Subjective vs objective assembly complexity assessment: a comparative study in a Human-Robot Collaboration framework

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Subjective vs objective assembly complexity assessment: a comparative study in a Human-Robot Collaboration framework

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Key words: manufacturing complexity, perceived complexity, assembly, quality

Extended Abstract

The impact of manufacturing complexity on company performance can be significant, affecting productivity, efficiency, affordability, and quality if not managed correctly. Assessing and managing manufacturing complexity is a multifaceted task that involves both objective and subjective features, such as product complexity, assembly sequence, operator factors, and operation/management strategies. This study proposes a structured methodology to assess the perceived complexity of human-robot collaboration assembly processes. The methodology is based on 16 assembly complexity criteria and a multi-expert decision-making method for evaluation. Operators assign importance scores and agreement levels to each criterion using a five-level ordinal scale, and the linguistic data is processed using the Multi-Expert Multi-Criteria Decision Making (ME-MCDM) method [Yager(1993)]. This approach combines linguistic information provided for non-equally important criteria using maximum, minimum, and negation operators to obtain an overall synthetic linguistic value of perceived complexity using fuzzy logic. The proposed approach provides an assessment of perceived complexity at both individual and overall levels, aggregating all individual complexity assessments by the operator Ordered Weighted Average (OWA) [Yager(1993); Filev(1994)].

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The proposed approach for assessing perceived complexity of assembly is compared with a purely objective assessment method, firstly proposed by Sinha et al. [Sinha(2012)]. This model was validated in various studies, and its effectiveness in quantifying the complexity of industrial products was demonstrated [Verna(2022)]. It is based on the molecular orbital theory and is applied to the engineering domain to analyse the complexity of cyber-physical systems. The model represents a cyber-physical system as several connected components where each component can be thought of as an atom, and the interfaces between them as inter-atomic interactions or chemical bonds. The complexity of the assembly is defined as the combination of three complexity components: handling complexity (C_1), connections complexity (C_2), and topological complexity (C_3), as follows $C = C_1 + C_2 \cdot C_3$. This objective model, based on structural characteristics of the assembly process, was used as a reference model for the subjective complexity model.

The comparison between subjective and objective assessment of complexity was performed in a real-world production environment, using a human-robot collaboration process for manufacturing custom electronic boards with different levels of complexity. The results showed a significant correlation between individual perceived complexity and objective complexity, indicating that the proposed perceived complexity model can be linked to the objective model. As structural complexity increases, higher levels of individual perceived complexity become more likely, but the variability in perceived complexity varies with structural complexity. These findings suggest that individual operator ability and cognitive factors, such as training, knowledge, and cultural and organisational factors, play a role in perceived complexity and require further investigation. The study also suggests that using perceived complexity to assess assembly complexity is suitable for low- and medium-complexity products, but not for high-complexity products, where objective complexity models may be more appropriate, since after a certain point operators do not distinguish between different levels of complexity.

The proposed methodology and data analysis approach offer a new perspective on assessing perceived complexity, relying solely on synthesis operators and statistical tools suitable for categorical data. Engineers can use the study's results to minimise perceived complexity and ensure alignment between perceived and objective complexity.

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