Ph.D. in Information Technology: Thesis Defense

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Chiara CIMINO – XXXIII Cycle

A New Paradigm to Combine Model- and Data-Based Digital Twins in Smart Manufacturing

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Abstract:

The main objective of this thesis is the proposal of a new paradigm to comprehend the many different interpretations of the Digital Twin concept proposed and applied in the context of advanced -- or ``smart'' -- manufacturing. The research motivation comes from observing on the one hand that entities named "Digital Twins" are nowadays of fundamental importance in the design, engineering, commissioning, control, maintenance and management of production assets, and on the other hand, that those entities are as heterogeneous as can be a BIM database, a system of differential and algebraic equations, and a neural network. This thesis takes a multidisciplinary approach, accounting in particular for the Systems and Control and the Operations and Management viewpoints, the major ones to come into play along the life of an asset. In the Systems and Control domain a Digital Twin is generally some kind of simulation model, while in Operations and Management a data-centric interpretation of the Digital Twin idea is most frequently adopted. Starting from the consideration that all the different Digital Twin interpretations lives in a Digital World, that has the nature of multiverse: it already contains different parallel realities and different viewpoints. The problem is that all the above knowledge is managed with separate tools, and the burden of keeping the knowledge base consistent (e.g., ensuring that a CAD modification does not invalidate a control study, to clarify that it is not just a matter of data interchange) stands with humans.

Elaborating on the above idea we introduce our paradigm, that we name Digital Multiverse. We show that different Digital Twin interpretation can be seen as “projections” or “views” applied to a more abstracted object, that we term Digital Meta Twin and offers the higher abstraction level envisaged above. We deduce that a Digital Meta Twin must take the form of a Model and Data Base, where consistency relationships need instating and automatically enforcing -- as is done in the

database domain for data alone -- but here involving both data and models. We then apply our paradigm to some relevant control-related problems, also with the aid of industrial case studies drawn from the Lombardia regional research and innovation project AD-COM, ``ADvanced COsmetic Manufacturing'' (ID 214632) that provided support for the presented research.

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