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Diagnosing Root Causes of Defectivity Patterns

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Introduction

In modern high-tech systems, product quality depends on the collective performance of interconnected components across multiple processes. When quality falls below specification, it is often difficult to pinpoint which faulty process is responsible for the resulting **defectivity pattern** – a set of anomalies or deviations observed on the final product. To address this challenge, the presented framework applies **Probabilistic Graphical Models** to relate these patterns to their underlying **root causes**.

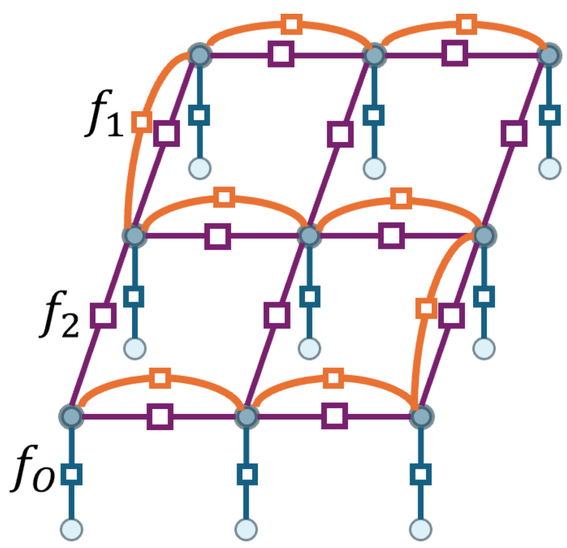

Figure 1

Methodology

The proposed framework classifies defectivity patterns on a product across time and space into a discrete set of root causes. To do so, we construct a **Probabilistic Graphical Model (PGM)** (Figure 1) that incorporates prior knowledge of system design (e.g., component layout) and failure modes.

The PGM is parameterized with **factors** that quantify how likely certain observations and root causes are to co-occur across different representations of a system, enabling **probabilistic reasoning** across the entire graph.

The flexibility of PGMs to model arbitrary graph structures and reason across multiple root causes simultaneously makes them well-suited for modeling performance dynamics of complex systems.

Application

The generic methodology was applied to an industrial use case for diagnosing print quality artifacts occurring in industrial inkjet printers. During the printing process, scanned test pages (Figure 2) provide indirect measurements of ink nozzle performance, which are then used to infer the root causes of **underperforming nozzles**.

Certain root causes appear as physical patterns on the print head (2D representation) while others manifest as patterns in the jetting order (1D representation), Figure 3.

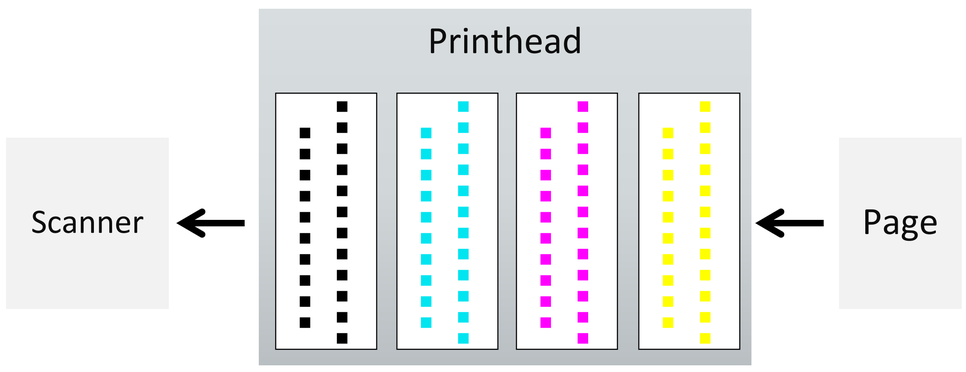

Figure 2

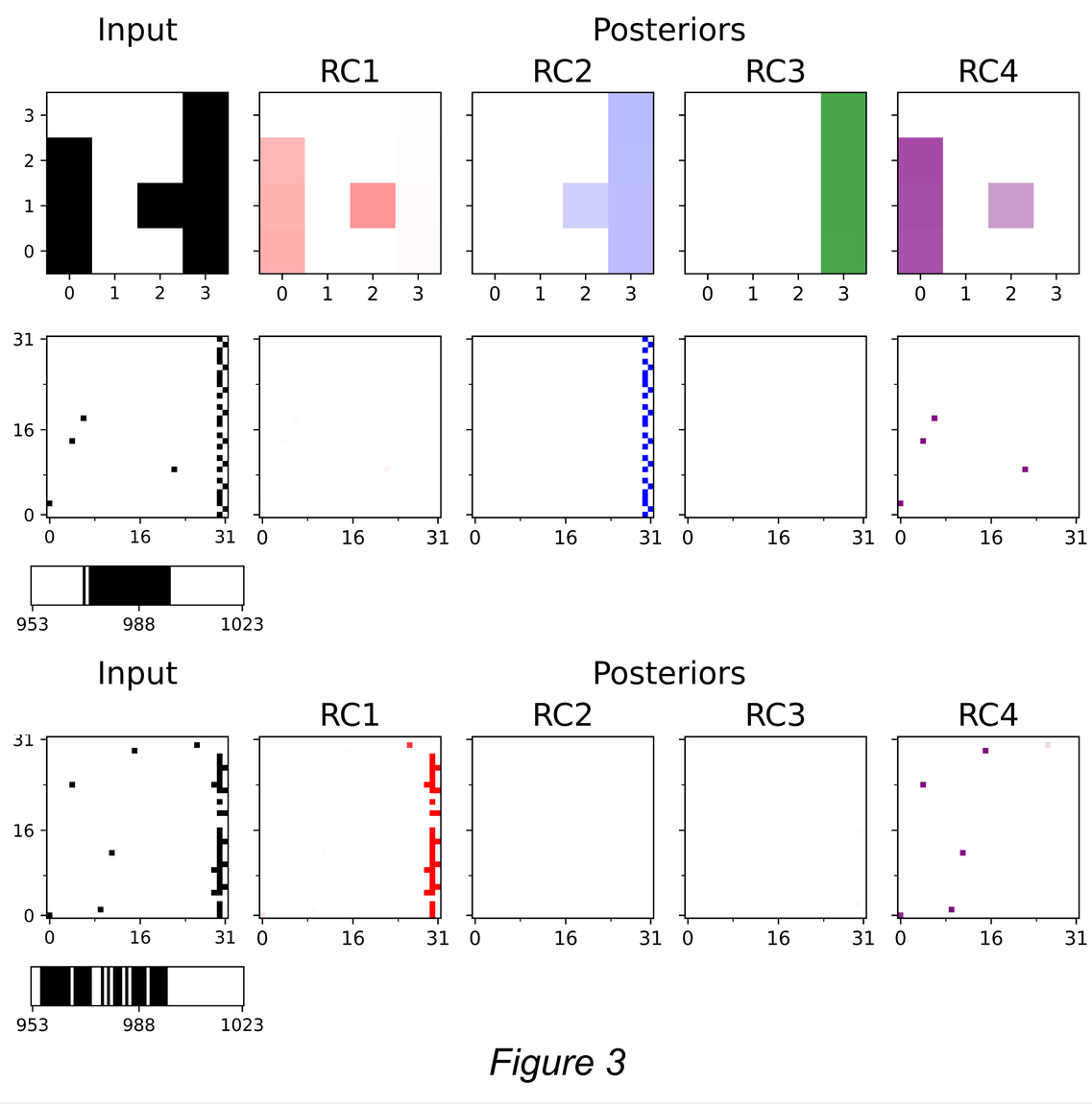

Figure 3

Findings

Preliminary validation on the print quality use case shows that our methodology produces diagnoses consistent with those of domain experts. Current limitations include its reliance on discrete data and the need for domain expertise when modeling the factors that parameterize the PGM.

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