

The Problem of Control in Extreme Design Regimes: Lessons from Ecosystem Sciences for Engineering

Recent technological and societal trends are giving rise to unprecedented engineering systems with very long lifetimes, operating conditions that cannot be experimentally replicated, and volumes of data that exceed the interpretive capacity of humans—and even machines. This paper argues that these systems define extreme design regimes. To address them, the paper draws on neighboring scientific disciplines—including ecology, Earth system science, and complexity science—that have long confronted analogous challenges and synthesize their methods into an engineering framework and toolbox for extreme design. The paper illustrates the proposed toolbox using the Historical Adoption of TeCHnology (HATCH) dataset, which comprises harmonized annual time series for more than 200 agricultural, industrial, and consumer technologies spanning the early twentieth century to the present. The illustration shows how the toolbox represents a shift in engineering thinking: from predicting future system states to anticipating regime shifts, understanding their dynamics, avoiding undesirable transitions, and exploiting favorable ones.



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Massimo Panarotto is an Associate Professor at Politecnico di Milano since 2024. Previously (since 2021) he has been Associate Professor at Chalmers University of Technology (Sweden). He was also Head of the Master's Programme in Product Development (with approximately 150 students enrolled every year). His research is focused on developing models and methods to support the early stages of product development. The research is conducted in collaboration with companies in the space, aeronautics and automotive sectors. He earned a PhD in mechanical engineering from Blekinge Institute of Technology (Sweden) in 2015, and a Master degree in mechanical engineering from the University of Padua in 2011. He is a member of the Design Society and author of over 60 publications in the fields of systems engineering and engineering design. He has also taught in more than 10 courses in mechanical and management engineering degree programs.



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All are welcome

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