POLITECNICO DI TORINO
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Task Modeling for Task-Oriented Robot Programming

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1. Introduction

Programming complex robotic tasks can be very difficult, and is usually carried out by programmers very skilled in different fields. A task-oriented programming approach, leaving the programmer design only the process itself and the robotic cell by means of some CAD drawer software, makes the programming process simpler and invariant to the skill level of the programmer. The usage of complex models, including the notions of task and world at the same time, allows to take into account both the process constraints and the physical ones.

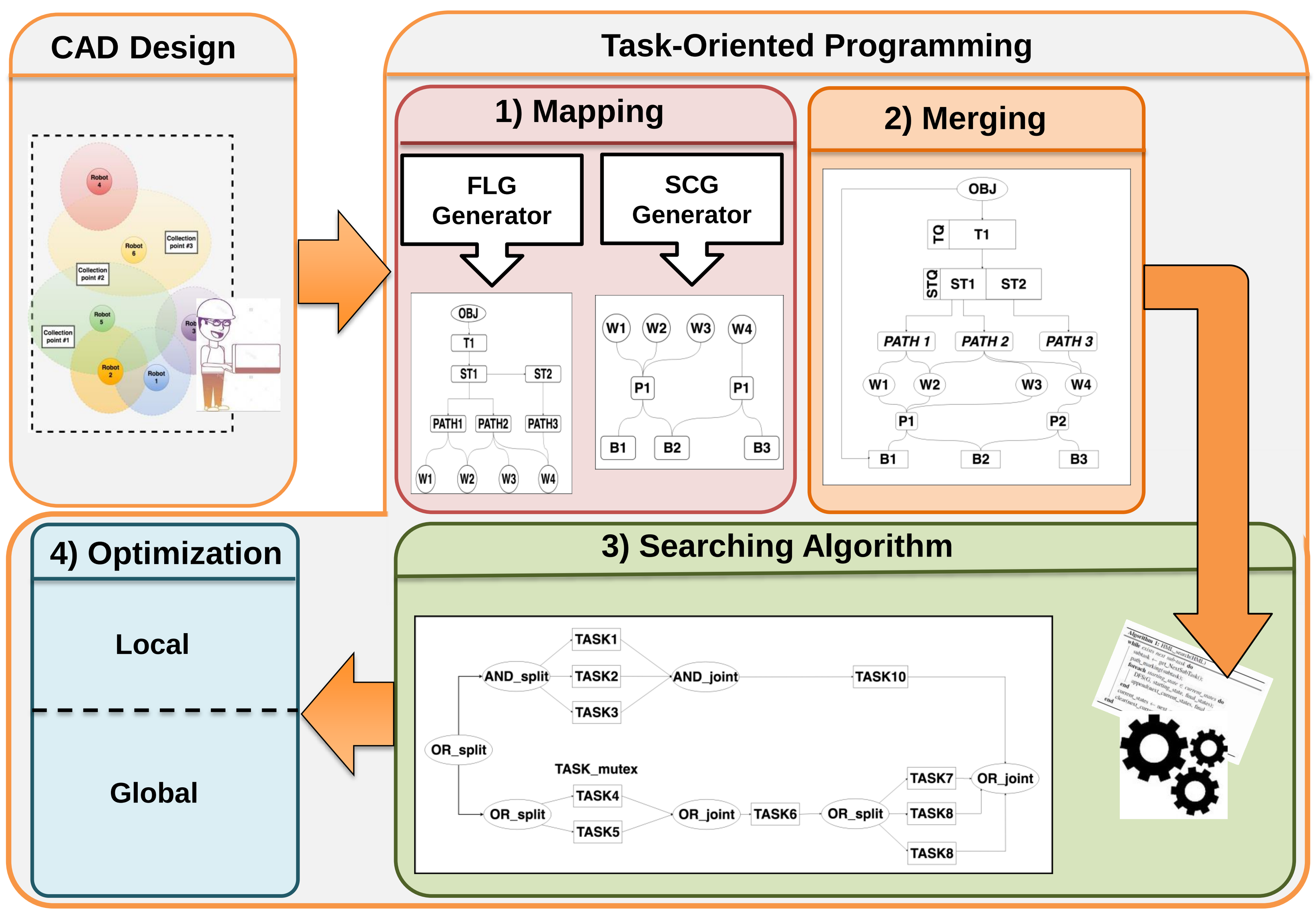
2. Goal

The final aim of this work is to develop a task-based robot programming approach that automatizes the programming of a generic robotic cell, providing as a result the work-flow defining the required process.

3. Method

The proposed methodology is divided into three main steps; the first one is carried out by the programmer, who has to design both the robotic cell and the process (as sequence of tasks), by means of a high level software (e.g., CAD software). Only the knowledge of the process and the software tool is required in this phase. The second step is carried out by the Task-Oriented Programming module, that defines the real actions to be performed by each machinery in the cell, using the information provided by the user. The third step concerns the deploy of the program into the real controller.

The work has been focused on the Task-Oriented Programming step, which is defined by 4 phases:



The approach is based on a proper task model able to take into account both **physical** constraints and **functional** ones between machineries and tasks.

- **Assumption:** Any task can be described by the sequence of four basic phases (or by a subset of them): i) picking the workpiece, ii) positioning the work-piece within a proper sub-set of the working-area, iii) working, iv) placing the work-piece.
- **Functional constraints**: the set of relations between the required tasks and the available machineries (e.g., $task_1$ can be performed by $machine_1$), can be modeled by a proper graph called Functional Link Graph (FLG).
- **Physical constraints**: the adoption of some machineries can be limited because of their location or their physical characteristics; such constraints can be modeled by a proper graph called Spatial Constraints Graph (SCG).

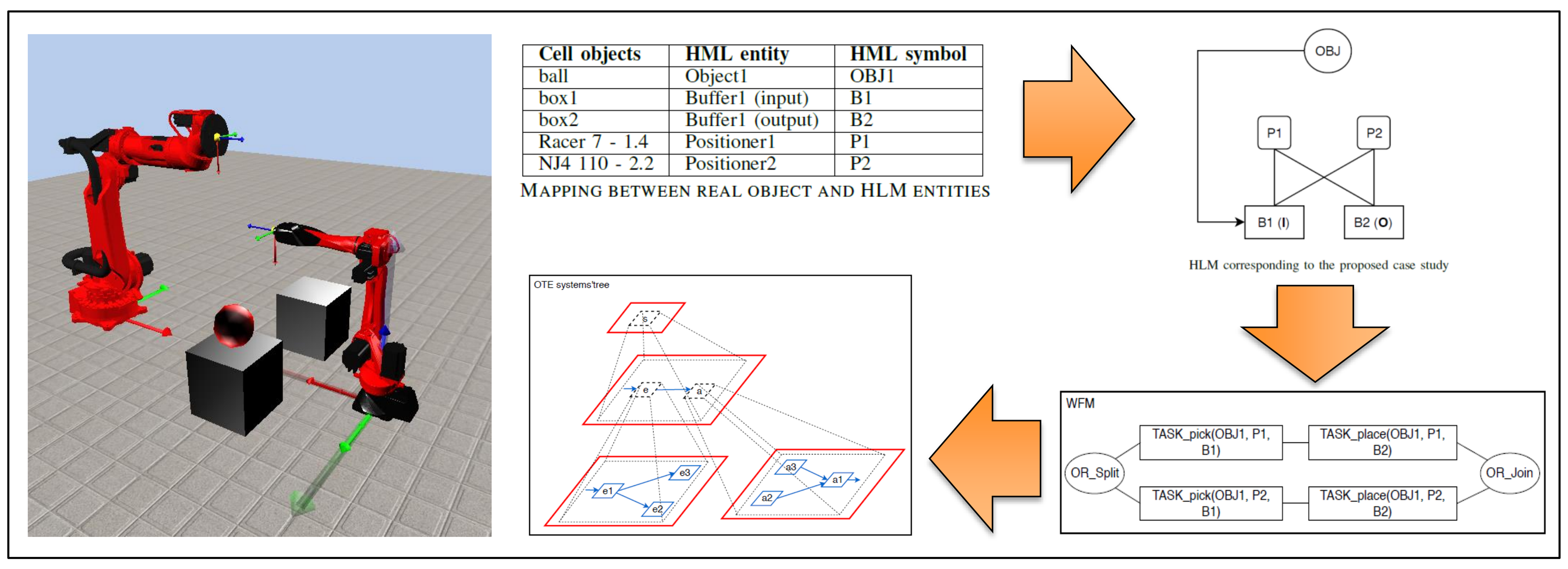
A set of logical entities and a three-level task descriptor (Task, Sub-Task and Path) have been developed to build the FLG and the SCG within a mapping process. An overall model, called High Level Model (HLM), including functional and physical constraints is obtained by merging the FLG and the SCG. All the possible work-flows carrying out the process (with each work-flow given by a sequence of basic phases) are represented using the Work Flow Model (WFL).

Entities	Role	WFM block	Role
Buffers	Real objects used to store the work-piece	**AND_Split**	Open a parallel execution
Positioners	Real objects able to grip the work-piece	**OR_Split**	Open a mutual exclusion execution
Workers	Real objects able to perform a specific process	**AND_Join**	Close a parallel execution
Objects	Real objects that need to be processed	**OR_Joint**	Close a mutual exclusion execution
Virtual	synchronization and physical connections	**TASK**	Recursive basic blocks or a basic task

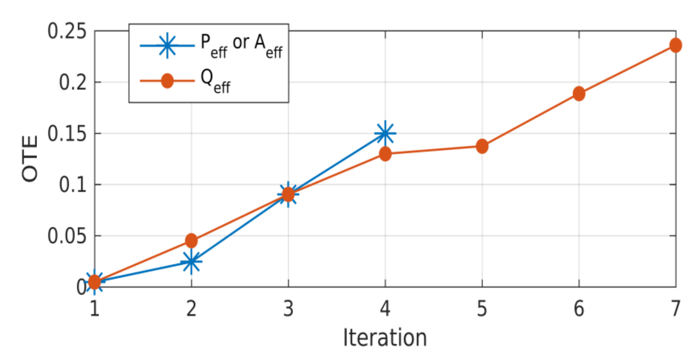
The WFM can be automatically obtained applying a specifically developed searching algorithm to the HLM. The algorithm carries out a DFS search inside the SCG (that corresponds to a not oriented connected graph $G(V,E)$) for k times, where k is the number of basic tasks required by the process. The overall complexity can be approximated as $O(k \cdot n \cdot m)$ where $n = |V|$ and $m = |E|$.

4. Results

The proposed approach was tested for realistic industrial applications (e.g., Pick&Place), for which the WFM has been obtained. It was also integrated in a general optimization framework based on the usage of Key Performance Indicators (KPI) called OTE/OEE, in collaboration with the Università Politecnica delle Marche (UNIVPM). The architecture was tested for a pick and place application carried out in a robotic cell composed by two industrial Comau robots, a Racer 7 – 1,4 and a NJ4 110 – 2,2.



The output of the Task-Oriented Programming was tested using the Comau robot simulator (ORL). The integration of the optimization methodology allowed to improve the performance of the robotic cell



5. Conclusions

The work proposes a programming approach for robotic cells that automatizes a portion of the programming process. The goal has been reached through the development of a complex task model (HLM), taking into account physical and functional constraints at the same time. The approach provides all the feasible work-flows performing the given task (WFM) in a known robotic cell. An optimization process allows to chose the best work-flow according to some criteria. The developed workflow model is suitable for a possible conversion into Petri Nets, as well as for the inclusion in production efficiency frameworks aimed at optimizing the overall process and avoiding possible bottlenecks.

6. Other results

The PhD Project has been carried out in Apprenticeship in collaboration with COMAU, co-funded by Regione Piemonte. The project is part of a common research activity devoted to Smart Factories issues, including the development of general procedures and service algorithms of general validity. In particular very successful results have been obtained in the collision detection field, with the development of a general procedure (acknowledged among the five finalists of the 2017 euRobotics Technology Transfer Award) now integrated in the control software of all the Comau robots and applied to factories and production lines all over the world.

7. References

[1] Trapani, Stefano, and Indri, Marina. “Task modeling for task-oriented robot programming.” 22nd IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2017)

[2] Indri, Marina; Trapani, Stefano; Bonci, Andrea; Pirani, Massimiliano. “Integration of a production efficiency tool with a general robot task modeling approach”, 23rd IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2018)

[3] Indri, Marina and Trapani, Stefano. “Programming robot work flows with a task modeling approach”, 44th Annual Conference of the IEEE Industrial Electronics Society (IECON 2018)

[4] Indri, Marina; Trapani, Stefano; Lazzero, Ivan. “Development of a Virtual Collision Sensor for Industrial Robots”, SENSORS.- 17:5(2017), pp. 1-23.