

# Platform requirements

**Prize:** The overall prize of the system should ideally not exceed 30.000 € including VAT

**Availability:** The system should be commercially available at least in the US, Europe, Japan and China

## A.1 Robot manipulator

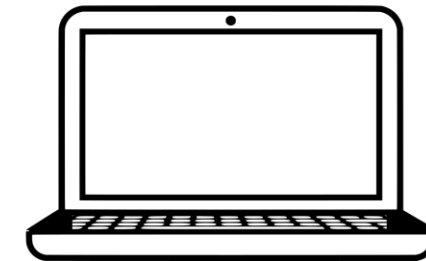
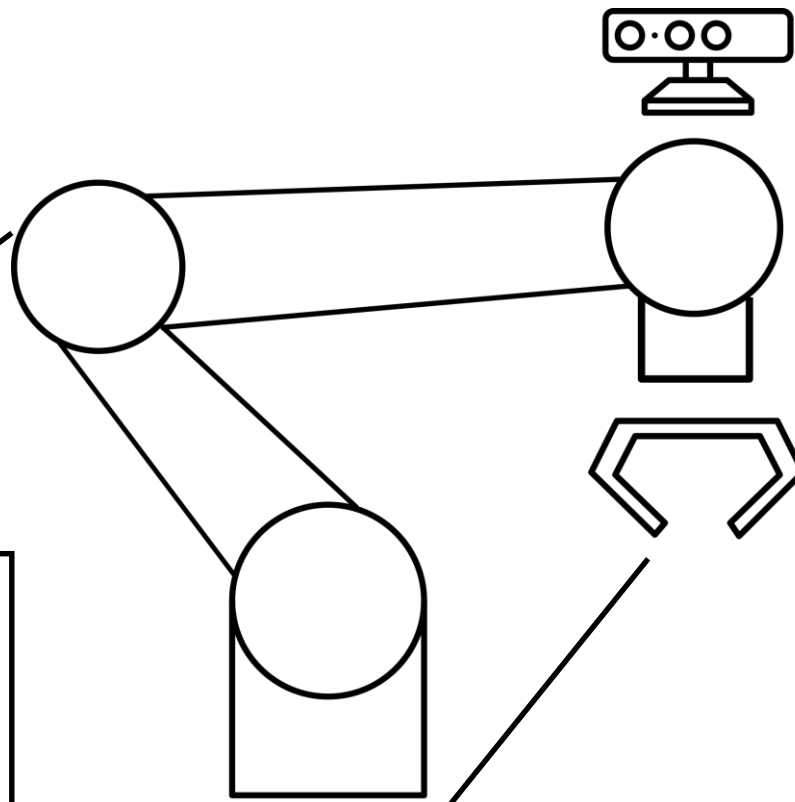
- Minimum requirements:
  - At least 6 DoF
  - Joint velocity interface
  - Payload 1 kg
  - Control API
  - Position and velocity measurements
- Ideal requirements:
  - 7 DoF
  - Joint torque interface
  - Control rate 1 kHz
  - At least 3 kg at 0.5 m/s
  - Position, velocity, torque, external torque and external wrench measurements

## A.2 End effector

- Minimum requirements:
  - Two finger gripper
  - Position controlled
- Ideal requirements:
  - Dexterous hand
  - Torque controlled
  - Control rate 1 kHz

## A.3 Camera

- Minimum requirements:
  - RGB-D camera
  - Resolution 640 x 480
  - Refresh rate 15 Hz
- Ideal requirements:
  - Resolution 1920 x 1080
  - Refresh rate 60 Hz



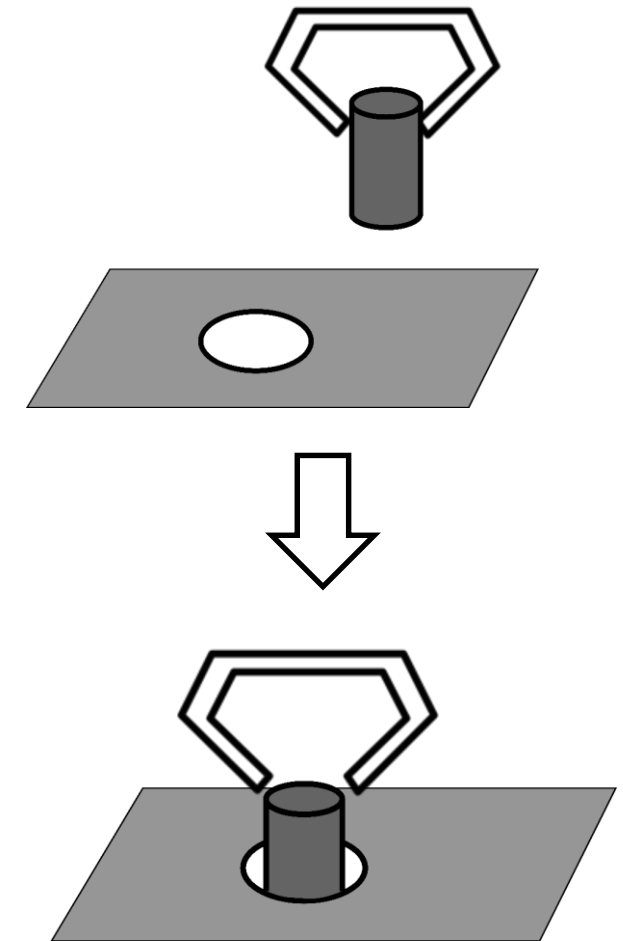
Specify a suitable computer system to control the proposed full setup

# Benchmark tasks – General notes

- In the following, we give a broad description of the tasks targeted by this workshop. Please note that the final specification of the benchmarking tasks will be completed after the proposal submission is closed.
- All parts can be placed such that they are reachable by the robot
- If necessary, any parts may be modified such that stable grasping is possible.

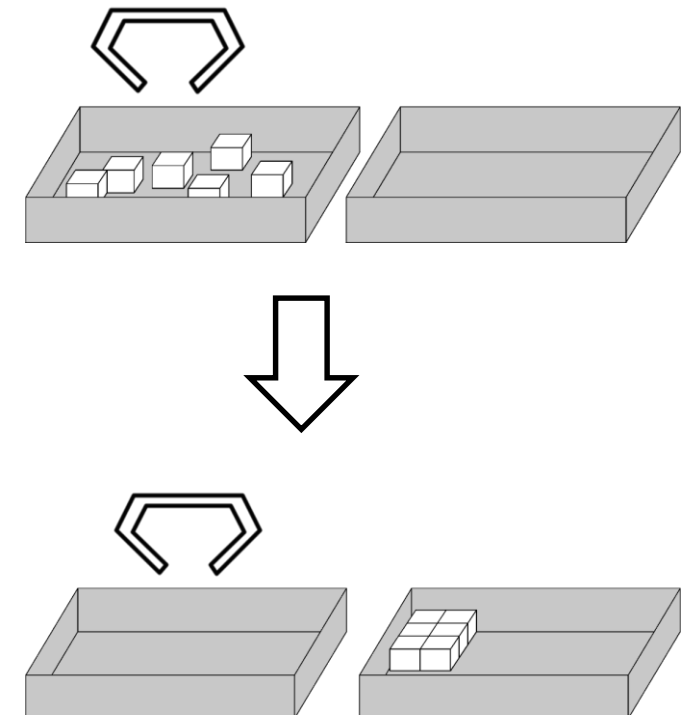
# Industrial benchmark tasks – Shaft insertion

<b>Short description:</b> A gear shaft has to be inserted into a corresponding bearing.	<b>Experimental setup:</b> Shaft: <ul style="list-style-type: none"><li>• Diameter: 5 - 100 mm</li><li>• Height: 50 - 100 mm</li><li>• Tolerances: &lt; 0.1 mm</li></ul> Hole: <ul style="list-style-type: none"><li>• Corresponds to shaft geometry</li><li>• Is fixed in environment</li></ul>
<b>Prior knowledge:</b> <ul style="list-style-type: none"><li>• Without visual perception: Hole pose is known with small errors</li><li>• With visual perception: Only the general area of the hole is known</li></ul>	<b>Initial state:</b> <ul style="list-style-type: none"><li>• Shaft is already grasped by robot</li><li>• End effector with peg is in vicinity of hole</li></ul>
<b>Performance measures (Examples):</b> <ul style="list-style-type: none"><li>• Execution time</li><li>• Average external forces</li></ul>	<b>Goal state:</b> <ul style="list-style-type: none"><li>• Shaft is completely inserted into hole</li></ul>



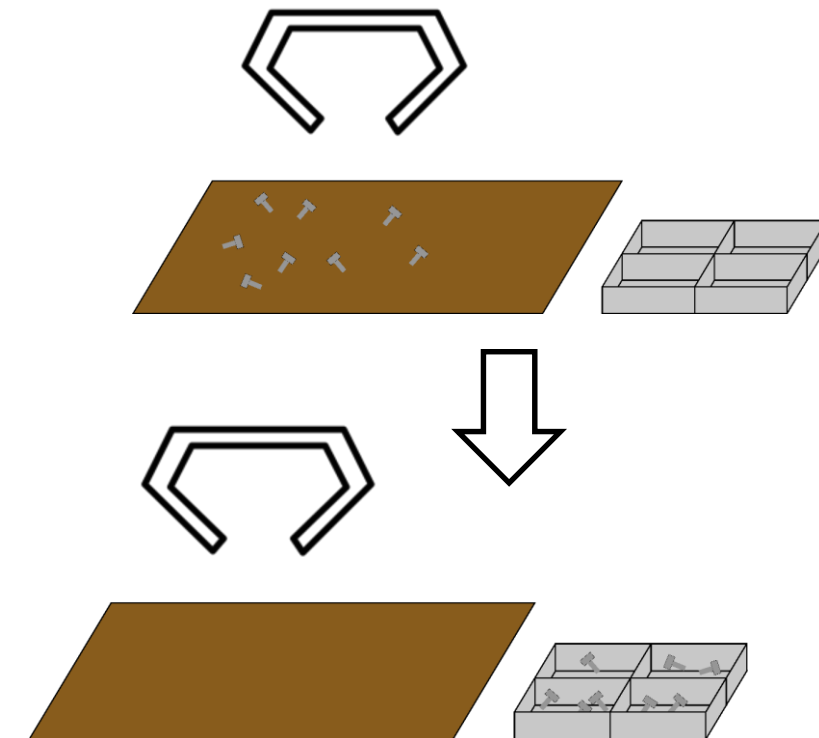
# Industrial benchmark tasks – Box Stacking

<b>Short description:</b> Several small boxes are lying randomly in a larger box and have to be put into another large box in an ordered fashion.	<b>Experimental setup:</b> Boxes: <ul style="list-style-type: none"><li>• Rectangular geometry: one side is max. 50 mm</li></ul> Storages: <ul style="list-style-type: none"><li>• Initial storage is large enough to hold all small boxes</li><li>• Target storage has dimensions such that all boxes fit into it</li></ul>
<b>Prior knowledge:</b> <ul style="list-style-type: none"><li>• Location of initial storage box is known</li></ul>	<b>Initial state:</b> <ul style="list-style-type: none"><li>• All boxes are in an initial storage box</li><li>• Robot has not grasped anything</li><li>• Target storage box is empty</li></ul>
<b>Performance measures (Examples):</b> <ul style="list-style-type: none"><li>• Execution time</li></ul>	<b>Goal state:</b> <ul style="list-style-type: none"><li>• All boxes have been sorted from the initial storage to the target storage</li></ul>



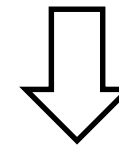
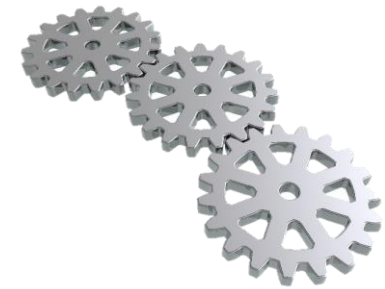
# Industrial benchmark tasks – Sorting screws

<b>Short description:</b> A number of screws of different types is lying on a board and have to be sorted into a cabinet.	<b>Experimental setup:</b> Types of screws (defined by ISO, max. M6 x 100): <ul style="list-style-type: none"><li>• Hex screws (ISO 4014)</li><li>• Countersunk screws (ISO 10642)</li><li>• Cylinder head screws (ISO 4762)</li><li>• Raised countersunk screws (ISO 2010)</li></ul> Maximal length of screws is 40 mm Cabinet: <ul style="list-style-type: none"><li>• Every type of screw has its own compartment of about 50 mm x 100 mm width and length</li></ul> Board: <ul style="list-style-type: none"><li>• Initial board for screws, has an area of about 400 mm x 400 mm</li></ul>
<b>Prior knowledge:</b> <ul style="list-style-type: none"><li>• Location of board is known</li><li>• Location of cabinet is known</li><li>• Locations of screw type compartments are known</li></ul>	<b>Initial state:</b> <ul style="list-style-type: none"><li>• All screws are lying randomly on the board</li><li>• Robot has not grasped anything</li><li>• Cabinet is empty</li></ul>
<b>Performance measures (Examples):</b> <ul style="list-style-type: none"><li>• Execution time</li><li>• Sorting success rate</li></ul>	<b>Goal state:</b> <ul style="list-style-type: none"><li>• All screws are in their respective compartments</li></ul>



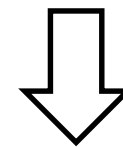
# Industrial benchmark tasks – Gear assembly

<p><b>Short description:</b> Multiple gears and shafts are lying on a board and have to be assembled.</p>	<p><b>Experimental setup:</b> Several gears and shafts (According to ISO) Dimensions:<ul style="list-style-type: none"><li>• Gears have a maximum diameter of 100 mm</li><li>• Shafts have a maximum diameter of 50 mm</li><li>• All single part weights are beneath 1 kg</li></ul>Partial assembly: The initial partial assembly is fixed in the environment.</p>
<p><b>Prior knowledge:</b></p> <ul style="list-style-type: none"><li>• Location of board is known</li><li>• Location of assembly is known</li></ul>	<p><b>Initial state:</b></p> <ul style="list-style-type: none"><li>• All gears and shafts are on the board</li><li>• Robot has not grasped anything</li><li>• Initial part is fixed to environment</li></ul>
<p><b>Performance measures (Examples):</b></p> <ul style="list-style-type: none"><li>• Execution time</li><li>• Minimal external forces</li></ul>	<p><b>Goal state:</b></p> <ul style="list-style-type: none"><li>• Assembly is completed</li></ul>



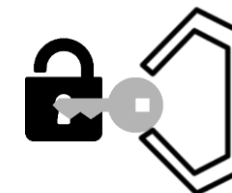
# Industrial benchmark tasks – Cabeling

<b>Short description:</b> Several cables have to be picked up and inserted into a standard computer.	<b>Experimental setup:</b> Computer: Mid-Tower case, ATX form factor, fixed to a table Cables: HDMI, USB (A/C), AUX, Display-port
<b>Prior knowledge:</b> <ul style="list-style-type: none"><li>• General location of cables is known</li><li>• Location of computer is known</li></ul>	<b>Initial state:</b> <ul style="list-style-type: none"><li>• The cables are lying in random shape on the table</li><li>• Robot has not grasped anything</li></ul>
<b>Performance measures (Examples):</b> <ul style="list-style-type: none"><li>• Execution time</li></ul>	<b>Goal state:</b> <ul style="list-style-type: none"><li>• All cables have been correctly inserted</li></ul>



# Household benchmark tasks – Key insertion

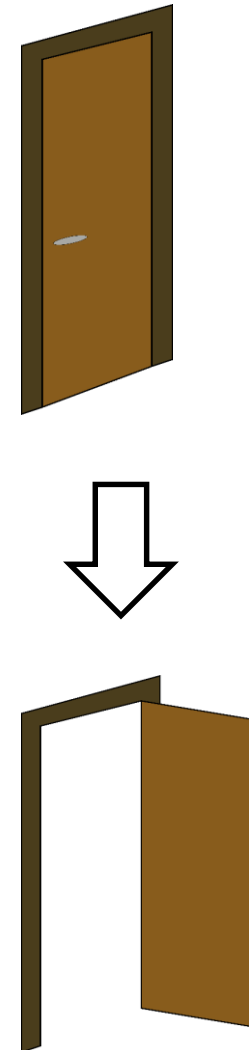
<b>Short description:</b> A key has to be inserted into a corresponding lock.	<b>Experimental setup:</b> Key: <ul style="list-style-type: none"><li>• Diameter: approximately 3 mm</li><li>• Height: 20 – 30 mm</li><li>• Tolerances: &lt; 0.5 mm</li><li>• Examples: Abus E30, Abus DX6</li></ul> Lock: <ul style="list-style-type: none"><li>• Corresponds to key geometry</li><li>• Is fixed in environment</li></ul>
<b>Prior knowledge:</b> <ul style="list-style-type: none"><li>• Without visual perception: Lock pose is known with small errors</li><li>• With visual perception: Only the general area of the lock pose is known</li></ul>	<b>Initial state:</b> <ul style="list-style-type: none"><li>• Key is already grasped by robot</li><li>• End effector with key is in vicinity of hole</li></ul>
<b>Performance measures (Examples):</b> <ul style="list-style-type: none"><li>• Execution time</li><li>• Average external forces</li></ul>	<b>Goal state:</b> <ul style="list-style-type: none"><li>• Key is completely inserted into lock</li></ul>





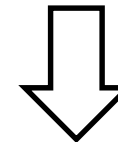
# Household benchmark tasks – Open door

<b>Short description:</b> A door is fixed in front of the robot and has to be opened at least 90 degrees.	<b>Experimental setup:</b> Door: <ul style="list-style-type: none"><li>• Height is max. 1000 mm</li><li>• Width is max. 500 mm</li><li>• Handle is fixed to door</li><li>• Handle has to be pushed down to open the door</li><li>• Door is fixed to environment</li></ul>
<b>Prior knowledge:</b> <ul style="list-style-type: none"><li>• General location of door handle is known</li></ul>	<b>Initial state:</b> <ul style="list-style-type: none"><li>• Door is closed</li></ul>
<b>Performance measures (Examples):</b> <ul style="list-style-type: none"><li>• Execution time</li><li>• Average external forces</li></ul>	<b>Goal state:</b> <ul style="list-style-type: none"><li>• Door is open 90 degrees</li></ul>



# Household benchmark tasks – Book Stacking

<p><b>Short description:</b> Several books are lying randomly on a board and have to be put into a book shelf. The order does not matter.</p>	<p><b>Experimental setup:</b> Books:</p> <ul style="list-style-type: none"><li>• Geometry:<ul style="list-style-type: none"><li>• Height: max. 300 mm</li><li>• Depth: max 250 mm</li><li>• Thickness: max 30 mm</li><li>• Weight: max 500 g</li></ul></li></ul> <p>Board:</p> <ul style="list-style-type: none"><li>• Has an area of about 500 mm x 500 mm</li></ul> <p>Book shelf:</p> <ul style="list-style-type: none"><li>• Book shelf has dimensions such that all books fit into it</li><li>• Book shelf is fixed in the environment</li></ul>
<p><b>Prior knowledge:</b></p> <ul style="list-style-type: none"><li>• General location of books is known</li><li>• Location of book shelf is known</li></ul>	<p><b>Initial state:</b></p> <ul style="list-style-type: none"><li>• The books are lying randomly on the board</li><li>• Robot has not grasped anything</li><li>• Book shelf is empty</li></ul>
<p><b>Performance measures (Examples):</b></p> <ul style="list-style-type: none"><li>• Execution time</li></ul>	<p><b>Goal state:</b></p> <ul style="list-style-type: none"><li>• All books have been put into the book shelf</li></ul>



# Household benchmark tasks – Folding clothes

<b>Short description:</b> Either pants or shirts are lying in random shape on a table. The task is to fold it.	<b>Experimental setup:</b> Pants: Normal fit, long-sleeved Shirts: Normal fit, long-sleeved, L
<b>Prior knowledge:</b> <ul style="list-style-type: none"><li>• Location of cloth is known</li></ul>	<b>Initial state:</b> <ul style="list-style-type: none"><li>• The clothes are lying in random shape on the table</li><li>• Robot has not grasped anything</li></ul>
<b>Performance measures (Examples):</b> <ul style="list-style-type: none"><li>• Execution time</li></ul>	<b>Goal state:</b> <ul style="list-style-type: none"><li>• Clothes have been folded as desired</li></ul>

