanced control technologies regards to bringing these, mathematically rather complex approaches, to a successful real-world application. The project will therefore also evaluate which strategies were pursued to ensure a real implementation success and where the difficulties arise in introducing new control approaches in the plants. Of course, industrial automation and control covers far more facets, and above methods are only a very small

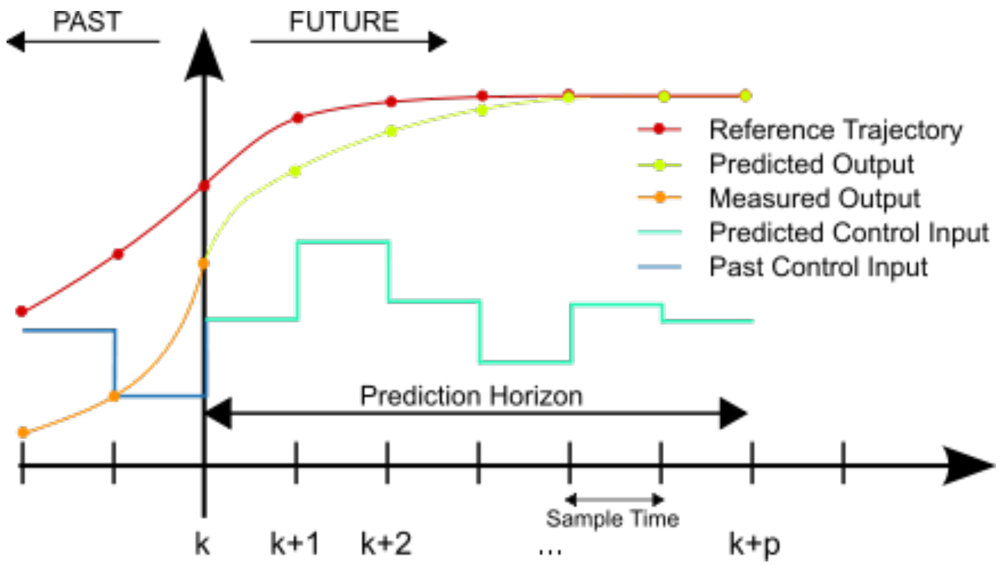

Figure 4. Model predictive control featuring a moving prediction horizon.

subset of examples. Further topics (e.g. internal model control, quaternion-based control) will of course be also part of the dissemination work.

Methods used for evaluating project results

In order to provide a systematic assessment of the impact, we first need to classify the encountered automation problem, the used 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 will build up controlled vocabularies. These vocabularies represent a common base of terminology that can be used to unify all approaches in the project.

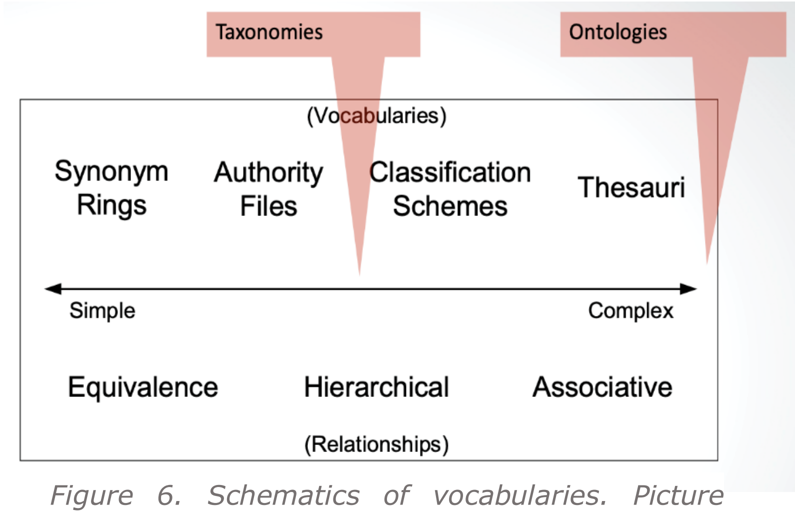

Figure 6. Schematics of vocabularies. Picture based on [1].

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

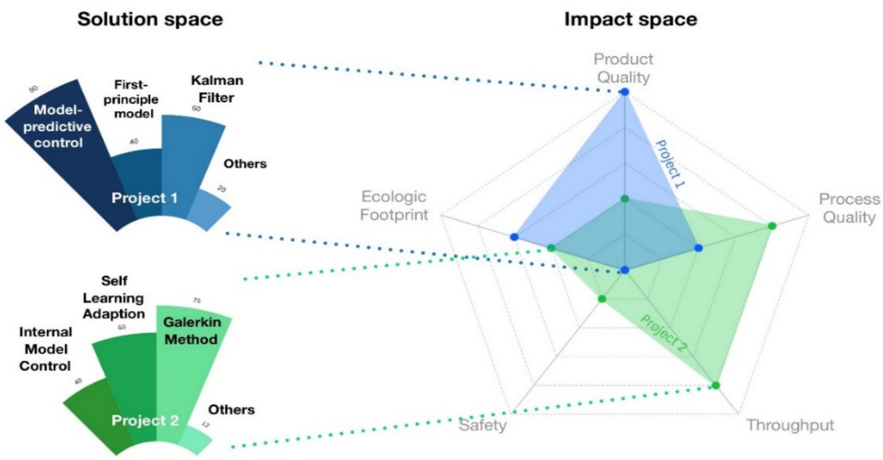

Figure 5. Idea of the mapping between solution portfolios in project 1 and 2, residing in (T2) and achieved impact (T3) projected onto its impact dimensions.

in physics. In the data acquisition systems we find diverse language related variations and strange abbreviations "Presskraft" (for the German termns) 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. Figure 6 shows the different types of vocabularies [1] 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.

ControlInSteel will introduce 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 following concepts similar as present by Reed et al. [2], where the base of the impact space will comprise 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 problems and challenges.

For our review, we follow strategies as presented in the book Gough et al. [3] and by Woolcock [4] for different, yet similar case analysis studies. 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.

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 Fig. 4.

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 permits to structure 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.

Via (T1) the problem is determined by the physical processes. If the same aggregate at a different plant exhibits similar problems, we can promote usage of a specific method portfolio proven the best to tackle the problem and predict the expected impact according to its dimensions.

3. Objectives

The primary objective of this dissemination project is to revisit the most important European projects related to "Advanced Automation and Control Solutions in Downstream Steel Processes" technologies in the field of steel production carried out in the last 20 years. Subobjective is to identify which approaches were successful technologies with respect to impact.

In RFCS projects, a special emphasize resides on the consideration of transferring the research results to other application scenarios. Further subobjective of this dissemination project will rigorously analyse, how control methods with large impact can be effectively transferred within the same plant and also to other plants. All of them can benefit from the research results of RFCS funded projects in the field of "Advanced Automation and Control Solutions in Downstream Steel Processes".

The information about the transferability is available in many project reports, as it has always been vital part of the project considerations. Nevertheless, although other dissemination activities have taken place, this specific information has not been evaluated in much detail and in such a scope before.

4. Bibliography

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