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Kalibrot Tutorial

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Kalibrot Features

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Kalibrot is an **open-source Matlab package** for **robot kinematic calibration**.

- At the moment, Kalibrot focuses only on **estimation of DH parameters** of any robotic structure.

- It provides **two solvers** for the calibration:
  - *Pinv* solver, for tradtitonal calibration based on jacobian pseudoinversion
  - *QP* solver, for calibration with additional bounds on the DH parameters

- It is based on a **fast iterative process** to compute **analytically** the derivatives of the calibration cost function.

- Provides useful **information about the identifiability** of the parameters and the **accuracy of their estimation**.

- **Allows for visualization** of the calibration results and of the calibrated robot kinematic structure.

Kalibrot Framework

Kalibrot Workflow

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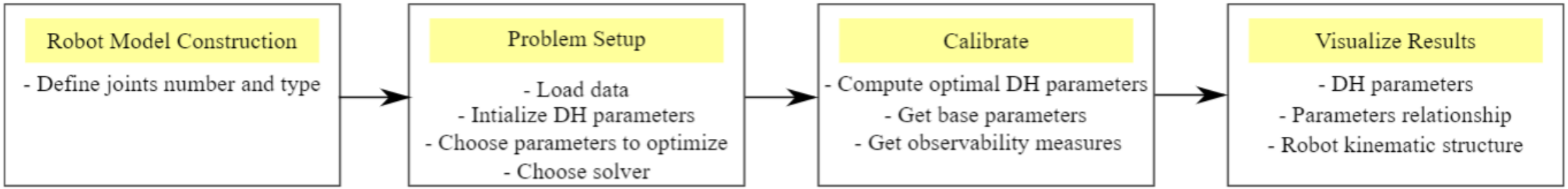
Kalibrot consists of a **simple workflow** to facilitate the process of robot calibration.



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Kalibrot Code Setup 1/2

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Setup robot object

Load collected data

Set DH parameters bounds (min and max)

Intial DH parameters guess

```
function Kalibrot_Calibration
%% Robot model
T_init = eye(4,4);
n_joints = 6;
types = 'rrprrr';

Robot = RobotKinematics(n_joints, types, T_init,[]);
```

```
%% Load measurements
load 'P_m_stanford_3'
load 'Q_stanford_3'

%number of measurements
m = length(P_m);
```

```
%% Intializations
% DH param limits for each link. 1 = min
% in R^njx4 [d1 theta1 a1 alpha1],;...[dn thetan an alphan]
Limits(1:n_joints,1:4,1) = ...
    [0.7 -pi/2 0 -pi/2;
    1.3 -pi 0 -pi/2;
    -0.1 -pi/2 -0.1 -pi/2;
    0.3 -pi/2 0 -pi/2;
    -0.1 -pi/2 -0.1 -pi/2;
    0.05 -pi/2 0 -pi/2];

Limits(1:n_joints,1:4,2) = ...
    [1.2 pi/2 0.1 pi/2;
    1.7 pi 0.5 pi/2;
    0.1 pi/2 0.1 pi/2;
    0.7 pi/2 0.1 pi/2;
    0.1 pi/2 1 pi/2;
    0.3 pi/2 0.1 pi/2];

% initial estimates
%d,theta,a,alpha
DH = ...
    [0.9 -pi/2 0.1 -pi/2;
    1.35 pi 0.05 -pi/2;
    0 0 0 0;
    0.3 -pi/2 0.05 pi/2;
    0 -pi/2 0.7 -pi/2;
    0.05 0 0 0];
```

Class for **kinematics computation**.
It also allows to compute the cost **function derivatives**

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Kalibrot Code Setup 2/2

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Parameters selection matrix (0 or 1)

Cartesian components and weight matrix

Set options for solvers and visualization

Solve calibration problem

```
%parameters selection. 0 = no optimize, 1 = optimize
w_p = [1 1 1 1;
    1 1 1 1;
    1 1 1 1;
    1 1 1 1;
    1 1 1 1;
    1 1 1 1];

%%motion directions: x,y,z,qx,qy,qz,qw
dim = [1,2,3,4,5,6,7];
%weight matrix for motion direction
W = [1*ones(length(1),m);
    1*ones(length(1),m);
    1*ones(length(1),m);
    1*ones(length(1),m);
    1*ones(length(1),m);
    1*ones(length(1),m);
    1*ones(length(1),m)
];
P_m = P_m(dim,:);

%Solver setup
options.solver = "pinv";
options.damping = 1e-03;
options.Visualize{1} = true;
options.Visualize{2} =[0,0,1,0,0,0]';
[DH_params_pinv,P_pinv,W_pinv,Info_pinv] = Calibrate(Robot,dim,P_m,Q,DH,W,w_p,Limits,options);
```

Choose what **parameters to optimize for**.

Choose what **components to utilize** and what weight to assign to each one.

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Kalibrot Visualization

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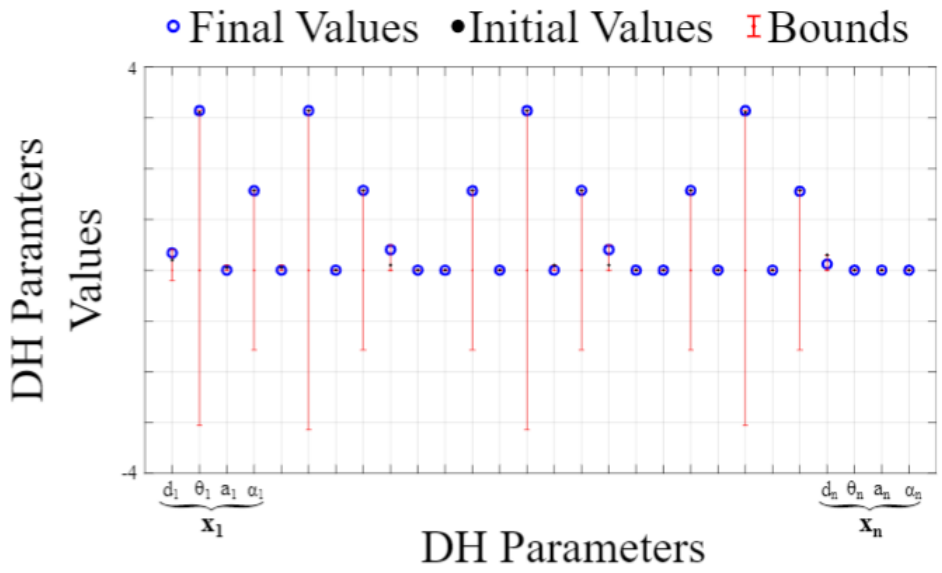
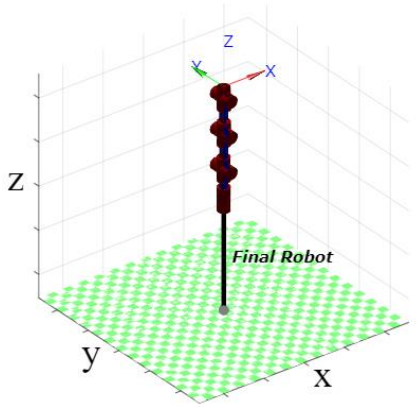
If the visualization layer is enabled, Kalibrot plots:

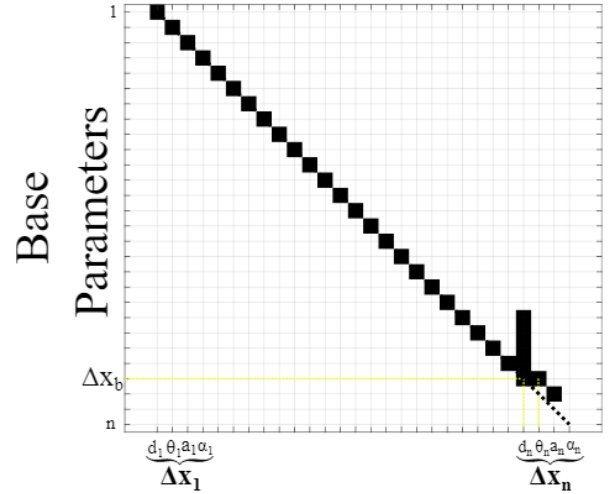
1) Calibrated DH parameters



2) Calibrated kinematic structure



3) Parameters identification matrix



The parameters on the diagonal can be identified completely and independently from the others. The black squares indicate if the parameter can be identified only in linear combination with others or not.

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