BIMANUAL MANIPULATION BENCHMARK

Reference No / Version	RAL-SI-2020-B19-0836-V1.0 (for the latest versions of the benchmark, please refer to: https://www.epfl.ch/labs/lasa/sahr/benchmark/)
Authors	Konstantinos Chatzilygeroudis, Bernardo Fichera, Ilaria Lauzana, Fanjun Bu, Kunpeng Yao, Farshad Khadivar, and Aude Billard
Institution	École polytechnique fédérale de Lausanne
Contact information	konstantinos.chatzilygeroudis@epfl.ch
Adopted Protocol	Bimanual Manipulation Protocol (RAL-SI-2020-P19-0836_1-V1.0 and RAL-SI-2020-P19-0836_2-V1.0)
Approaches	Four categories of approaches: Adaptive Control (AC) : the optimal plan (in kinematic space) to solve the task is assumed to be given and the goal is to find a control algorithm that is able to find the force profiles and adapt to the noisy observations of the computer vision part. No data-driven method is allowed in this category. Motion Planning (MP) under uncertainty: the goal is to find a working plan (not given) to solve the task with the ability of handling the uncertainty that comes from the computer vision estimation. No data-driven method is allowed in this category. Offline Learning (OFL) : the optimal plan (in kinematic space) to solve the task is assumed to be given or not (this is up to the users to decide; different leaderboards are available per case) and the goal is to find a data-driven algorithm that is able to reliably solve the tasks. In this category, all the learning must be offline, that is, performed only once with the collected real-world samples. Combination of learning methods with motion planning algorithms is allowed. Online Learning (ONL) : the goal is to propose a trial-and-error learning algorithm that is able to find a working controller (or policy) that can reliably solve the tasks despite the noisy observations. The algorithm is expected to interact with the system and improve over time. The final optimized controller/policy is evaluated.
Scoring	***Global Metrics*** (AC, MP, OFL and ONL): *G1 - Success rate metric*: $$S_{G1} = \frac{\sum_{i=1}^{N}\sum_{j=1}^{J} b_{ij}}{NJ}$$ *G2 - Normalized average completion time*: $$S_{G2} = \frac{\sum_{i=1}^{N}\sum_{j=1}^{J} t_{max} - t_{ij}}{NJt_{max}}$$ b_{ij} is a binary value determining if the *i-th* repetition for *j-th* initial orientation was successful; t_{ij} is the time needed to complete the task in the *i-th* repetition for *j-th* initial pose; $t_{max} = 60$ s is the maximum time allowed to perform the task; $N = 5$ is the number of repetitions; $J = 3$ is the number of initial poses.

Offline Learning Metrics (OFL):
A1 - Normalized number of offline real-world samples:

$$S_{A1} = \frac{k_{max} - k}{k_{max}}$$

A2 - Normalized model training time:

$$S_{A2} = \frac{t_{max}^{train} - t_{ij}^{train}}{t_{max}^{train}}$$

k is the number of samples needed to create the datasets:

- $k_{max} = 10000$;

t^{train} is the time to train the models:

- $t_{max}^{train} = 1800\ s$.

Motion Planning Metrics (MP):
M1 - Normalized average planning time:

$$S_{M1} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{J} t_{max}^{plan} - t_{ij}^{plan}}{t_{max}^{plan}}$$

t_{ij}^{plan} is the time the planner took to output a result in the *i-th* repetition for *j-th* initial orientation;
$t_{max}^{plan} = 1800\ s$ is the maximum time available for a planner to output a result.

Online Learning Metric (ONL):
T1 - Normalized interaction time:

$$S_{T1} = \frac{t_{max}^{te} - t^{te}}{t_{max}^{te}}$$

t^{te} is the interaction time needed to learn a controller for the task:

- $t_{max}^{te} = 1800\ s$.

Total score (AC, MP, OFL and ONL):
The total score is computed as a weighted sum over all sub-tasks and scores:

$$S_{benchmark} = \sum_{m} w_0(S_{G1}^m + S_{G2}^m) + w_1(S_{A1}^m + S_{A2}^m + S_{M1}^m + S_{T1}^m)$$

$m = \{watch_{small}, watch_{big}, rubber\ band\}$;
$w_0 = 0.25$;
$w_1 = \frac{0.5}{N}$, where N is the number of metrics that are active (apart from G1,G2); for example if G1, G2, A1, A2 are active, then N=2 and w1=0.25.

Details of Setup	• Type of approach (AC, MP, OFL or ONL) • Robots utilized. • Software architecture. • Specifications of vision based system (e.g. cameras used). • Tools used. • 3D printing technology used.

Results to Submit	• Metrics for approach chosen (including global metrics and total score) and optionally sub-metrics.
	• Comments on:
	    o Utilized learning technique (for OFL and ONL approaches).
	    o What makes the system successful?
	    o What makes the system fail?
	    o What kind of improvements are necessary?