



Martin Ron Ph.D. Thesis Assessment Report

Candidate Name:	Martin Ron
Research Degree:	PhD
Title of Thesis:	Pattern Discovery, Learning and Detection in Time Series

The PhD thesis "Pattern Discovery, Learning and Detection in Time Series" addresses time series analysis applied to data logged from robotic plants. The work has a strong interdisciplinary scientific foundation, involving machine learning, control theory, signal processing, and statistical modeling. The novel solutions developed are validated on a real industrial use case, namely a robotic cell running in Skoda Auto plant.

The thesis clearly formulates appropriate research questions, defining explicit research objectives that have been achieved by following rigorous scientific methods, with a constant focus on the experimental validation.

The dissertation is well structured and written, and the work is correctly based on strong hypotheses. The methods and results are presented in a clear, precise and comprehensive manner. Several relevant and original novel contributions are provided. The objectives, which are clearly stated and achieved, can be summarized as in the following:

- design methods for automatic search of a-priori-unknown patterns in time series;
- solution to cluster the variable-length sequences to reduce the number of the unsorted patterns into groups containing only patterns
- machine-learning methods for the identification of the model parameters and their application on an online detection of repetitive behavior observed in time series
- Validation of the results on a robotic cell running in Skoda Auto plant

In conformity with the requirements for awarding a Ph.D. degree in the Czech Republic, the following points are explicitly examined:

- **The subject of the thesis is relevant to the current needs of the scientific community**

The motivation to this study is clearly stated and well justified from both a scientific and industrial point of view, the subject of the thesis is original, innovative and

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relevant to the current needs of the scientific community; the reviewer believes that during the next years the thesis should achieve a good impact in the scientific and industrial community.

- **The main objectives of the work have been fulfilled**

Relevant and appropriate research objectives have been formulated, and their achievement has been demonstrated and correctly explained.

The modelling of the collision detection and path generation should need further work to be effectively used in real industrial case scenarios.

A novel contribution on the identification of unknown patterns as Motif Discovery problem has been provided. A novel similar measure utilizing the information content of the samples was presented for clustering variable-length sequences into groups containing only similar patterns. This contribution seems to have a wider application field. Original machine-learning methods have been developed for the identification of the model parameters and were applied on an online detection of repetitive behavior observed in time series.

In future works it would be relevant for the scientific community a deeper analysis on the validation of the proposed solutions on industrial case studies, with a tangible and quantitative evaluations on the improvements with respect to other solutions.

- **The methods used in the thesis are appropriate**

The work has been developed following a rigorous scientific approach, adequately motivated and explained. In chapter 2, the Model of Robot Dynamics is state of the art, the reviewer would suggest to improve it with models of the energy losses, which are fundamental to compute the energy consumption. The contribution of the energy stored in the robot/plant capacitors would be also important, especially when unexpected deviations from the nominal tasks occur (e.g. lack of a part in the feeder introducing delay in the robot task). At state of the art, robotic cells time series are triggered from robot controllers and PLCs. In the future, a quantitative comparison with such methods would be of interest, also for practitioners.

The thesis presents original and innovative methodological scientific contributions, which clearly prove the scientific maturity of the candidate, who has clearly demonstrated a solid knowledge and a strong interdisciplinary attitude in solving complex problems.

- **The work is important for the further development of science**

The work clearly improves the state of the art for the further development of science. The methods are original and valid, the results are presented in a clear, precise and comprehensive manner, providing the necessary quantitative and



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tangible evaluations. The interpretation of the results is performed correctly, following an accurate scientific method.

- **The thesis satisfies the conditions of a creative scientific work**

The thesis provides novel, creative and solid scientific contributions, that clearly prove the scientific maturity of the candidate. The list of the candidate's works related to the thesis further confirms a strong scientific research attitude with a prolific publishing activity.

The candidate proved to have the ability to perform high quality research and to achieve scientific results.

The author of the thesis proved to have an ability to perform research and to achieve scientific results.

I do recommend the thesis for presentation with the aim of receiving a Ph.D. degree.

Sincerely,

Prof. Marcello Pellicciari

Director of the PhD School

"E4E-Engineering for Economics, Economics for Engineering"

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