Automatic early **detection and correction of industrial design** and manufacturing **fl**aws - REINFORCE

Abstract: The REINFORCE project automates model generation, design and manufacturing flaws and removal in the early development stages of products by leveraging directed color graphs to represent system architecture and manufacturing systems' behavior. This has an important impact due to the significant constraints and costs tied to early decisions. The REINFORCE framework act as a computational assistant, providing innovative computer-aided support for designers, manufacturers and decision-makers at this critical stage.

Early design phases often involve ill-defined problems, combining text, functional descriptions, and numerical and textual data. Despite the increasing complexity surpassing human cognitive capabilities, model generation, reasoning, and flaw detection still depend heavily on human expertise. This is a major industrial challenge, negatively impacting quality, security, resilience, productivity, and costs for businesses and customers. The project addresses a critical gap not covered by existing methods.

The project develops an approach allowing qualitative reasoning with graph-based machine learning models by combining Π calculus, directed graphs and TRIZ inventive principles to detect and remove flaws and cybersecurity vulnerabilities. This advancement exploits unit decomposition, power laws, contact variables, and partial derivatives to enable the creation of high-quality, innovative design solutions, potentially leading to massive cost savings and better security. The progresses in fully automated model generation are enabling simulation, system control, hypothesis testing, and design optimization.

Application domains of the project include explainable and parsimonious machine learning models, cyber-physical system design, production machines' system control, and early-stage cybersecurity and resilience assessment to reinforce security-by-design principles.

The REINFORCE project automates the generation of models, as well as the design and removal of flaws in the early stages of product development, by leveraging directed color graphs to represent system architecture and the behavior of manufacturing systems. This project should generate a significant impact given the constraints and costs associated with early decisions. The REINFORCE framework acts as a computational assistant, providing designers, manufacturers and decision-makers with innovative, computer-aided support at this critical stage.

Early design phases often involve ill-defined problems that combine text, functional descriptions and numerical and textual data. Despite the increasing complexity surpassing human cognitive capabilities, model generation, reasoning and flaw detection still depend heavily on human expertise. This presents a significant challenge to industry, negatively impacting quality, security, resilience, productivity and costs for businesses and customers alike. The project addresses a critical gap not covered by existing methods.

It develops an approach that enables qualitative reasoning with graph-based machine learning models, combining Pi calculus, directed graphs, and TRIZ inventive principles to detect and eliminate flaws. This advancement exploits unit decomposition, power laws, contact variables and partial derivatives to enable the creation of innovative, high-quality design solutions, which could lead to significant cost

savings and improved security. Progress in fully automated model generation enables simulation, system control, hypothesis testing and design optimization.

The project's application domains include explainable and parsimonious machine learning models, cyber-physical system design, control of production machines, and early-stage cybersecurity and resilience assessment, all of which reinforce security-by-design principles.

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