Karlsruhe Institute of Technology

Institute of Production Science

# Robot-based guiding of extrusion profiles – reduction of the material waste in the manufacturing process

**International Conference on Sustainable Manufacturing, ICSM 2014**
**Shanghai, 2014/10/24**

**wbk** Institute of Production Science

# Agenda

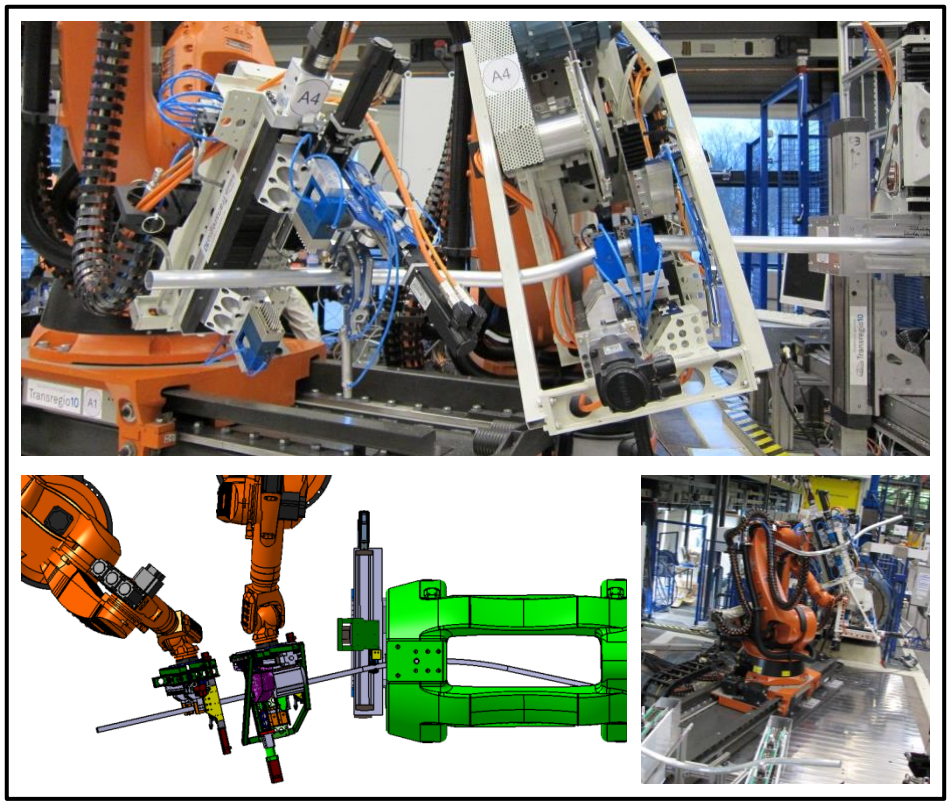
*Motivation*

*State of Art*

*Approach*

*Sequence optimization of the manufacturing process*

*Summary*



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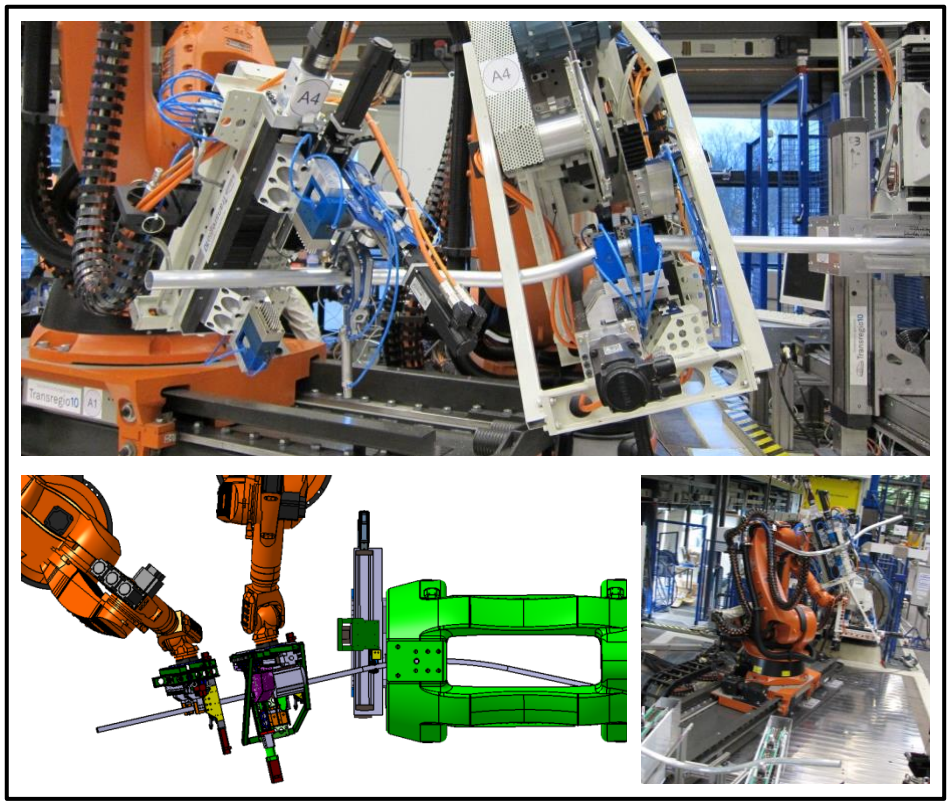

# Motivation
## *Trends in industry*

- Weight reductions especially in the area of automobile and aviation industry
- Enlarged required-product-diversity, i.e. small series production.


http://www.leichtbau.de/tr10

A flexible production of individual product varieties and lighter construction of aluminum space-frame-structure is needed

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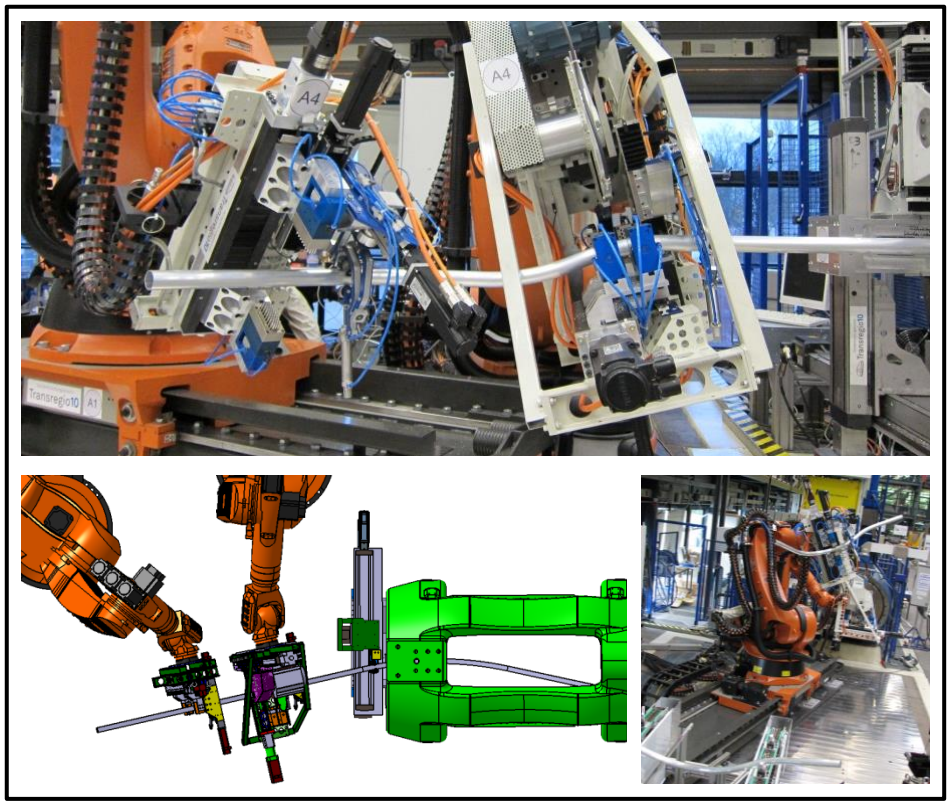
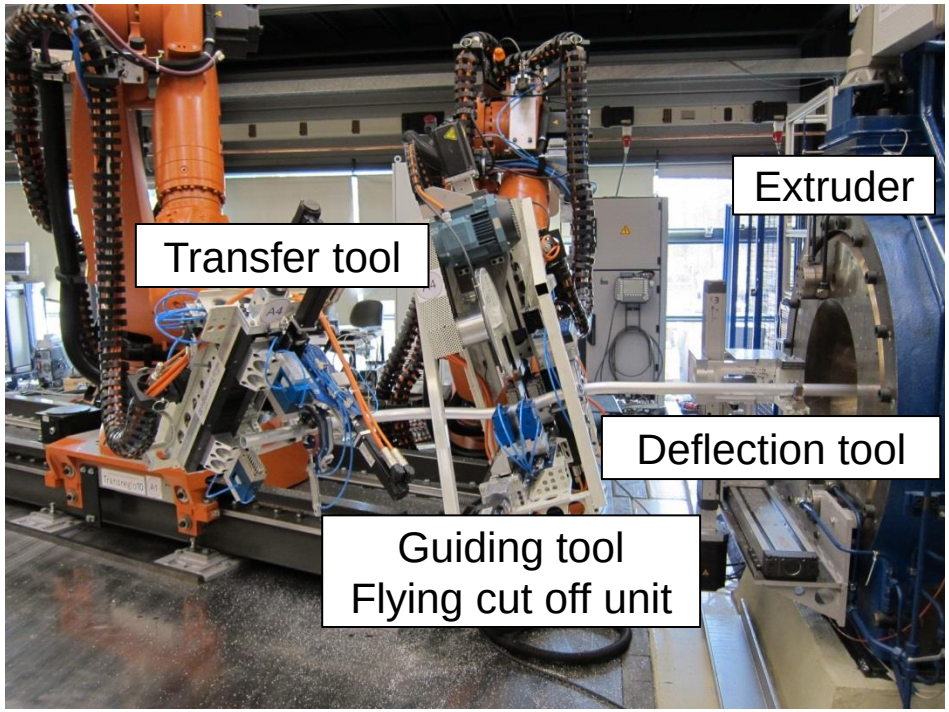


# State of the art

## *The flying cut-off*

**Real manufacturing process**

- Manufacturing through extruder
- ↓
- Shaping by deflection tool
- ↓
- Guidance through the room synchronously to the process by industrial robots
- ↓
- Cut-off on the desired length by the flying cut-off unit




Flying cut-off installation

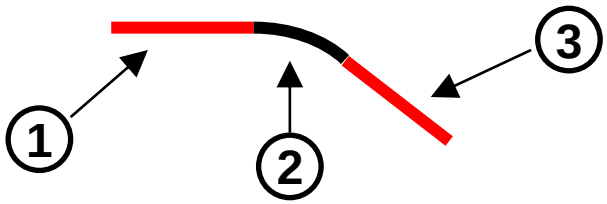
# State of the art

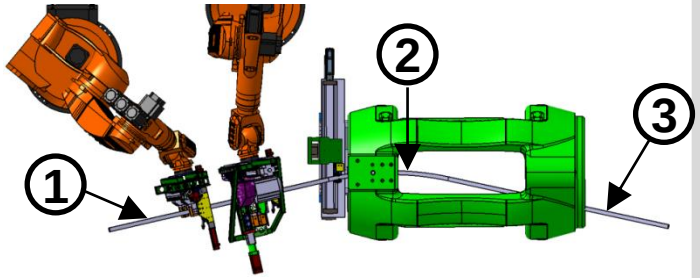
## *Material needed to create one profile*

The actual manufacturing installation only extrudes profiles one at a time.

In order to extrude a 3D curved profile (for instance Profile 2), two straight profiles have to be extruded (Profile 1 an 3).

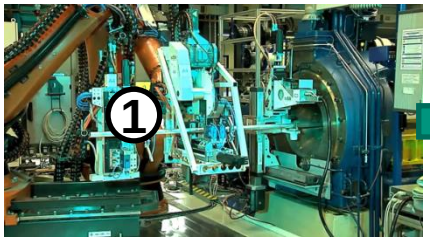
- Profile 1: straight profile has to be produced to align the guiding tools and the deflection tool in front of the extruder output. (Material waste)
- Profile 2: 3D profile
- Profile 3: straight profile, for the same reasons as the profile 1 (Material waste)



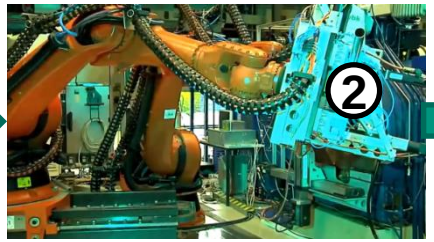




**Material waste:**

**circa. 50%**




Profile 1 is extruded




Profile 1 has been cut off,
Profile 2 is being extruded


Profile 2 is being cut off,
Profile 3 is being extruded

**Objective:**

Reduce the material waste thanks to a continuous production

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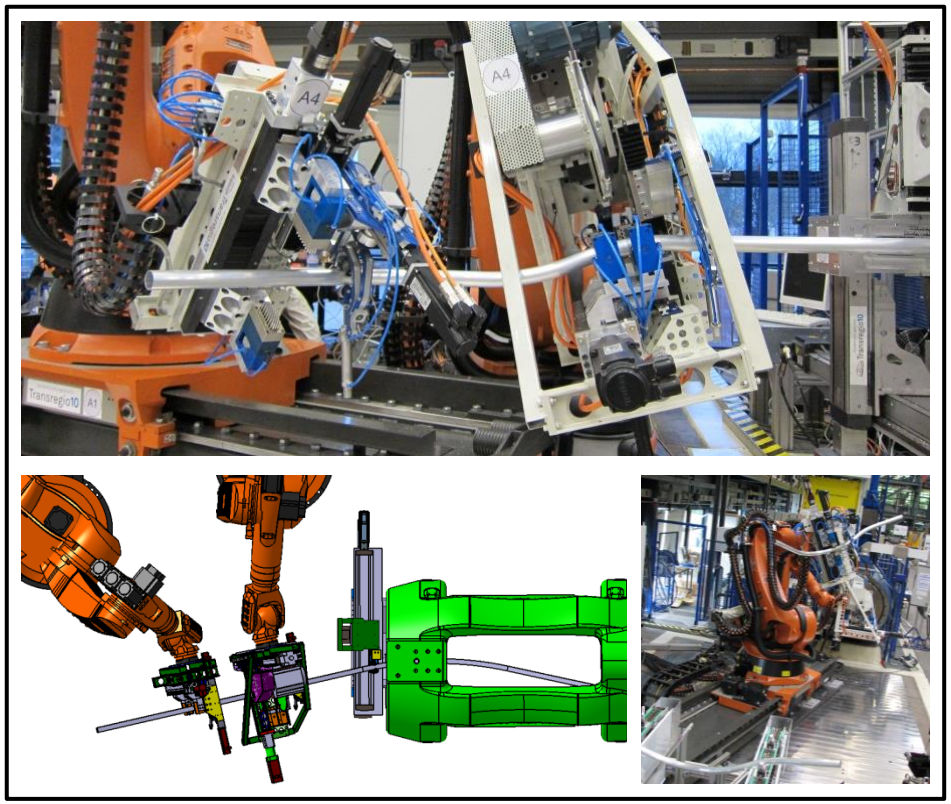
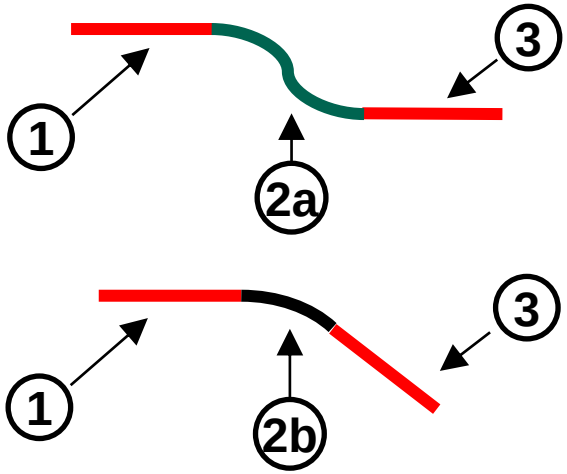
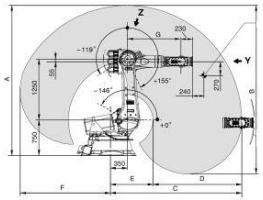


# Approach

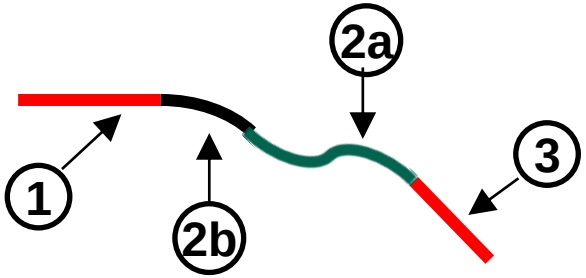
To produce several profile in a batch a straight profile is needed in between each 3d curved profiles.




Working Range of IR



optimization algorithm




Optimization based on

- Rotation of the profile
- Change of the chronological order of production
- Insertion of a straight profile

**Approach:**
Development of an optimization algorithm to determine the optimal chronological order of profiles to be produced and their orientation to each other

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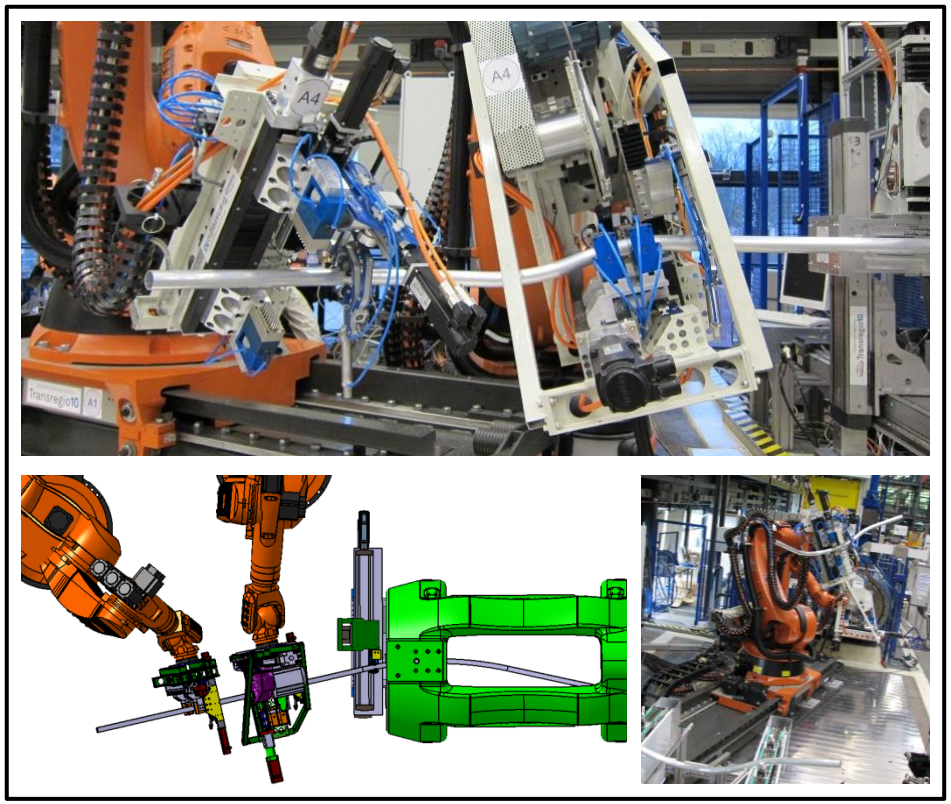
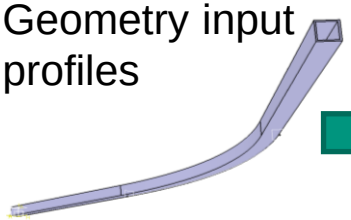


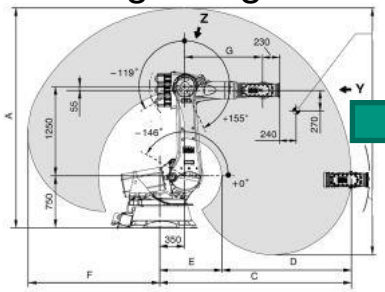
# Sequence optimization of the manufacturing process

## *Modelling of the optimization algorithm*

Geometry input profiles

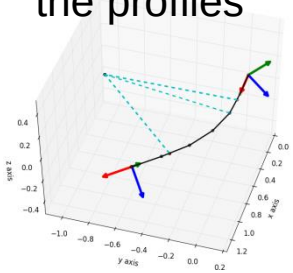


Working Range of IR

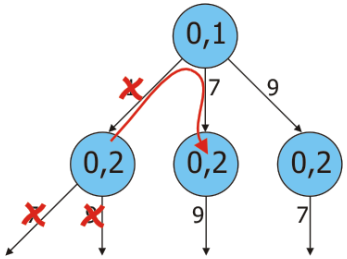



optimization algorithm

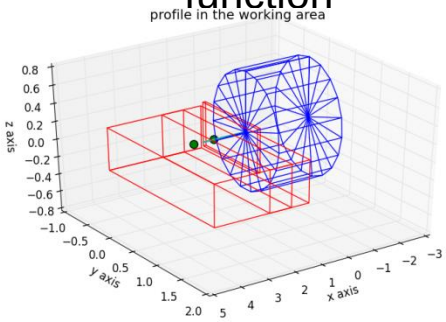
Mathematical description of the profiles



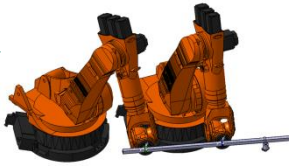

Optimization Method




Produceability test function

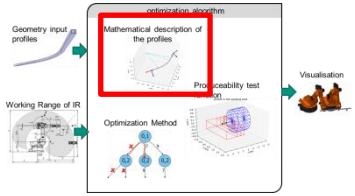



Sequence of profiles



# Sequence optimization of the manufacturing process

## Mathematical description of the profiles




**Working of the algorithm:**

- Joining of two profiles together
- Rotation of profile
- Test of the produceability

**Input profile:**

Line or cicle with:

- Initial orientation
- Start point, end point
- Rotation center point

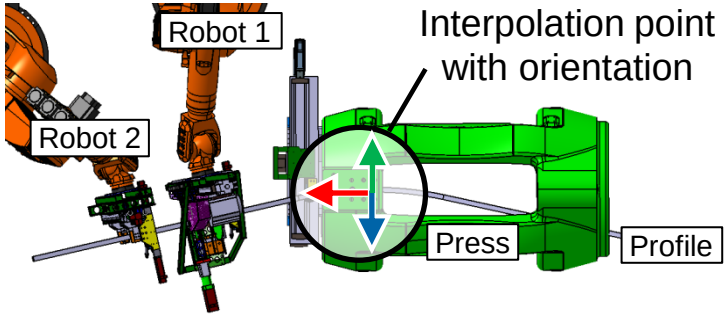
**Mathematical description of the profiles:**

Interpolation of the profile:

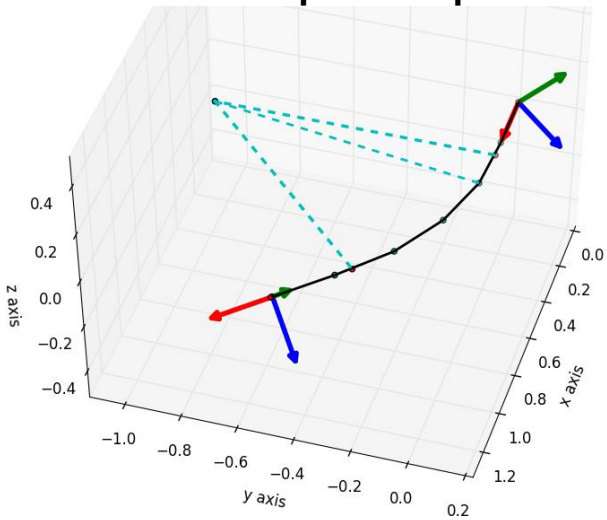
- Interpolation points with orientation
- Orientation of the end point

Profiles can now be joined and rotated to re-create the production process

**Produceability test**




**Creation of the interpolation points**

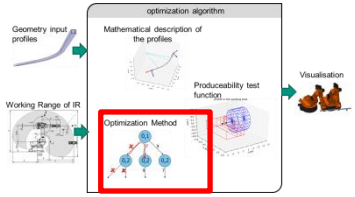





Prof. Dr.-Ing. J. Fleischer, Prof. Dr.-Ing. G. Lanza, Prof. Dr.-Ing. habil. V. Schulze

# Sequence optimization of the manufacturing process

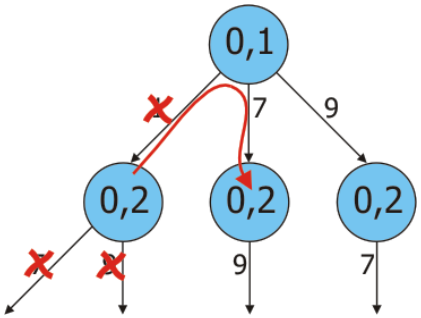
## Optimization Method




**Optimization algorithm:**

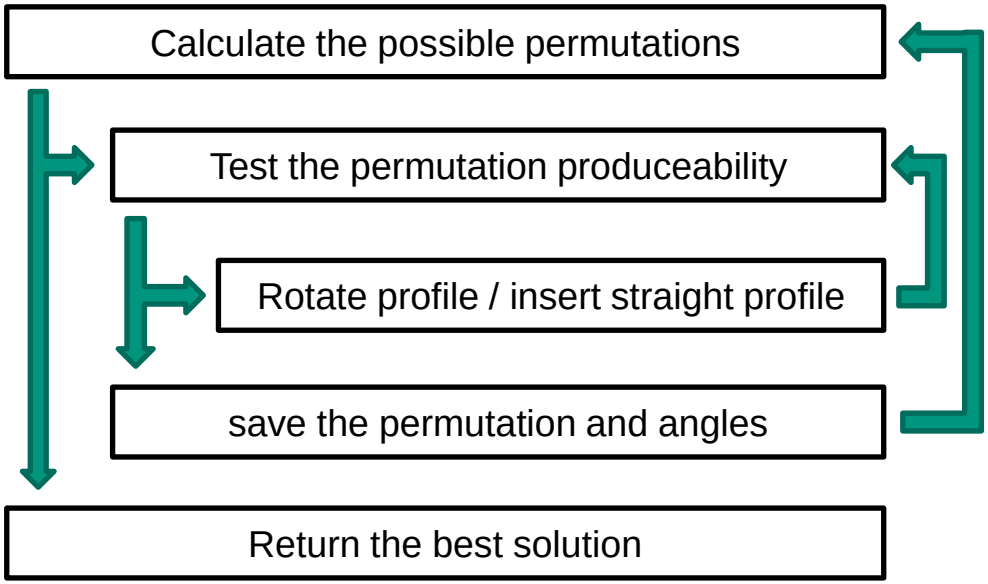
- Backtracking algorithm for testing the combinations
- Return of the less expensive solution in terms of material waste
- Time optimization through storage of joined profiles that can be produced together

**Backtraking algorithm**



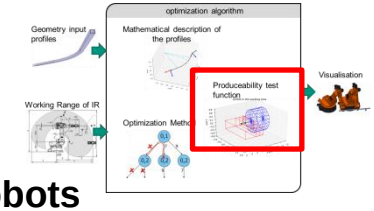

Profiles combinations are tested,
The best solution is returned

**Simplified chart flow**



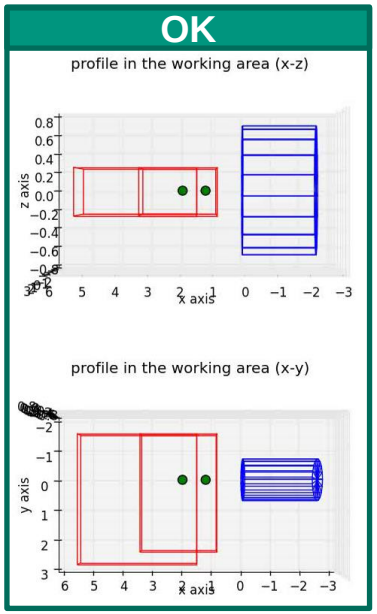
# Sequence optimization of the manufacturing process

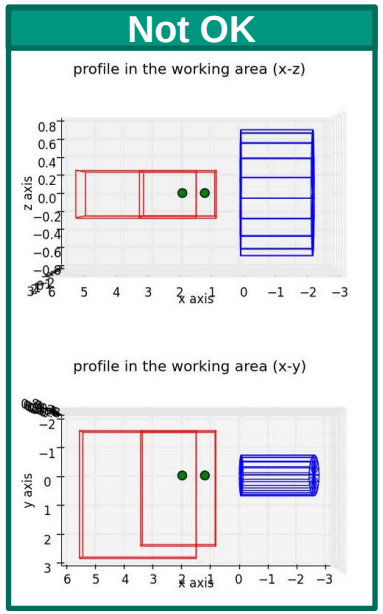
## Produceability test function




### Test function:

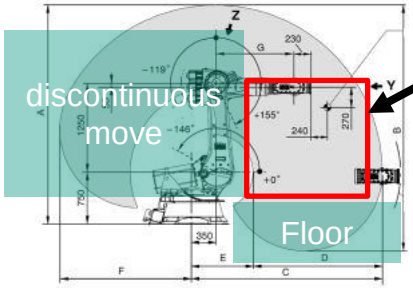
- Working range of Industrial Robots is limited by the installation floor or discontinuous move
- The profile combination is tested step by step



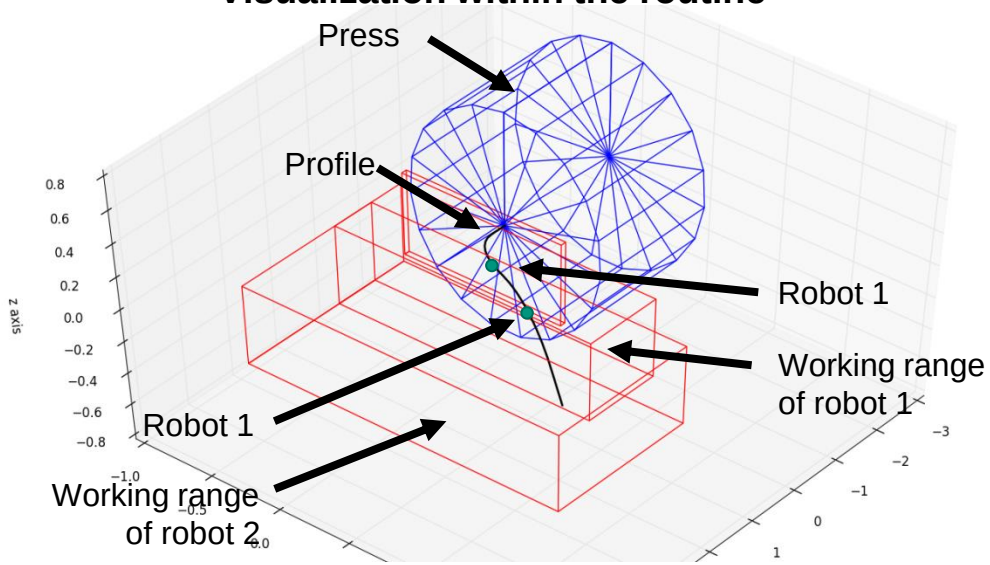




The combination is tested based on the producing process

### Working area of the robots



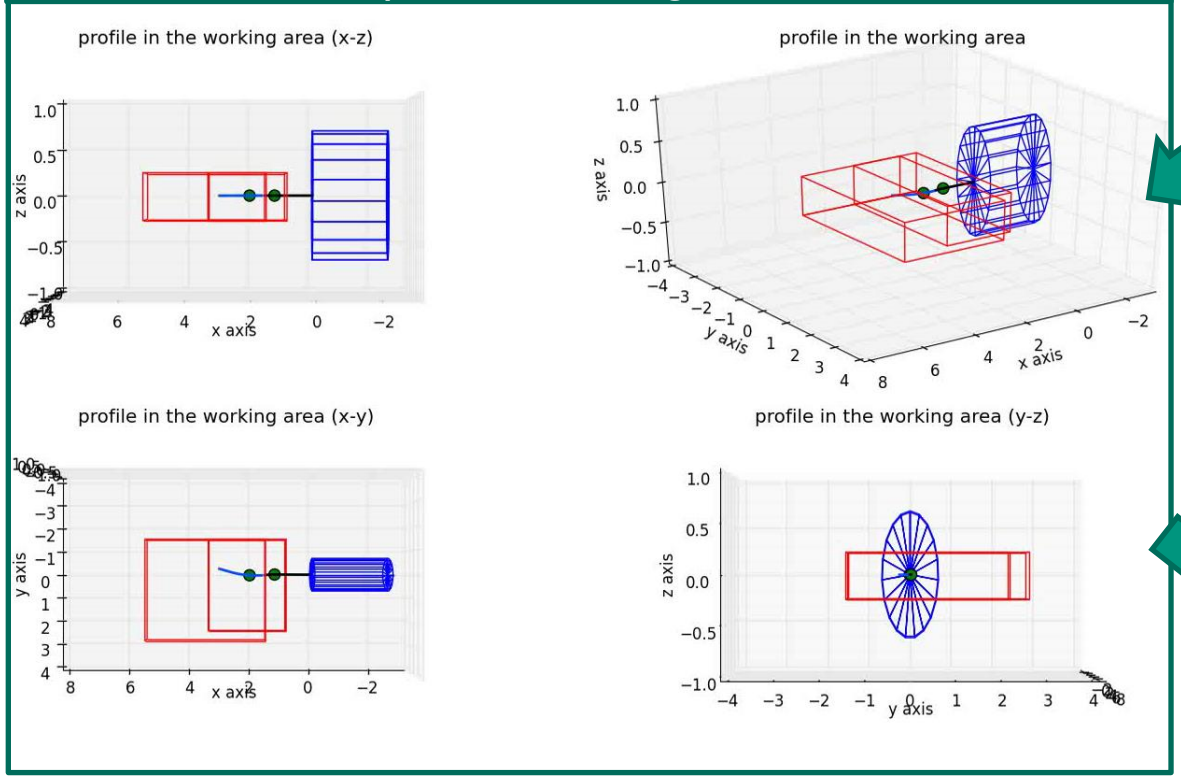

### Visualization within the routine



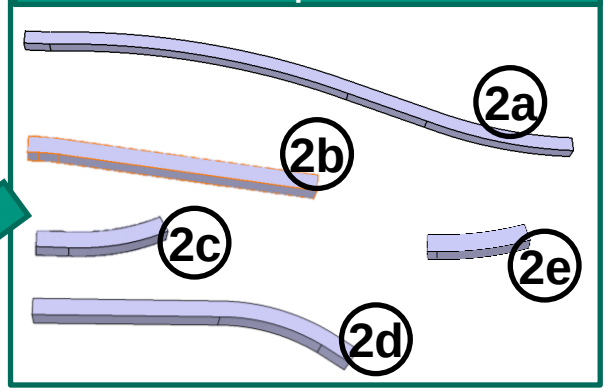
# Results

## Test of the algorithm:

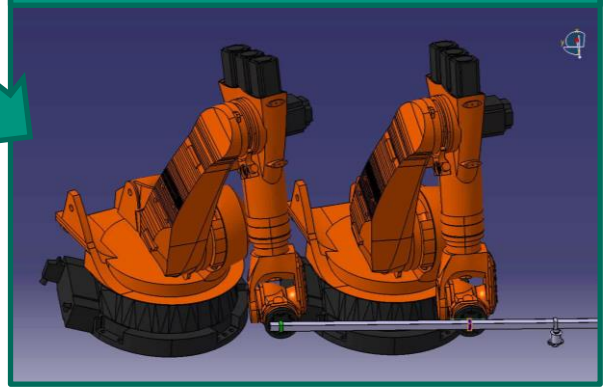
### optimization algorithm




### input




### results



Material reduction up to 50%

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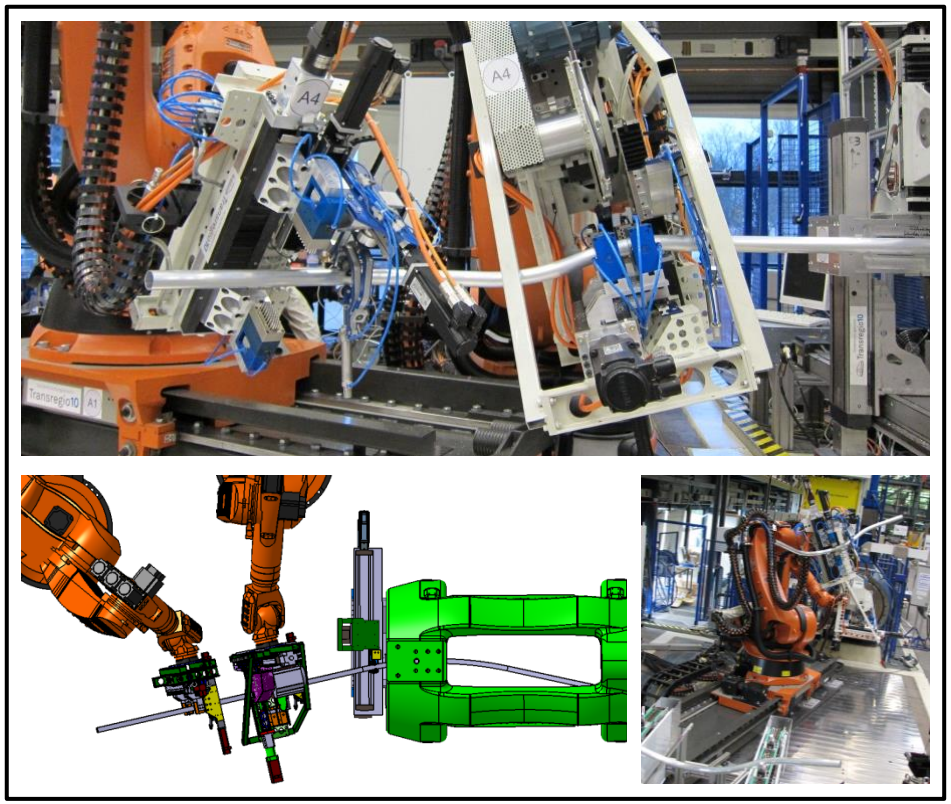
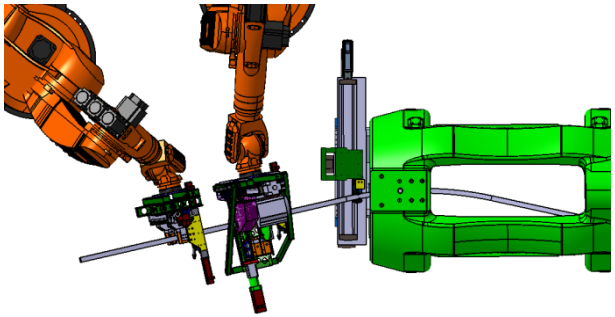


# Summary

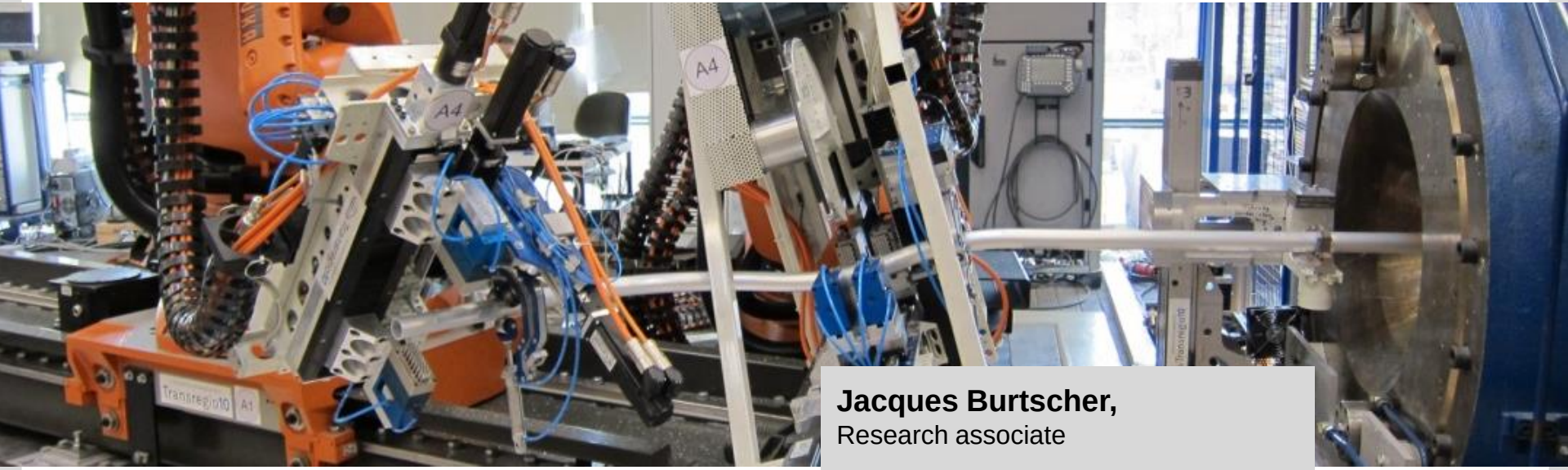
- **Objective:**
  Reduce the material waste by the means of a continuous production

- **Approach:**
  Development of an optimization algorithm to determine the optimal chronological order of profiles to be produced and their orientation to each other
  - Development of functions to describe the profile with interpolation points and their orientation
  - Development of functions to join the profile together, rotate the profile in the room and finally test the produceability of the combination
  - Test of the combinations thanks to backtracking

- **Result:**
  The best solution is returned, in this solution there are few or no inserted straight profiles.
  Material waste reduced (up to 50%)



# Thank you for your attention

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