Efficient Application of Metaheuristic Algorithms for Balancing Human Robot Collaborative Assembly Lines

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Introduction

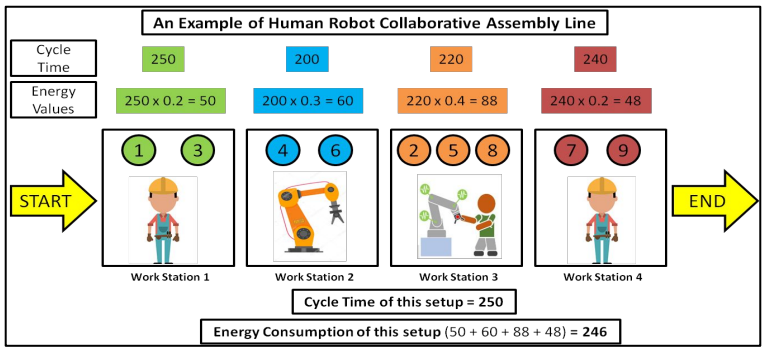
Assembly line balancing (ALB) is a method of optimization in which the overall assembly workload is divided in such a manner that each task in the workload follows precedence relationships and their allocation to workstations and the available set of resources yield the least amount of lead time to complete the entire assembly process.
This project is regarding the Human-robot collaborative (HRC) ALB, where workforce allocated to the lines involve both humans and automation. The workforce resources are to be allocated such that the assembly line is made efficient.

Scope of the project

- To develop and implement multi-objective metaheuristic algorithms for balance semi-automated assembly lines by **minimizing cycle-time & energy consumption**.
- To improve existing metaheuristic algorithms using a new hybridization approach.
- Develop **flexible HRC data generation methods** for industrial settings.
- **Case study**: Test & validate performance on industrial data.

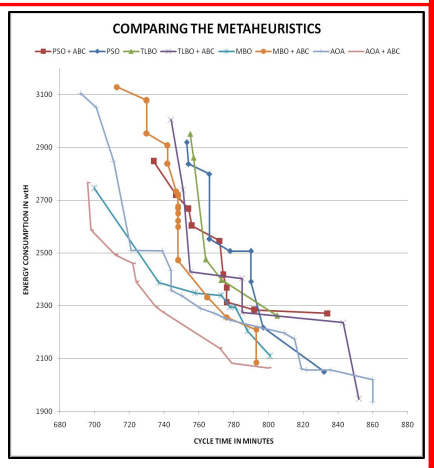
Methodology

- Input datas of **task & setup times, precedence**, robots and human resource availability, line specifications (**constraints**) are considered.
- Optimal task sequence and resource allocation is generated by the developed algorithms using **consecutive method**.

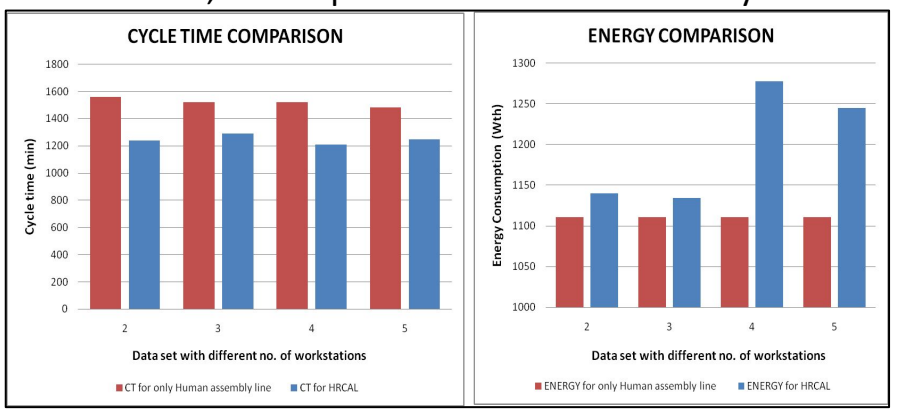


- To find solutions of optimal allocation (Pareto optimal set) that simultaneously considers both cycle-time & energy consumption (multi-objective), **non-dominated sorting** is implemented.
- Four multi-objective discrete algorithms **PSO, TLBO, MBO & AOA** are developed using newly proposed discretization procedure.
- **Hybridization** for all algorithms are carried out using scout phase from **ABC** algorithm, to enhance performance.
- Developed algorithms are tested using five performance indicators that measure solution counts, spacing, error, etc.
- **Parametric fine tuning** methods are implemented for the developed algorithms, to provide researchers the best individual parametric value range for easy implementation.
- **32 standard testing HRC datasets** are proposed and generated based on problem sizes of small (<50 tasks) , medium (50 to 100 tasks) & large (>100 tasks).

Result and Discussion



- All developed standard & hybrid algorithms were run for the 32 developed datasets, for equal no. of iteration and population size.
- **Friedman test** showed significance ($p < 0.05$) between the algorithms.
- To investigate significance, a post-hoc test (**Scheffe test**) was carried out, which revealed that the AOA algorithm showed the highest significance in performance with large pareto front & better solutions as shown.
- The input data as mentioned in methodology are gathered from an electronic parts assembly industry(**Sanmina Corp**).
- Existing **manual sub-assembly process was identified and was semi-automated** considering managerial implications, to implement the HRC problem.
- Results from the algorithmic allocation of task and resources showed the improvement in cycle-time for a small compromise in energy consumption due to automation, as compared to a manual assembly line.



- The results also validate the working of the algorithm in generating balanced and feasible assembly line allocation where both human & robots work together.

References

Tamás Koltai, Imre Dimény, Viola Gallina, Alexander Gaal, Chiara Sepe, An analysis of task assignment and cycle times when robots are added to human-operated assembly lines, using mathematical programming models, International Journal of Production Economics, Volume 242, 2021, 108292, ISSN 0925-5273, https://doi.org/10.1016/j.ijpe.2021.108292.
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Conclusion and Discussion

HRC workspaces proves to be economical and efficient as cost of automation is reduced. The associated advantages of human such as decision-making, flexibility can be combined with the speed, accuracy and consistency of robots. The level of HRC resource allocation can also be adjusted according to the needs of any industry.

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