THESIS REVIEWER'S REPORT

I. IDENTIFICATION DATA

Thesis title:	**Anomaly detection in robotic assembly process using force and torque sensors**
Author's name:	**Aleš Trna**
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis reviewer:	Hossein Barghi Jond, Ph.D.
Reviewer's department:	Department of Cybernetics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment — **challenging**

How demanding was the assigned project?

The assignment is extensive and requires the student to explore various areas, including anomaly detection and time series analysis of multi-dimensional signals, both offline and online, using several state-of-the-art approaches.

Fulfilment of assignment — **fulfilled with minor objections**

How well does the thesis fulfil the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.

The thesis fulfills the main assigned task of applying at least two offline and one online anomaly detection method, thereby achieving its main goals. However, it lacks a comprehensive definition and discussion of the key aspects of anomaly detection in automation. Additionally, a thorough background investigation of anomaly detection in multi-dimensional time series is missing. The related work section is superficial and does not adequately familiarize the reader with the topic of the investigation and its associated literature.

Methodology — **correct**

Comment on the correctness of the approach and/or the solution methods.

The approaches used in the thesis are standard and commonly employed methods for addressing similar problems. The statistical and soft computing tools utilized are typical knowledge for a bachelor's graduate in information technology and automation or a related field.

Technical level — **C - good.**

Is the thesis technically sound? How well did the student employ expertise in the field of his/her field of study? Does the student explain clearly what he/she has done?

The thesis is technically sound, and the student has employed all the appropriate statistical and soft computing tools effectively. While the writing and organization of the thesis is poor, the student has made an effort to clearly express the work undertaken.

Formal and language level, scope of thesis — **E - sufficient.**

Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?

The thesis exhibits several issues with formalisms and notations. Abbreviations are introduced without spelling out the full term at its first mention (e.g., "CNN-MLP" and "LSTM" in subsection 1.1. Additionally, there are potential notational errors in formulas (3) and (4), where "s" should likely be "i" or "n" to denote the updated mean after the nth data point.

The organization of the thesis could be improved. Before subsection "1.1 Related Work," the thesis should have defined anomaly detection and its key aspects of anomaly detection in automation, as well as time series analysis, possibly supplemented with figures or tables. Additionally, the related work section would benefit from categorizing approaches into "statistical methods," "deep learning," "data-driven methods," etc., and discussing related works under these categories.

The thesis is extensive but includes too much unnecessary information, making it difficult to read and poorly organized.

The presentation of the thesis has several shortcomings. It lacks appropriate flowcharts of the algorithms and methods used, which would facilitate understanding the work. Additionally, some figures in Chapter 5 are either not referred to or poorly described within the text.
The language is not consistently clear and understandable. There are grammar and writing issues, such as vague sentences (e.g., "For both architectures of methods, the principle, training, and approach to all variants built upon the idea of the given architecture is presented" in Chapter 3 and poorly represented mathematical formulas.
The English needs improvement. Issues include abbreviations used before being defined, improper capitalization (e.g., "table 1.1," "chapter 2.3.4," "euclidean"), and unclear references (e.g., "The process of training the detector to work on the data streams is explained in the following article" on page 21, which lacks a specific article reference). Additionally, equations are reset in Chapter 4, with the first two being well-known and not needing citation in the equation line itself.

Selection of sources, citation correctness **D - satisfactory.**

Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?

The selection of references and their relevance to the state-of-the-art and technical aspects is satisfactory. While I lack familiarity with the state-of-the-art for the specific industrial problem focused on the thesis (i.e., anomaly detection in production line), the technical aspects are not clearly distinguishable as it utilizes common statistical and soft computing tools. However, the specific industrial problem addressed in the thesis could be discerned from the literature and may merit further exploration in a paper. The bibliographic citations at the end of the thesis do not adhere to a specific citation style.

Additional commentary and evaluation (optional)

Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.

It sounds like the student has put forth a significant effort in preparing the thesis. Undertaking tasks such as applying theoretical knowledge, collecting data, training models, and conducting experiments within a single semester can be challenging for an undergraduate student. It's understandable that with such time constraints, issues regarding thesis organization, writing errors, and explanation improvements may arise. Despite these weaknesses, the strength of the work lies in its endeavor to address an industrial problem. The theoretical and experimental results demonstrate the student's potential and readiness for a career in automation.

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Summarize your opinion on the thesis and explain your final grading. Pose questions that should be answered during the presentation and defense of the student's work.

Questions the student could be asked in the defense session:
What are the common distance metrics used for feature vectors in training supervised learning models?
Why were Euclidean distances (L2 norm) chosen in Subsection 3.2.2 for the training algorithm?
How does the multidimensionality of the signals affect the choice of the distance metric, if at all?
What are the dimensions of the feature vector in the training algorithm in 3.2.2, and are the features correlated?
In Subsection 3.2.5, it is claimed that, based on experience, it is better not to update the prototypes in the continual learning model. Can this experience be justified mathematically?
What are the hyperparameters of the LSTM-MLP architecture in Figure 4.2 that need adjusting for the efficiency of the task in this thesis, and how are they adjusted?

The grade that I award for the thesis is **C - good.**

Date: **25.5.2024** Signature: