Literature Review: Simulating Flexible Assembly System Event Logs for the Purposes of Process Modelling and Machine Learning – DRAFT

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Keywords. Flexible Assembly System, Simulation

1 Topic

Flexible Assembly System is a modular and reconfigurable assembly and tooling workshop with a focus on small and medium-sized batches of varying products. Flexible Assembly System was described formally by Donath and Graves [1] as a system consisting of a set of products each with a specified volume assembled on a workshop consisting of a fixed number of cells.

The assembly steps are performed in cells in parallel. Assemblies and components are transported to the cell where they are combined, tooled or inspected. Products are transported out of the cell for the next assembly step in another cell, or out of the system as end products. The work steps executed in the cells can be manual or automatic. There can be a central storage such as a shelf for storing components, the intermediate assemblies between the steps and the end products waiting to be transported out of the system.

Flexible Assembly System work loads consist of small and medium sized batches where there can be some variation in the products based on customization and personalization. The Flexible Assembly Systems are modular and often composed out of independent modules from different suppliers. The Flexible Assembly System event stream consists of events received from all the separate modules of the system, and additional sensors and triggers added to the system in integration phase or later.

Using a Flexible Assembly System to assemble batches of products generates an electronic event stream which is logged. The events in the event stream are typically at least partially agnostic to the assembly process being performed, and therefore the events do not include tokens connecting the event to a specific final product instance.

Simulating these kinds of event streams provides valuable material for learning systems which can be used to derive assembly process models and to detect deviances.

2 Description of Method

A proper literature review is a methodological, continuous process. The goal of the literature review is to accumulate a body of relevant existing knowledge about the topic, categorized based on subtopics and keywords. Ultimately the literature review can be presented in the article in a summary form to present the context of the research. The collected references represent a focused area of the existing literature relevant to the object of research.

The review starts from discovery, discovering information sources and starting points of review. The literature review process progresses towards synthesis where the relevant existing knowledge is synthesized together to form an understanding of the composite.

The discovery phase includes a listing of subtopics and keywords, to structure the gathered discovered information into a manageable form. The goal of the discovery phase is to form questions about the existing knowledge and to find answers to them.

The synthesis is composed of the description of the existing knowledge and possible gaps related to the research.

3 Discovery Phase

The topic under review is somewhat cross-discplinary relating to industrial assembly processes, business process modelling and learning systems. Overall the following subtopics are recognized:

1. Assembly process modelling and simulation

    (a) Fault modelling and simulation

2. Mathematical analysis of log data

    (a) Analysing interleaved event streams
    (b) Analysing delays and intervals

3. Process mining

4. Visualization of event logs

3.1 Keywords

The keywords relevant for the research were collected from a set of articles deemed especially relevant for this research. A representative set of articles was read and relevant keywords were picked from titles, abstracts and references. This set of keywords allows for directed browsing of relevant literature.

- assembly process
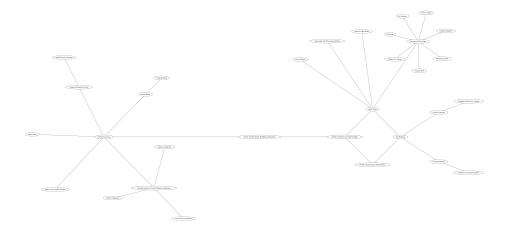- assembly system
- complex robotic system
- compliant parts

Figure 1: The mind map of the research topic

- dimensional quality

- dimensional variation propagation

- Failure mode and effects analysis (FMEA)

- failure rates

- failure records

- failure report

- fault detection

- fault mode

- fixture variation

- interleaving

- leaf spring

- multiple failure modes

- Multi-Station Assembly Systems

- outflow visualization

- part variation

- petri nets

- process control

- process failures

- process FMEA

- reduction of irregularities

- reliability

- simulation

- time-domain visualization

- uncolored petri nets

- variation propagation

- visualization of sequences

- welding gun variation

The core questions about the existing literature are:

1. What methods are there to model and simulate assembly processes and related faults?

2. What methods are there to visualize event logs with or without timestamps?

3. What are the relevant keywords and terms to describe this problem space?

4 Synthesis

Flexible Assembly Systems are modelled as colored Petri nets.

Process mining is the field of inferring the underlying business processes based on observed events and transitions. The current de facto methods for describing process logs in the context of process mining are loosely based on the alpha algorithm and they all expect process instances to be identified in the input event streams. This means that the corresponding Petri net models are colored[2].

References

[1] M. Donath and R. J. GRAVES, "Flexible assembly systems: an approach for near real-time scheduling and routeing of multiple products," *The International Journal Of Production Research*, vol. 26, no. 12, pp. 1903–1919, 1988.

[2] W. Reisig, *Applications and Theory of Petri Nets: Selected Papers from the 3rd European Workshop on Applications and Theory of Petri Nets Varenna, Italy, September 27–30, 1982 (under auspices of AFCET, AICA, GI, and EATCS)*. Berlin, Heidelberg: Springer Berlin Heidelberg, 1983, ch. Petri Nets With Individual Tokens, pp. 229–249. [Online]. Available: http://dx.doi.org/10.1007/978-3-642-69028-0{_}16