A Manufacturing Innovation Institute

Collaborate.Innovate.Deploy.

Collaborative Robots in industry

Robots in Society: Event 2 – Current robotics

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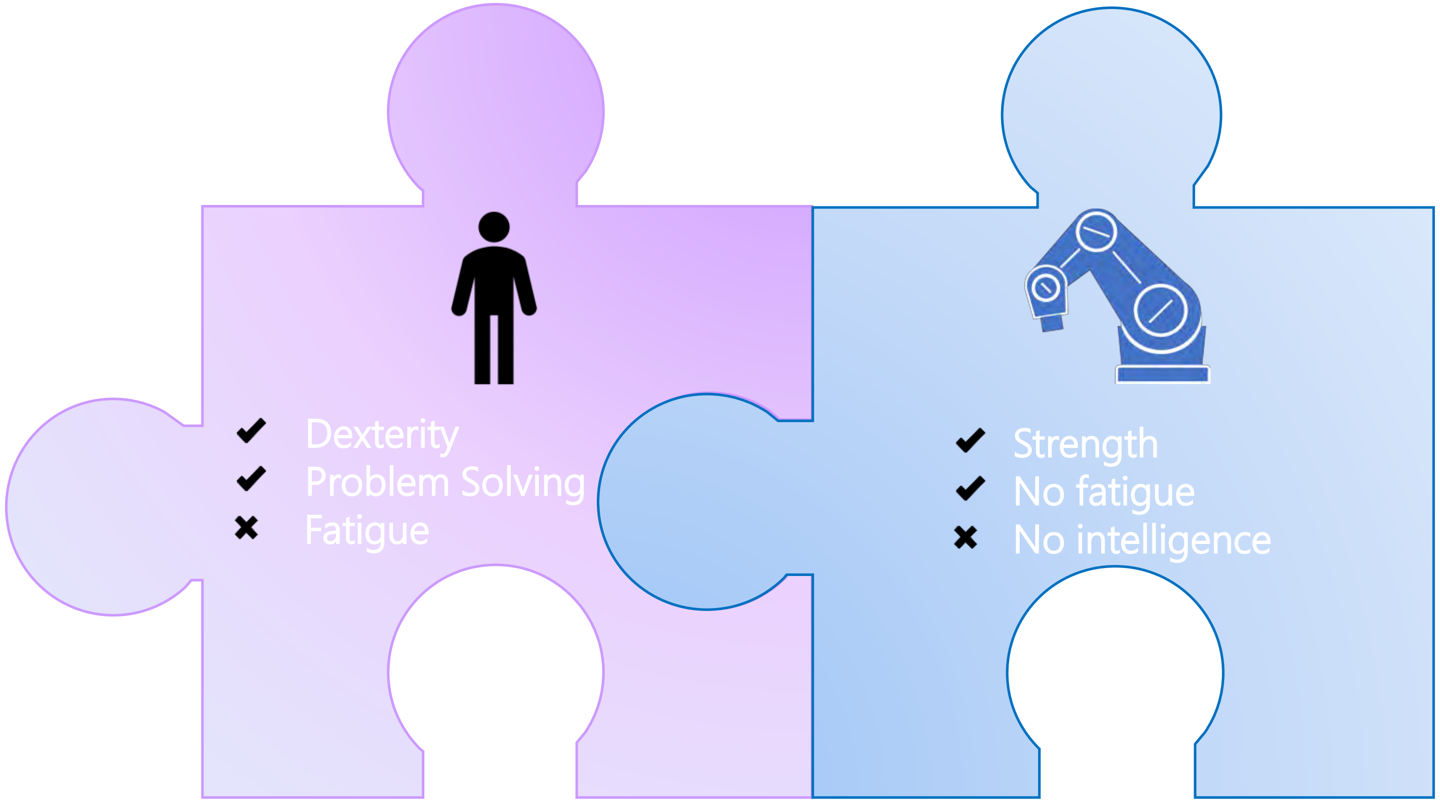
08/11/2017

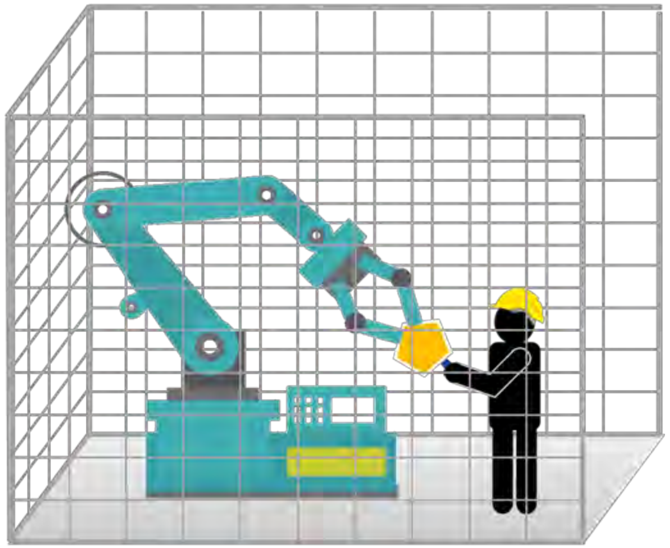
Introduction and context

Human-Robot Collaboration in industry

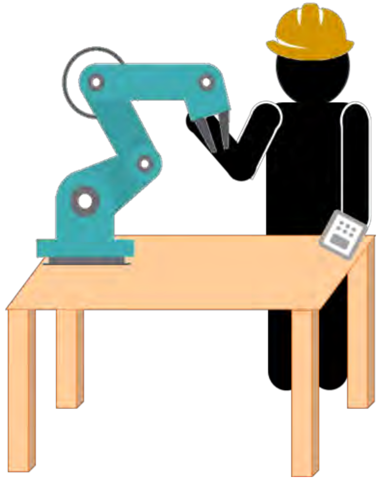
Principle: Human and robot sharing workspace without any fence



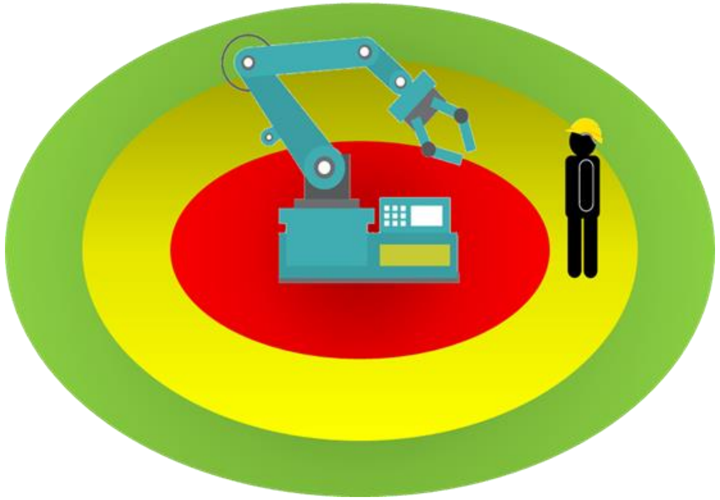
Types of Collaboration (ISO 10218)



Safety Monitored Stop



Hand guiding



Speed and Separation Monitoring

Power and Force Limiting

Benefits and key applications in automotive industry

Maximum value for

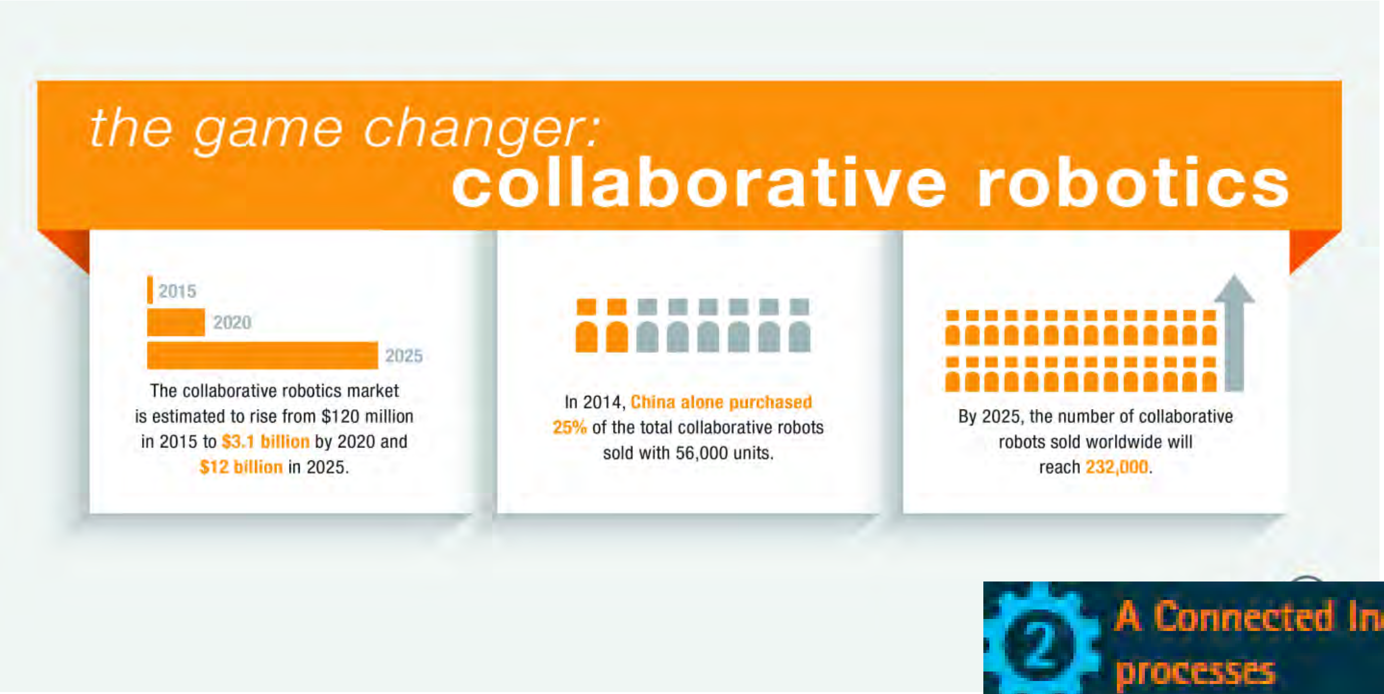
- ✓ Ergonomics improvements
- ✓ Use as a third hand
- ✓ Line balancing activities
- ✓ Quality improvement
- ✓ Better floor space utilization
- ✓ Versatile and flexible operations

Key applications

Screwing	Loading	Handling
Assembly	Gluing	Inspection

The Cobots working group

Headlines



#COBOTICS

The Future is Man with Machine

Cobots cheaper than fenced options

Cobots at forefront of the factory of the future

Context

Issue

- Perception from leading UK Automotive manufacturers that UK plants are falling behind their European and Global competitors in the application of Collaborative Robots
- UK plants perceived as less productive
- The issue is largely seen as the interpretation of standards and the development of implementation guidelines

Objectives of the working group

- Understand the root cause of this competitive disadvantage
- Facilitate safe, consistent and cost effective deployment of Collaborative Robots systems in UK automotive plants
- Develop and share best practice related to safe application

Partners and consultation process

Partners

- Supported by the Health and Safety Executive

Consultation process

- Commenced its activities in August 2016
- Meetings at regular intervals over a period of 10 months
- Workshops, consultations, interviews and gathering information through questionnaires
- Wide variety of inputs collected from universities, robot manufacturers, Catapult centres, software providers, automotive OEM's, trade organisations, and other European industrial safety organisations

Main outcome

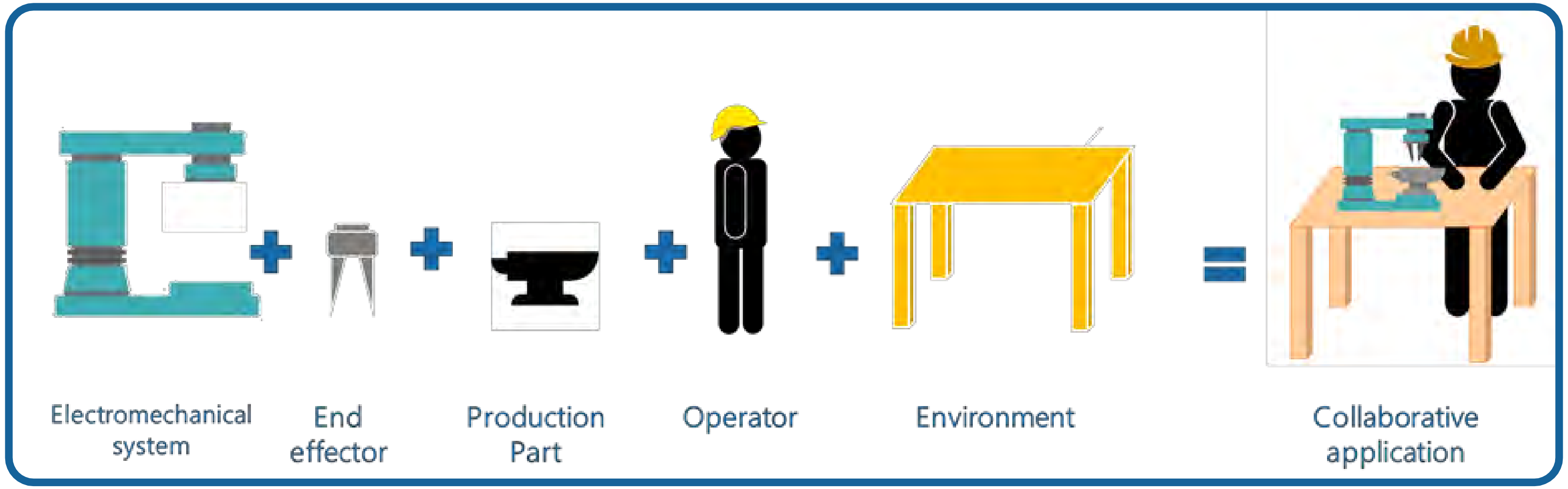
'Implementation of Collaborative Robot Applications'

http://hssmi.org/portfolio-items/implementation-collaborative-robot-applications-report-industrial-working-group/

Aim:

- Provide a definition of a truly collaborative application and identify the differences to the standard collaboration modes
- Understand the legal requirements of safety compliance versus technical specifications
- Develop implementation guidelines for truly collaborative applications along with guidance for risk assessment
- Identify key applications for automotive manufacturing
- Establish key limitations for collaborative applications

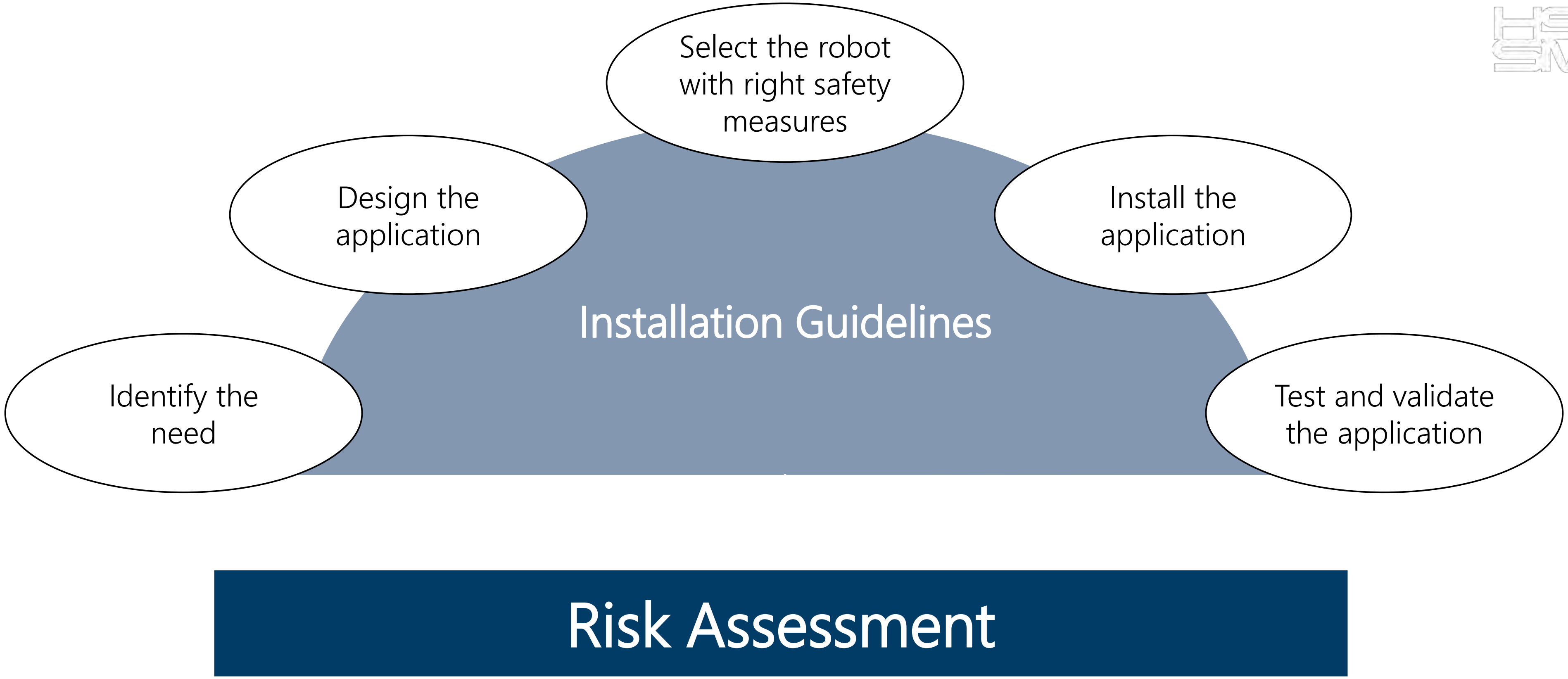
Truly Collaborative application



Definition given by the working group:

*"A truly collaborative application is a **programmable electromechanical system** that has been designed, constructed, assessed and locked through a **certified change control process**, within a **prescribed** environment to operate within a **tolerable level of risk** in all reasonably foreseeable modes whilst collaborating in a **shared workspace** with a **trained employee** performing a standard operation."*

Installation Guidelines for Collaborative applications



Standards and regulations

ISO 12100: "Safety of machinery, General principles for design, Risk assessment and risk reduction"	Table B1, 2 & 3	Hazards, hazardous situations and hazardous events to consider to perform risk assessment
ISO 10218-2: "Robots and robotic devices, safety requirements for industrial robots, Part 2: Robot systems and integration"	Section 5.11.2 (a)	General requirements of collaborative robot operation; points to consider to perform risk assessment Ex: Robot characteristics, end-effector hazards, layout of the robot system, operator location, operator path application-specific hazards
ISO 10218-2: "Robots and robotic devices, safety requirements for industrial robots, Part 2: Robot systems and integration"	Section 5.11.5.5	Safety features to select for ensuring a safe work environment when using a truly collaborative robot
ISO/TS 15066: "Robots and robotic devices, Collaborative robots"	Section 4.2 (b)	Access and clearance factors to consider to reduce risks and hazards when designing a collaborative application.
ISO/TS 15066: "Robots and robotic devices, Collaborative robots"	Section 4.3.2 (b)	Identification of hazards related to robot applications, including Ex: end effector and workpiece hazards, operation motion and location, influence of the surroundings
ISO/TS 15066: "Robots and robotic devices, Collaborative robots"	Section 4.3.3	Identification and documentation of reasonably foreseeable tasks and hazards combination associated with the robot cell

TS 15066 : Bio Mechanical Limits

Body region		Specific body area	Quasi-static contact: Maximum permissible pressure [a] p_s N/cm²	Quasi-static contact: Maximum permissible force [b] N	Transient contact: Maximum permissible pressure multiplier [c] P_T	Transient contact: Maximum permissible force multiplier [c] F_T
Skull and forehead [d]	*1*	*Middle of forehead*	*130*	*130*	*not applicable*	*not applicable*
	2	*Temple*	*110*		*not applicable*	
Face [d]	*3*	*Masticatory muscle*	*110*	*65*	*not applicable*	*not applicable*
Neck	4	Neck muscle	140	150	2	2
	5	Seventh neck muscle	210		2	
Back and shoulders	6	Shoulder joint	160	210	2	2
	7	Fifth lumbar vertebra	210		2	2
Chest	8	Sternum	120	140	2	2
	9	Pectoral muscle	170		2	
Abdomen	10	Abdominal muscle	140	110	2	2
Pelvis	11	Pelvic bone	210	180	2	2
Upper arms and elbow joints	12	Deltoid muscle	190	150	2	2
	13	Humerus	220		2	
Lower arms and wrist joints	14	Radial bone	190	160	2	2
	15	Forearm muscle	180		2	
	16	Arm nerve	180		2	

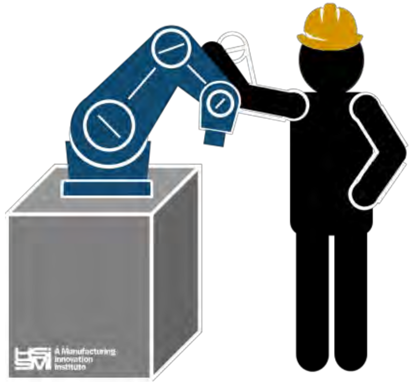
- General industry perception is that the standard is restrictive
- Regular working on line more force and pressure are experienced on the shop floor
- For payloads above 5kg within a shared workspace speed of 250mm/sec to 400mm/sec would satisfy the TS15066 (from a study of 6 applications)

Limitations

Low payload
⇩
Low variety of parts to handle

Level of risk
⇩
Unpredictability of human behaviour

Low speed
⇩
Difficulty to meet the cycle time



Limited applications
⇩
Shared workspace solve specific problems

RACE

Introduction

- Risk assessment for collaborative applications is extremely critical
- Gap in conducting risk assessment virtually before the physical installation

Goal: Create a virtual risk assessment tool for truly collaborative applications

Overview

RACE= **R**isk **A**ssessment for **C**ollaborative work **E**nvironment

Robot CAD model
Robot task/ script
Operator task & positions
End effector CAD model

Simulation

Hazard Evaluation

Foreseeable risk of collision
Exposed body region
Type of end effector
Trap points

Result

No hazard identified

Needs further attention

- Developed as an add-on of an existing simulator
- Simulator should include both human and robot dynamic models

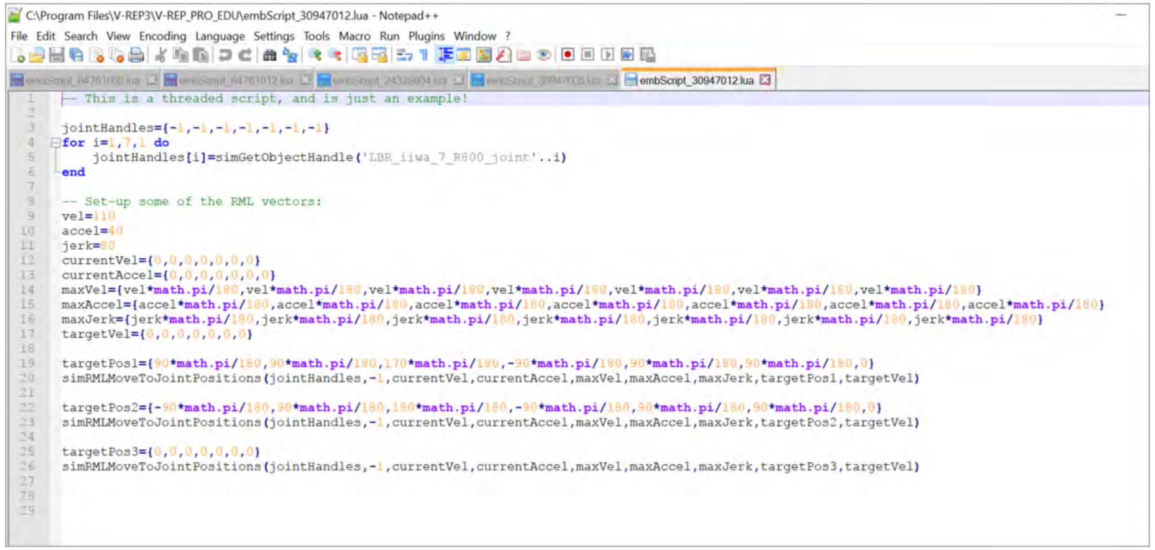
Simulator

v-rep
virtual robot experimentation platform

- Highly customisable simulator
- Versatile and ideal for multi-robot application
- Large library of collaborative robot models
- Scripts written in C/C++, Python, Java, Lua, Matlab or Octave

Feature 1: Programing the Robot task

Option a: Script Writing

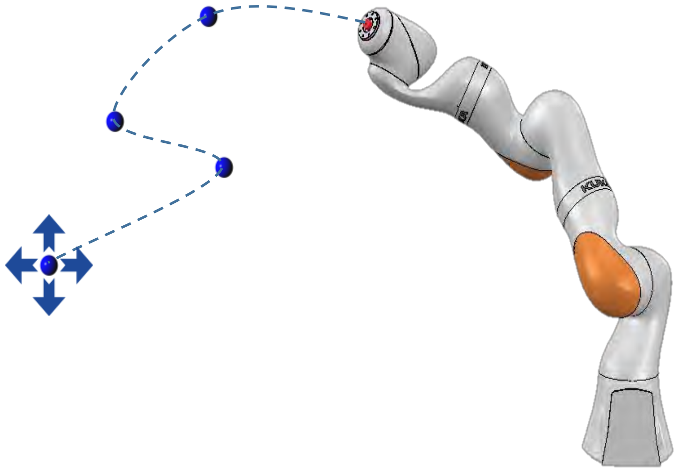



```lua
-- This is a threaded script, and is just an example!

jointHandles={-1,-1,-1,-1,-1,-1,-1}
for i=1,7,1 do
    jointHandles[i]=simGetObjectHandle('LBR_iiwa_7_R800_joint'..i)
end

-- Set-up some of the RML vectors:
vel=110
accel=40
jerk=80
currentVel={0,0,0,0,0,0,0}
currentAccel={0,0,0,0,0,0,0}
maxVel={vel*math.pi/180,vel*math.pi/180,vel*math.pi/180,vel*math.pi/180,vel*math.pi/180,vel*math.pi/180,vel*math.pi/180}
maxAccel={accel*math.pi/180,accel*math.pi/180,accel*math.pi/180,accel*math.pi/180,accel*math.pi/180,accel*math.pi/180,accel*math.pi/180}
maxJerk={jerk*math.pi/180,jerk*math.pi/180,jerk*math.pi/180,jerk*math.pi/180,jerk*math.pi/180,jerk*math.pi/180,jerk*math.pi/180}
targetVel={0,0,0,0,0,0,0}

targetPos1={90*math.pi/180,90*math.pi/180,170*math.pi/180,-90*math.pi/180,90*math.pi/180,90*math.pi/180,0}
simRMLMoveToJointPositions(jointHandles,-1,currentVel,currentAccel,maxVel,maxAccel,maxJerk,targetPos1,targetVel)

targetPos2={-90*math.pi/180,90*math.pi/180,180*math.pi/180,-90*math.pi/180,90*math.pi/180,90*math.pi/180,0}
simRMLMoveToJointPositions(jointHandles,-1,currentVel,currentAccel,maxVel,maxAccel,maxJerk,targetPos2,targetVel)

targetPos3={0,0,0,0,0,0,0}
simRMLMoveToJointPositions(jointHandles,-1,currentVel,currentAccel,maxVel,maxAccel,maxJerk,targetPos3,targetVel)
```

Option b: Graphical programming

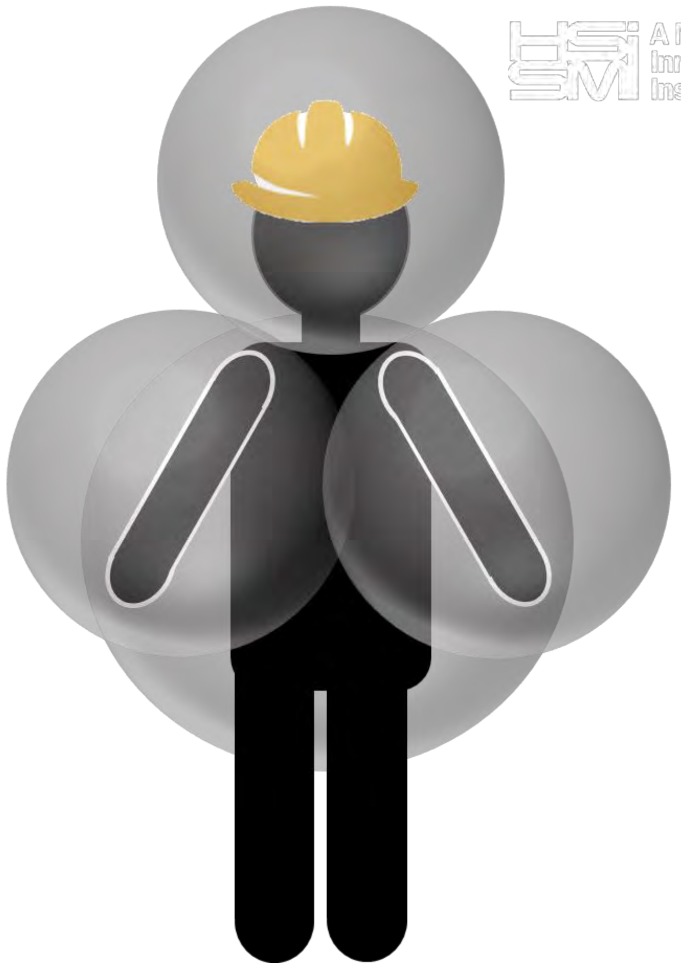
Define manually the robot trajectory with waypoints

From inverse Kinematics



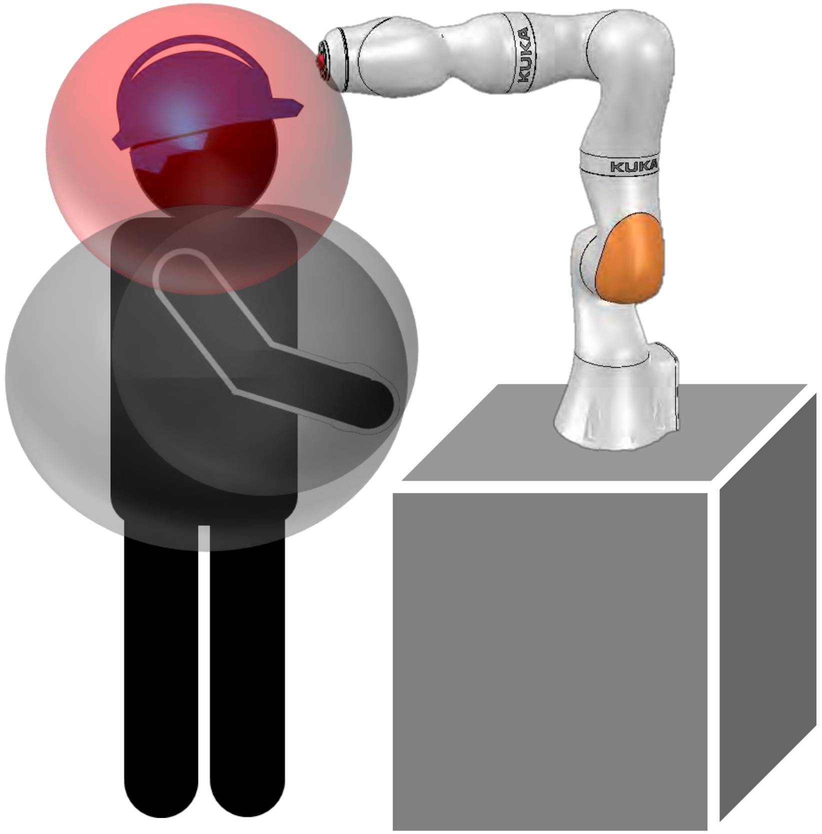
Feature 2: Operator envelope

- Envelope around the human model
- Collision tolerance
- Diameter = body segment length



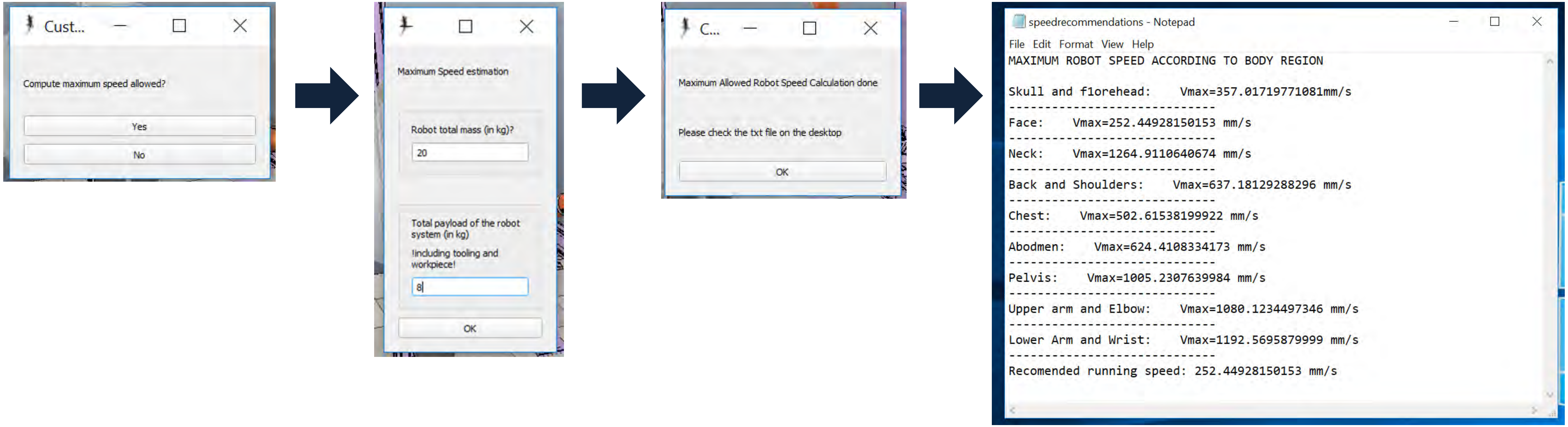
Feature 3: Collision detection

- Detects any collision:
  - Human/Robot
  - Human Envelope/Robot
- Visual output: colour change during simulation



Feature 4: Speed calculation

- Maximum recommended speed calculation:
  - According to the body region
  - Compliance with ISO/TS15066

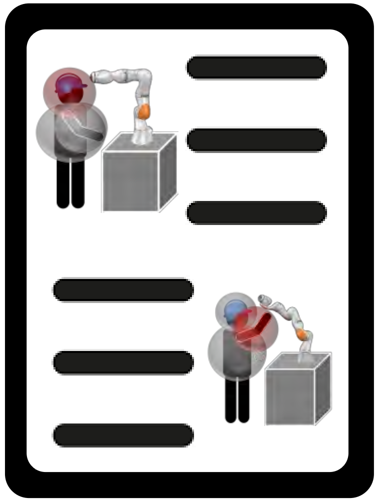


Next steps

Robot script transcription:

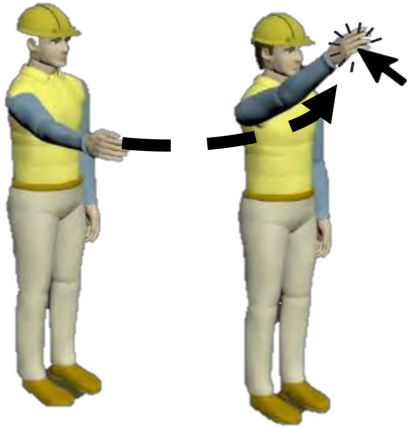
Import the robot script to program the robot task

User interface



Collision Report with details:

- Body region affected, time
- Type of contact (point, line, contact),
- Screenshot



Operator task

Graphical programming

Thank you.

www.hssmi.org