ASSEMBLY PLANNING FOR HUMAN ROBOT INTERACTION WORK SYSTEMS

Introducing process building blocks and calculating accurate cycle times

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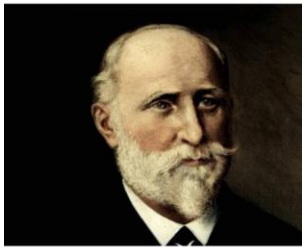
AGENDA

1. Overview Adam Opel AG
2. Human-robot-interaction (HRI) – Definition and motivation
3. Assembly planning HRI
4. Validation - Pilot case
5. Summary

OPEL – TRADITION & INNOVATION



Founder Adam Opel …

… and his five sons

Opel Lutzmann (1899)

Source: Adam Opel AG

OPEL – FACTS AND FIGURES

Headquarter, Rüsselsheim

Employees

- Total 35.600 in Europa
- More than 18.250 in Germany
- Sale of **over 1 Million** cars per year

- 10 Plants
- 1 Design center
- 2 Development centers

HRI - BENEFITS

Challenges

- **Shorter product lifecycle and increasing product variety**
- Assembly: High percentage of manual labor

Human-robot-interaction

- Human advantages: Cognitive skills, flexibility, versatility
- Robot advantages: Strength, precision, repeatability

⇨ Goal: Efficient cooperation between human and robot

Benefits

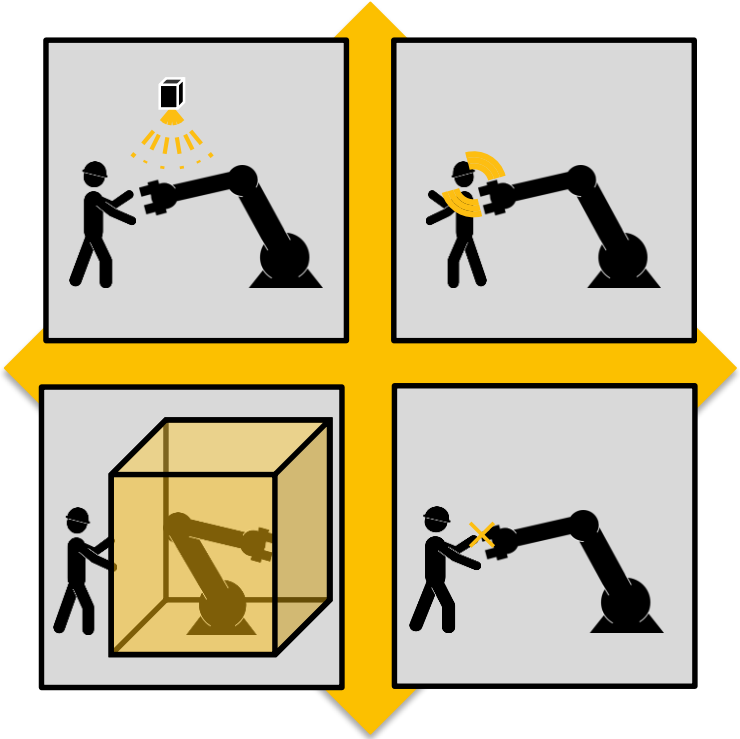
- **Improved ergonomics**
- Improved quality
- Lower unit cost

HRI DEFINITION

DIN EN ISO 10218: Types of collaborative operation

Speed and separation monitoring

Robot velocity dependent on distance to human



Power and force limiting by inherent design or control

Protective stop, if parameter limit is exceeded

Safety-rated monitored stop

No robot movement, while human is in workspace

Hand guiding

Robot movement controlled by human via hand guiding equipment

HRI - ASSEMBLY PLANNING

Assembly planning for direct human robot interaction

- Technical solutions for HRI are available
- Approaches for ‘classical’ assembly planning **do not** include HRI
- Simulation of work systems is very time intensive

Scientific gap

- Planning of assembly contents and task distribution for human **and** robot
- Guidance for the development of valid safety concepts in the early stage of assembly planning
- Assessment of different solutions in terms of economic benefits

Development of tool chain for designing and planning of human robot interaction work systems

HRI - ASSEMBLY PLANNING

Assembly planning for human robot interaction

- Definition of process building blocks for industrial robots independent of robot manufacturer
- Applicable for articulated arm robots with a payload up to 35 Kg
- Definition of content, work flow and significantly influencing factors for each process building block
- Assembly planning of HRI work systems in combination with MTM-1

MTM-1	Robot
Reach	Reach
	Orientate
Grasp	Grasp
Move	Move
Position	Position
Release	Release

Comparison of MTM-1 and robot process building blocks

Planning and design of human and robot based assembly systems in a single process language

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HRI - ASSEMBLY PLANNING

MTM-Process building block - Notation

Application independent part	Application specific part
1. Description	5. Factor • Quantity • Frequency
2. Content	
3. Process sequence	
4. Boundaries	10. Description with boundaries
6. Influencing factors	11. Target time
7. Codification	12. Additional attributes • Ergonomics • Value added
8. Norm time value	
9. Application rules	

Source: Handook Industrial Engineering, Bokranz and Landau, 2012

HRI - ASSEMBLY PLANNING

Definition process building block *Move*

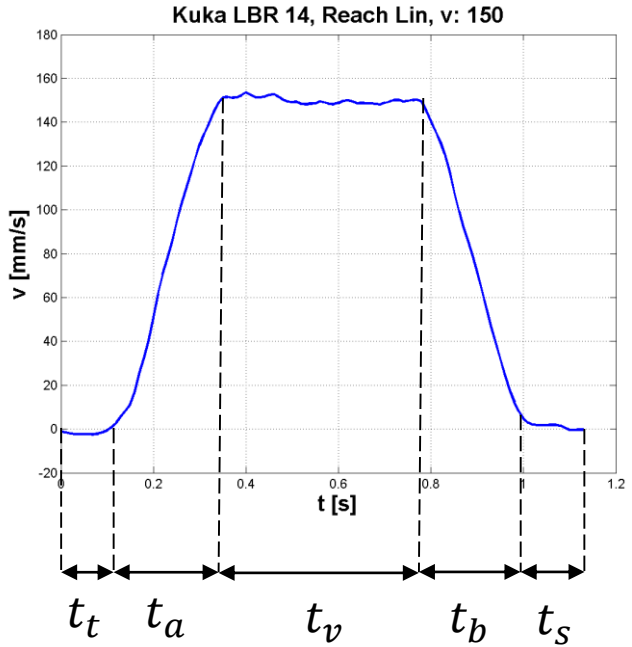
Move describes a motion transporting one or more objects to a target position.

Content and boundaries	
Start	Execution of the first move-instruction on the robot controller
Content	Movement of one or more objects to a target position
End	Object located in the target position (exact stop) or when the next line of code is executed on the robot controller (blending).
Boundaries	The motion can be either performed linear or joint specif. The target point can be either programmed as exact stop or can be blended. In case of a point blended prior to the target point, time values for response time and acceleration are dismissed as long as the tartget point is approached in the same speed.

HRI - ASSEMBLY PLANNING

Process building block *Move*

- Influencing factors: manipulated mass, length of motion, velocity, acceleration and type of movement



t_t: response time
t_a: time for acceleration
t_v: time of const. velocity
t_b: time for deceleration
t_s: time until standstill

$$t_g = t_t + t_a + t_v + t_b + t_s$$

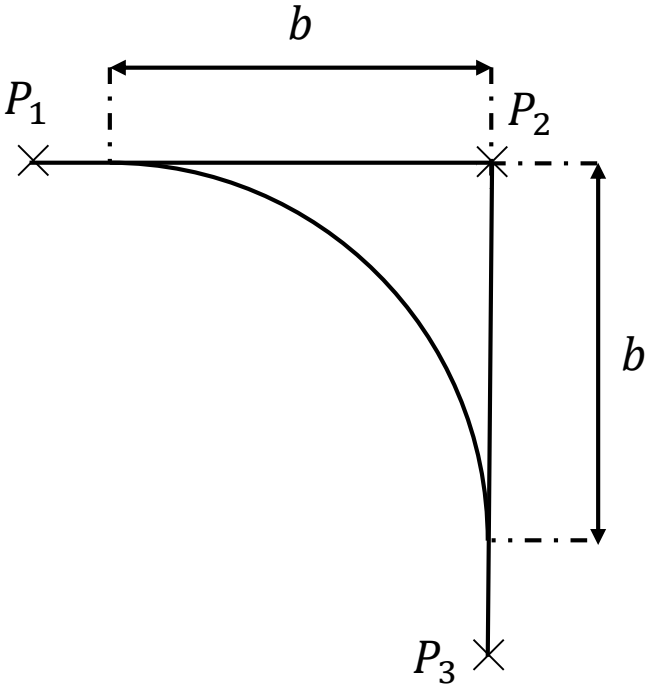
$$t_g = t_t + \frac{v}{a} + \frac{s_g}{v} + t_s$$

→ Error < 3 %

HRI - ASSEMBLY PLANNING

Process building block *Move* - Blending

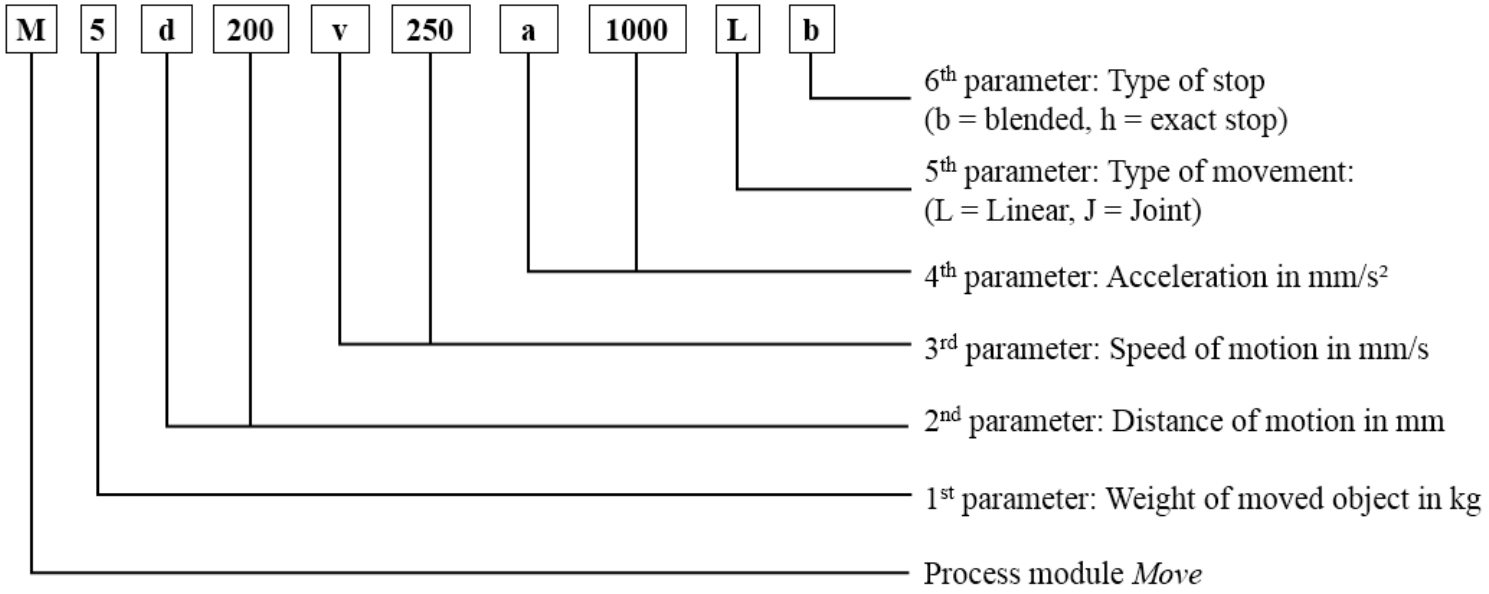
- Pick and place operation for one object requires several intermediate waypoints in order to avoid collisions
- Intermediate points are blended to smoothen motion and improve cycle time
- Robot path is shortened by Δs with the blending radius r impacting the required time by Δt



$$\Delta s = 2 \cdot b - \frac{\pi \cdot b}{2} \qquad \Delta t = \left(2 \cdot b - \frac{\pi \cdot b}{2}\right) \cdot \frac{1}{v}$$

HRI - ASSEMBLY PLANNING

Process building block *Move* - Codification



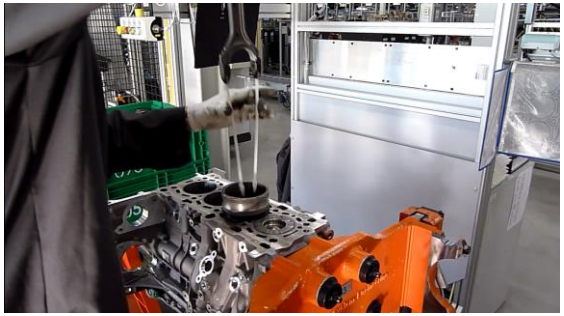
APPLICATION EXAMPLE

Application – Piston stuffing

- Joining of piston and connecting rod in engine block
- Quality requirement: No contact between connecting rod and inner surface of the bore
- Robot assists worker with pneumatic guiding tool when joining piston

Benefits:

- Improve Ergonomics
- Improved quality
- Time savings



APPLICATION EXAMPLE

Application Piston stuffing – Power and force limiting

SUMMARY

Motivation

- HRI offers potential for improvement in assembly regarding ergonomics, quality and costs
- Planning of HRI work systems very time intensive as of the current state of the art

Assembly planning for HRI work systems

- Development of process building blocks for HRI
- Definition of work content and task distribution in the early phase of assembly planning
  - → Description of assembly content for both resources human and robot
  - → Calculation of exact cycle times

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THANK YOU!