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Data-driven probabilistic logic programming applied to movement analytics in manufacturing

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Abstract: Manufacturing companies aim to produce items efficiently while maintaining quality standards and ensuring the safety of their workers. Data analysis provides companies with an evidence-based approach to make tactical decisions around improving a factory's efficiency, productivity and safety.

IoT tracking systems have become cheaper and more accessible, making it is possible to monitor factory work such as component parts in the production line or worker movements. CSIRO's Data61 has developed two such systems: the camera-based 3D Situational Awareness system and the tag-based Embedded Intelligence Platform. Current analysis tools are mainly limited to dashboards which visualise the output of trackers, but more can be done to extract value from tracking data. We refer to data analytics methods that extract value from tracking systems as *movement analytics* (Baumgartner et al., 2022)

Probabilistic logic programming (PLP) is a modelling framework which uses logic to encode domain knowledge about a physical system (such as a factory) as a set of logical rules which can then be used to deduce further attributes about the system. It is probabilistic in the sense that each rule can be assigned a probability of being true, which quantifies the uncertainty within the system. For example, a worker's movement can be described by assigning probabilities to each of the possible locations they might move to next. Fusemate (Baumgartner, P., Tartaglia, E., 2023) is a PLP system for both simulation and exact probabilistic inference. In this project, we used Fusemate to describe the motion of workers in a tricycle production line (Delamare et al., 2020). We encoded the behaviour of the workers such as standing at a workbench or moving between workbenches, along with their associated probabilities. Data was then simulated from this model by drawing from the distributions of possible behaviours. Fusemate was also used to classify worker behaviour based on input trajectories by encoding a Dynamic Bayes net.

The parameters in PLP models are often determined using domain knowledge, but there is an opportunity to employ data-driven methods. In this project, we estimated the probabilities of the various worker behaviours based on the data set (Delamare et al., 2020). We assumed a Poisson process, where the events were a worker staying at their current workbench or moving to another. This means that the events had a fixed average rate, but that they occured randomly. The average rate could then be estimated from the data.

We developed two models. In the first, we simulated a situation where data was recorded at a fixed time interval of 30 seconds. A Poisson distribution was used to estimate the probability of k events occurring within the 30 second interval, where an event represented the worker moving. The second model simulated the data being recorded every time a worker moved, using an exponential distribution to estimate the time between moves.

In this talk we will explain the method as outlined above and report on our experiments with the trajectories simulated using this method.

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