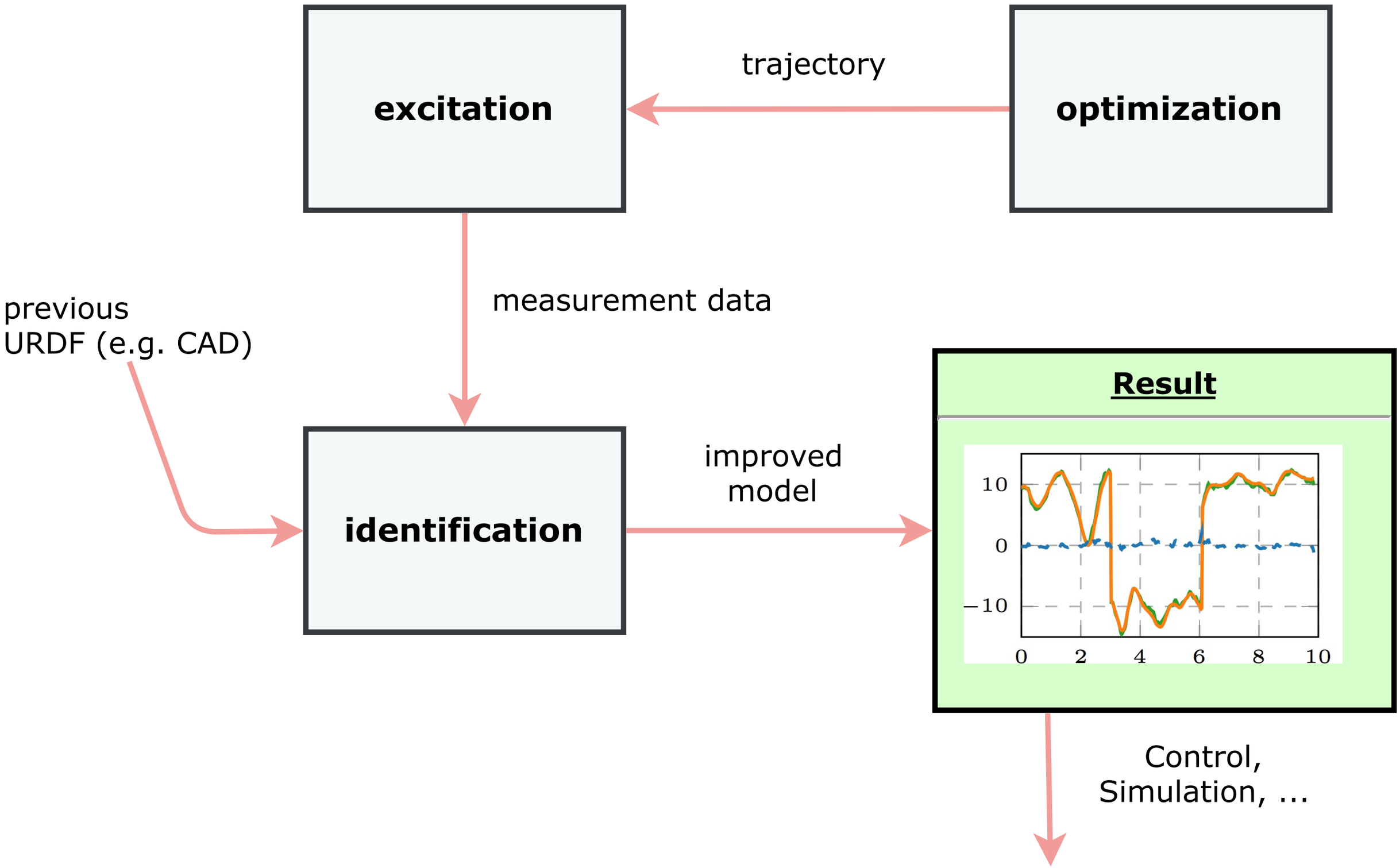
Steps of identification



Goals

- *Standard* Parameters
- Physical consistency
- Prevent overfitting (Generality)
- Floating-base, humanoids

Tools

- FloBaRoID - Floating Base Robot Identification
- Generic toolkit for
  - trajectory optimisation
  - excitation (ROS, YARP)
  - identification of parameters
  - 3D visualisation and data plots

https://github.com/kjyv/FloBaRoID

Dynamics Eqns

$$\boldsymbol{\tau} + \boldsymbol{\rho} = \boldsymbol{H}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \boldsymbol{C}(\boldsymbol{q}, \dot{\boldsymbol{q}})\dot{\boldsymbol{q}} + \boldsymbol{g}(\boldsymbol{q}) + \boldsymbol{d}(\dot{\boldsymbol{q}})$$

$$\boldsymbol{\tau} + \boldsymbol{\rho} = \boldsymbol{Y}(\boldsymbol{q}, \dot{\boldsymbol{q}}, \ddot{\boldsymbol{q}})\boldsymbol{x}$$

$\boldsymbol{x}$ - Parameter vector, in linear form:

- 0: mass m
- 1-3: first moment of mass (center of mass * m)
- 4-9: second moment of mass (inertia tensor expressed at frame origin, c.f. parallel axis theorem)

Base Parameters

- We want to solve for $\boldsymbol{x}$ as linear problem:

$$\boldsymbol{x} = \boldsymbol{Y}^{+} \left(\boldsymbol{\tau} + \boldsymbol{\rho} \right)$$

- $\boldsymbol{Y}$ generally is not of full rank, so no unique solution

- Projection of $\boldsymbol{Y}$ to linear independent subspace, „base parameter space“ B

- Project $\boldsymbol{Y}$ to base regressor $\boldsymbol{Y}_b$

$$\boldsymbol{Y}_b = \boldsymbol{Y}\boldsymbol{B}$$

$$\boldsymbol{x}_b = \boldsymbol{Y}_b^{+} \left(\boldsymbol{\tau} + \boldsymbol{\rho} \right)$$

Using Optimisation

- non-linear optimisation: local gradient based or global methods (e.g. genetic, particle swarm)

- SDP to solve as linear convex optimisation problem

$$\min \| (\boldsymbol{\tau} - \boldsymbol{Y}_b \, \boldsymbol{x}_b \|^2$$
$$\boldsymbol{x}_b$$

- (linear) constraints allow physical feasibility, previous knowledge

- We can get standard parameters directly:

$$\min_{\boldsymbol{x}} \| (\boldsymbol{\tau} - \boldsymbol{Y}_b \, \boldsymbol{B}\boldsymbol{x} \|^2$$

Physical feasibility

- inertia matrix H needs to be positive definite for stable control and simulation

- physical feasibility of parameters guarantees that it is

- Constraints on Standard params:

  - mass > 0; COM within link convex hull; inertia tensor positive definite, triangle inequality

  - extra: friction params > 0, mass sum = known value, known symmetry

Base vs. Standard

- Base parameters already allow Control, Torque prediction, Simulation
- Physically feasible base parameters can be found, (so positive definite H matrix)
- Why standard parameters?
    - URDF; existing tools and libraries; physical meaning