Combining visual and force feedback for the precise robotic manipulation of bulky components

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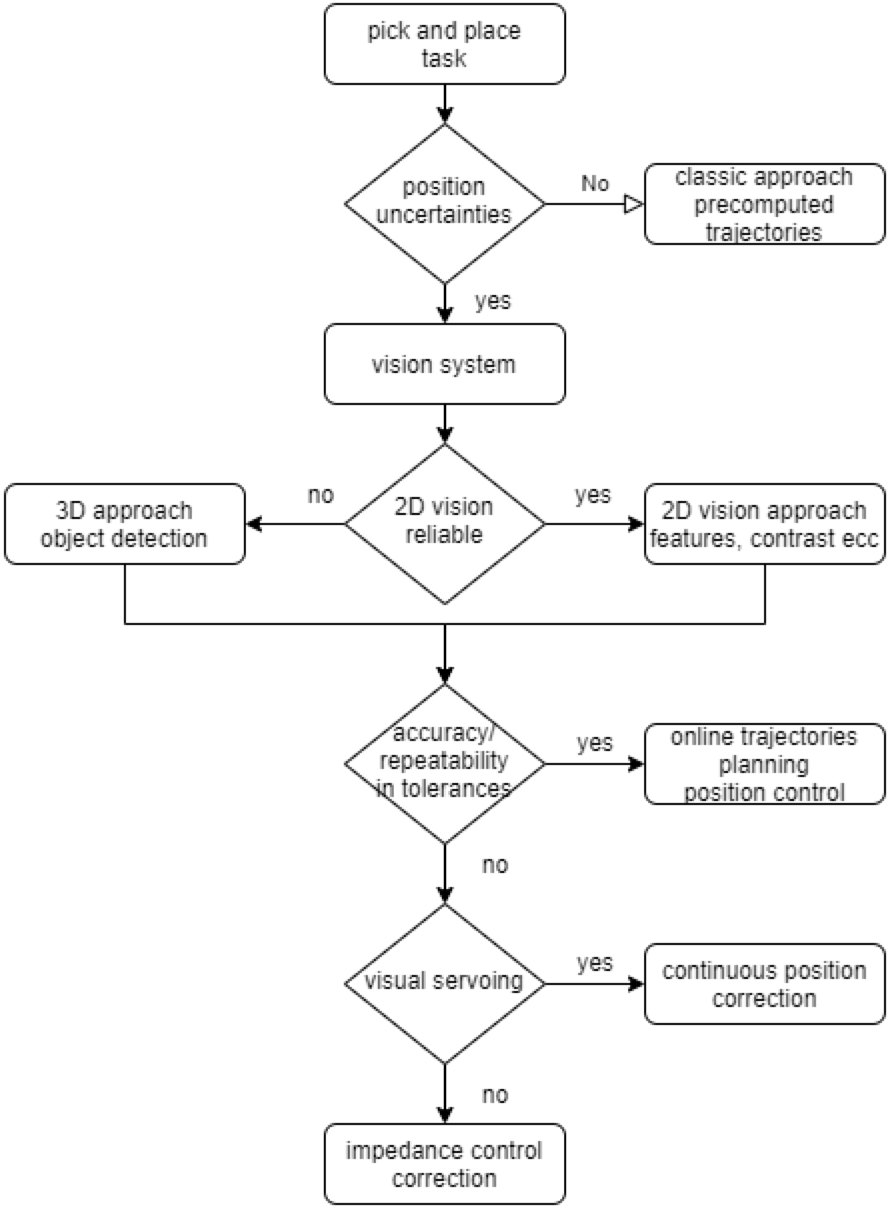
Typical industrial applications involve:

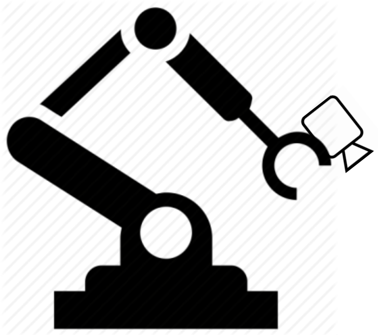
- Fixed base manipulators
- Repetitive tasks (pick and place)
- Precomputed motions
- Lines designed on purpose for the automation
- Small components handling (wrt their workspace)

Decision flowchart



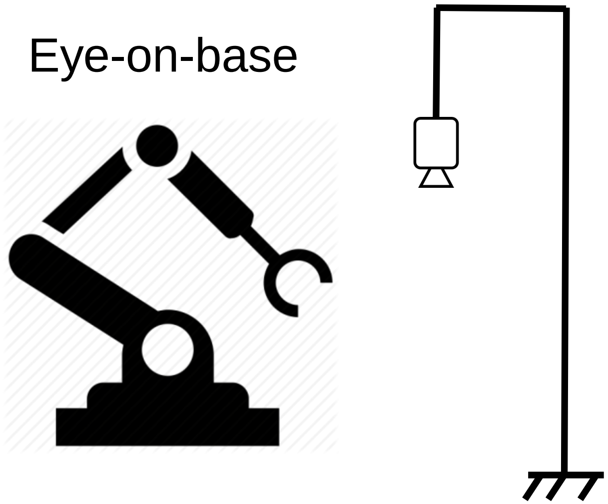
Typical configurations for vision system

Eye-in-hand



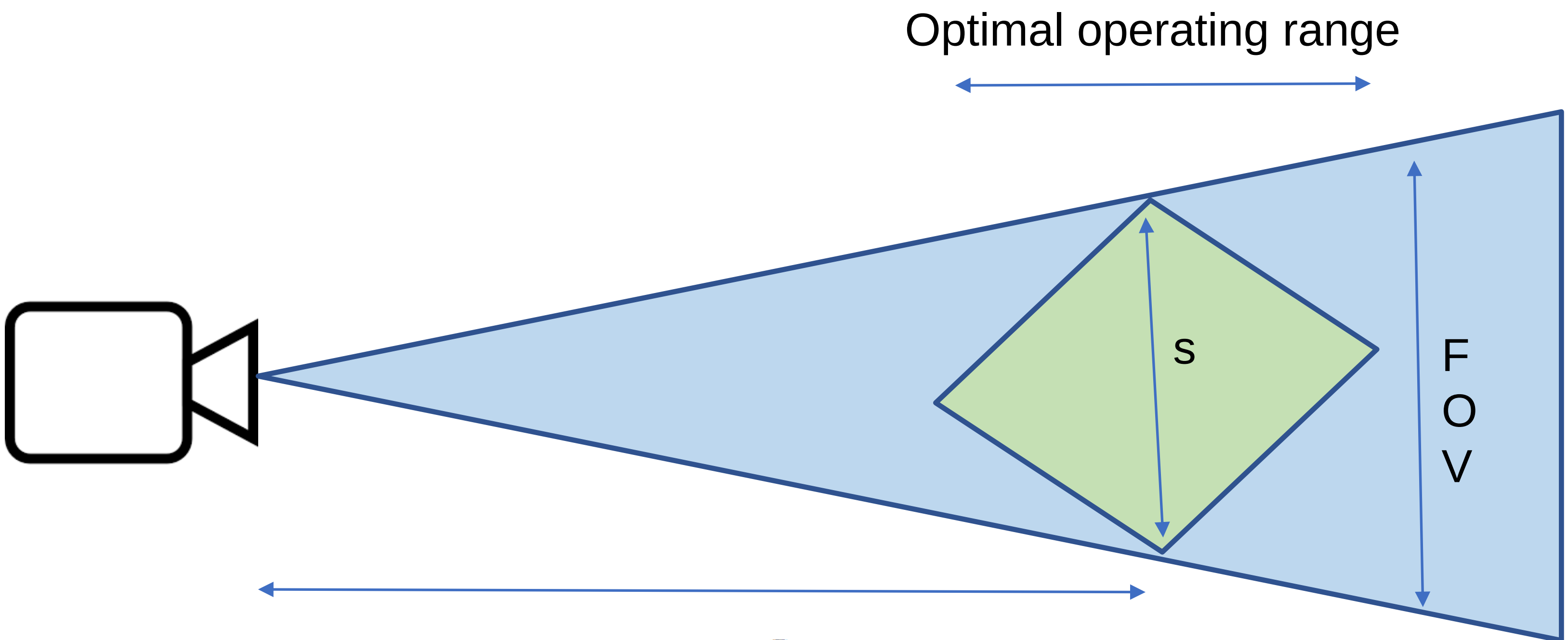
- High achievable accuracy
- suffers from occlusions
- For texture-less objects, as close the camera is, as less references it can see

Eye-on-base



- great flexibility in the positioning of the camera
- avoid occlusion
- if the vision system is mounted far from the object, the accuracy of the estimated position decreases

The camera Field of view limits its minimum distance from the target object, while the camera operating range defines its maximum distance



$$d_{camera}^{min} = \frac{s}{2\tan\left(\frac{FOV}{2}\right)}$$

2d Vision:
- Good when exist trong features as textures, contrast, color
- Lack in performance if orientation is not fixed: different viewpoints of the same object can create a different perception
- Requires proper illumination

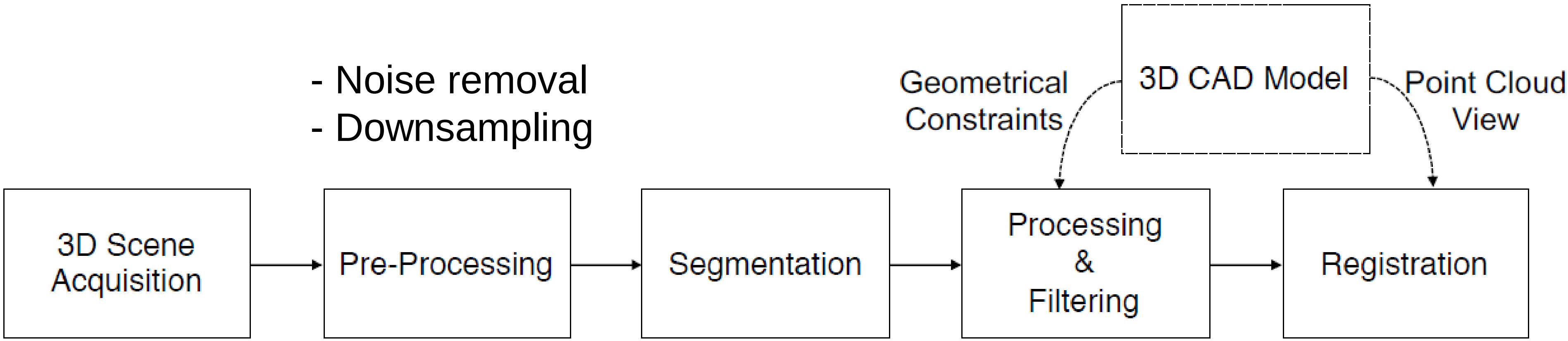
3d Vision:
- Cad based methods
- Robust with respect to changes in lights
- Do not require strong features as textures, contrast, color

Visual servoing: visual feedback position control. Not applicable for huge textureless objects!
Eye-in-hand: The huge object occludes the vision field
Eye-on-base: The robot occludes the vision field, poor accuracy

The proposed solution identifies the object and the assembly pose, than the robot compensates for deviations with interaction control

Visual servoing --> visual feedback position control. Not applicable for huge textureless objects!

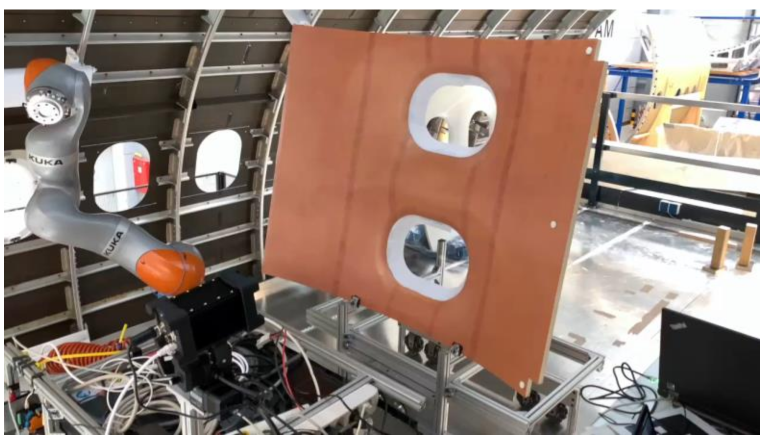
- Noise removal
- Downsampling



Segmentation: allows to subdivide the scene into clusters that represent a part each one

Processing & Filtering: the Oriented Bounding Box (OBB) is computed for each cluster and compared with the CAD one

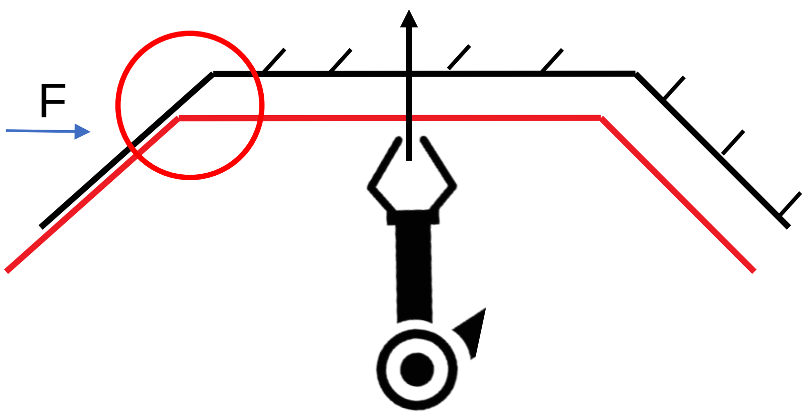
Registration: ICP for shape matching

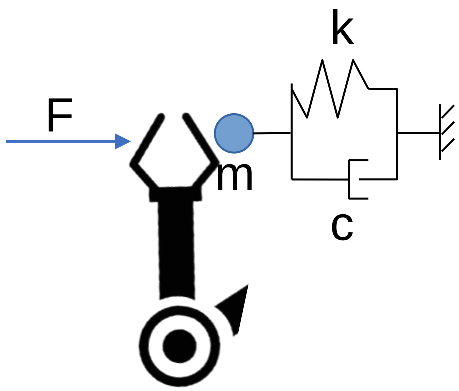


the acquisition phase and pointcloud fusion of a huge object

Impedance control: design a control loop to allow the robot motion behave as an equivalent mass-spring-damper system. Some recent robots already has it implemented – Easy to be implemented

Objective: given the maximum interaction force, the maximum displacement, the motion velocity, define M, C, K parameters





$$\begin{cases} M_i\ddot{x} + C_i\dot{x} + K_i x = F_{ext} \\ F_{ext} = K_{env}\Delta x \\ \Delta x = x_{env} - x = vt - x \end{cases} \longrightarrow$$

$$M_i\ddot{x} + C_i\dot{x} + K_{aug}x = K_{env}x_{env}$$

$$K_{aug} = K_{env} + K_i$$

$$M_{cr} = \left\{\left[\frac{F_{max}}{K_{aug}} - v\bar{t}\left(1 - \frac{K_{env}}{K_{aug}}\right)\right]\frac{K_{aug}^2}{2\zeta_{aug} v\sqrt{K_{aug}}}\right\}^2$$

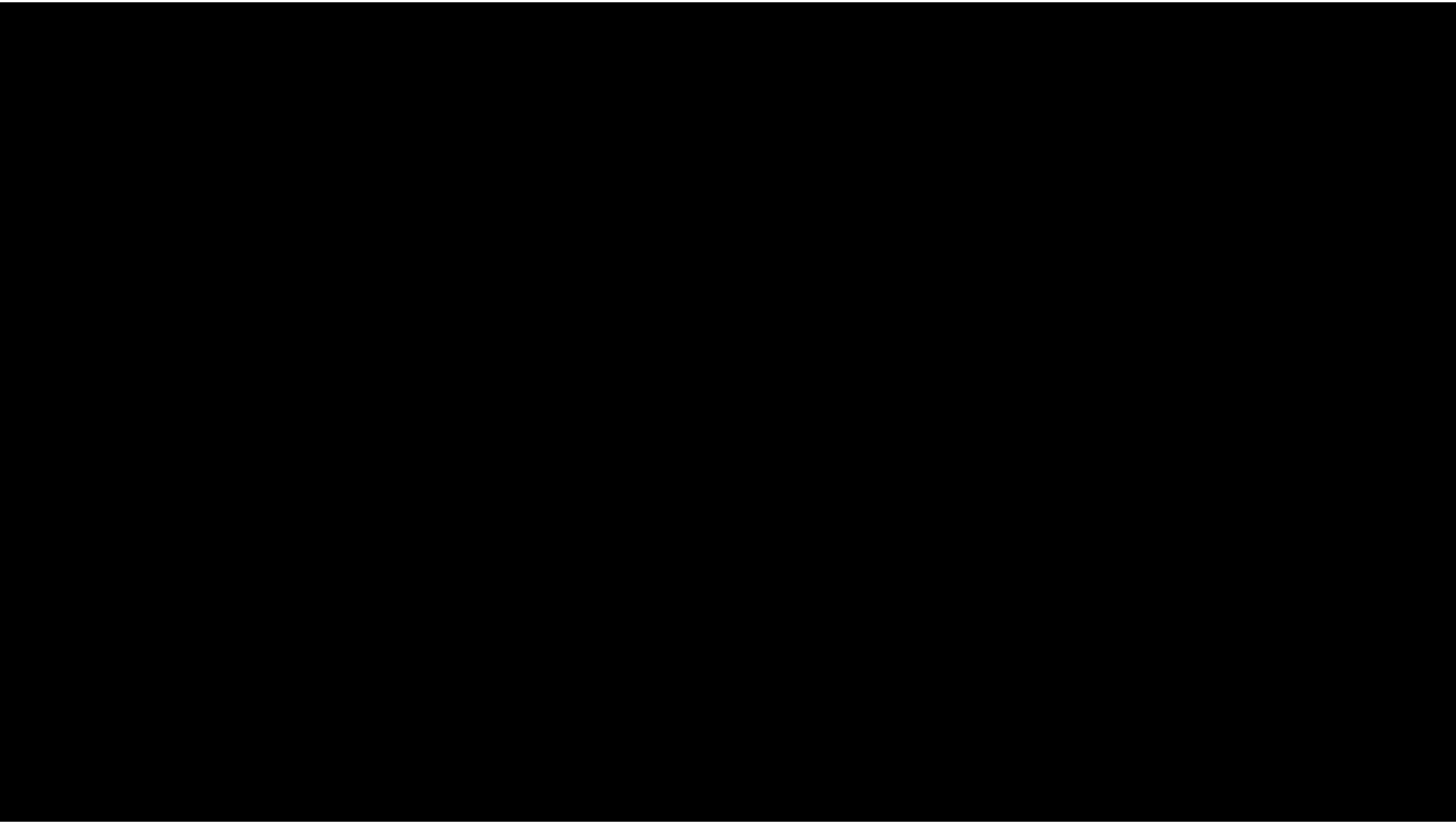
mass for which the maximum force is reached

$$\frac{K_i}{K_{env}} < K_{\lim} = \frac{1}{1 - \frac{F_{max}}{K_{env} v\bar{t}}} - 1$$

limit stiffness ratio can be computed, imposing the mass equal to zero

$$\begin{cases} K_i = k_s k_{\lim} K_{env}, 0 < k_s < 1 \\ M_i = m_s M_{cr}, 0 < m_s < 1 \\ C_i = 2\zeta_{aug}\sqrt{K_{aug} M_i} \end{cases}$$

Sidewall panel assembly



Vision estimation

	mean	diff
x_w [m]	1.0660	0.0136
y_w [m]	0.1319	0.0034
θ_w [°]	0.6037	0.8756
x_p [m]	-0.4273	0.0129
y_p [m]	-0.7399	0.0346
θ_p [°]	89.108	1.6363

Deviation of about 15mm at 500 mm distance

Success rate

	Robot Localization	Panel Localization	Panel Grasping	Panel Assembly
Vision and position control	100%	100%	40%	0%
Impedance control without vision	n/a	n/a	70%	10%
Vision and impedance control	100%	100%	100%	90%

STIIMA

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Thank you for your attention

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