Dissertation title:

Visual Analytics for Production and Transportation Systems

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The manufacturing sector, as any major part of the economy, is facing new challenges in the increasing pace at which its business environment changes on both the local and the global scale. Globalization increases competition, but it also opens up new markets with customers that may have very different needs and expectations. Emerging markets typically offer inexpensive labour and low production costs whereas the established markets focus on technological sophistication and highly qualified workers. To remain competitive, manufacturers look for ways to increase their efficiency by reducing costs, delays, and throughput times while increasing product quality and other customer benefits such as customization options. Advanced manufacturing engineering designs future factories as complex systems under technological, organizational, and social considerations. These systems exist in an ever-changing environment that dictates raw material prices and customer demands, brings occasional technological advances, and imposes restrictions through laws and regulations. To ensure their long-term survival, they need to be flexible and adaptable. They must be able to react to sudden changes in these environmental factors and to adapt their inner structure to evolve along with the world they exist in.

Information technology plays an important role in reaching these goals. The advent of digital engineering has now introduced various ways of collecting and processing data on the manufacturing process. There is, however, a certain lack in the ability to analyse this data in order to understand and improve the process and to ensure its flexibility and adaptability. Visual analytics is a technique that combines the processing power of automatic data analysis algorithms with the creativity and implicit knowledge of human analysts. Its application to the manufacturing domain can contribute to a successful exploitation of the available data. As an example of how visual analytics may be implemented in future, flexible manufacturing systems, this thesis applies the technique to the task of planning process layouts in a reconfigurable manufacturing system. Process simulation is used as an automatic analysis component and its results are presented visually to aid the human process planner in the search for suitable process layouts. An evolutionary algorithm is used to automatically find and suggest layout variations. This is proposed as an alternative to the traditional process planning and control, which plans for weeks in advance and is not generally meant to take full advantage of the flexibility of a reconfigurable manufacturing system.

The layout planning prototype operates on implicit data, given by the specification of the available process elements, their behaviour, and their interactions. The challenge in handling this data lies not in accessing a large volume of stored data but in evaluating a given point in a virtual data space. Handling an explicit data set is discussed in the context of another system for the classification of machine conditions based on pre-recorded diagnostic data. Issues of increasing response times when handling large volumes of explicit data are then addressed in a system for the exploration of a large real-world data set from the public transport domain. The thesis also includes the proposition of a novel way of navigating through data ordered along

one dimension such as time, as analysing data over time is very common in both manufacturing and public transport.

The contribution of this thesis is a classification of visual analytics data space types and analysis tasks, each derived from one of the presented systems. It is shown how this classification can be extended to other works of contemporary visual analytics research.