Final Project
Practical Course Robotics

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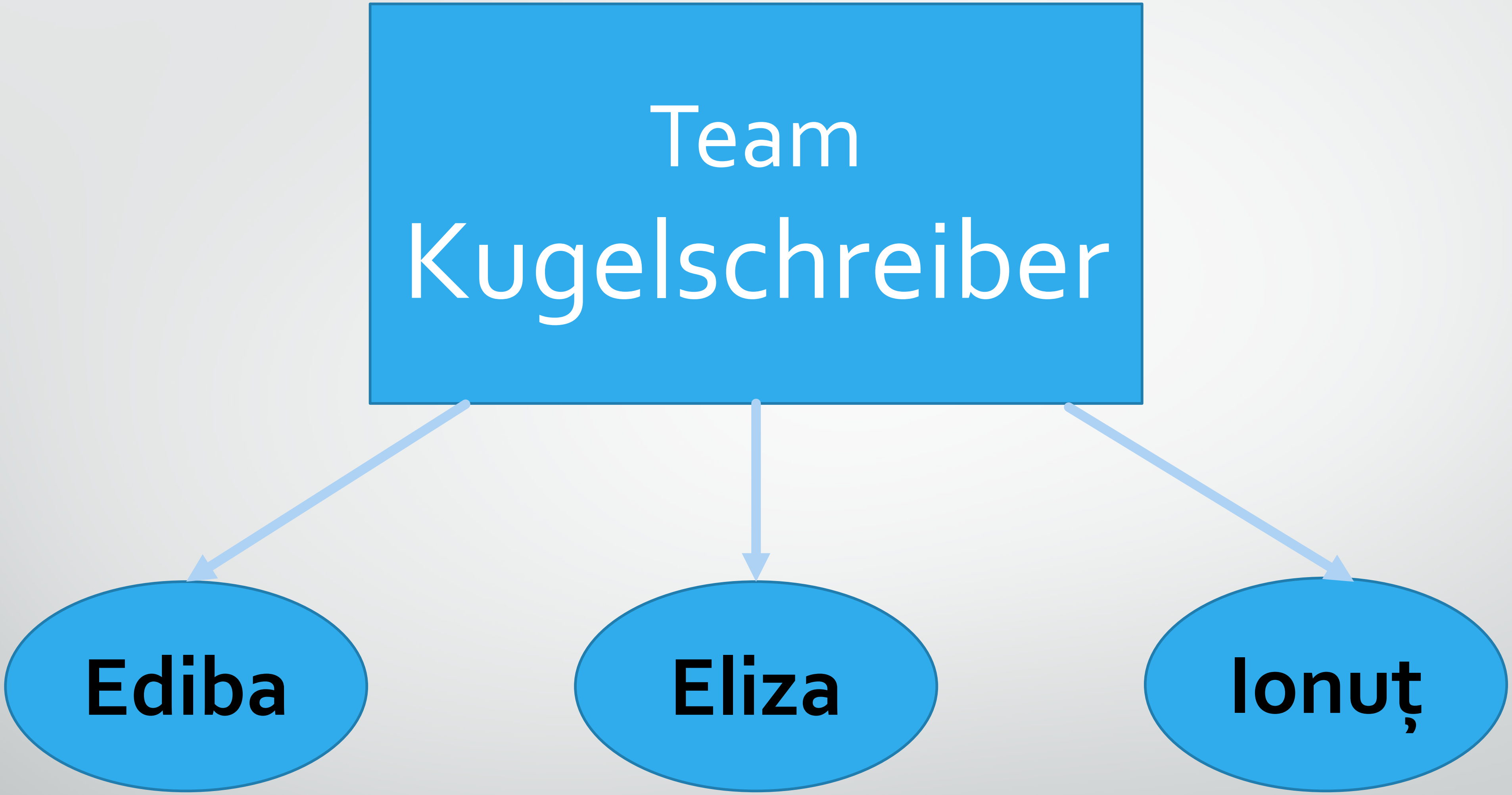
Team Kugelschreiber
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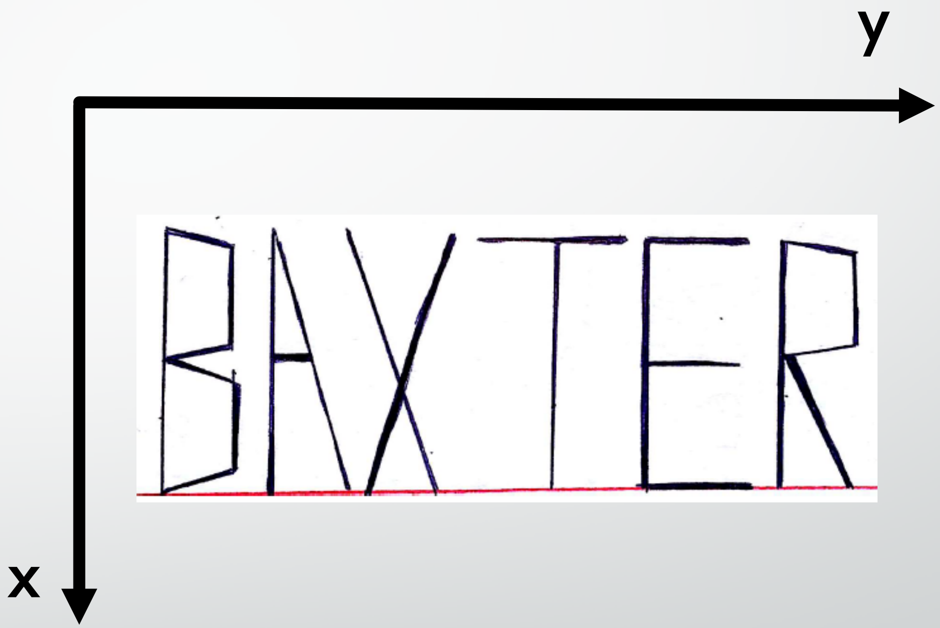
Project Goal

Make Baxter write!

What to write?

- Make Baxter sign "autographs";
- Designing the letters;

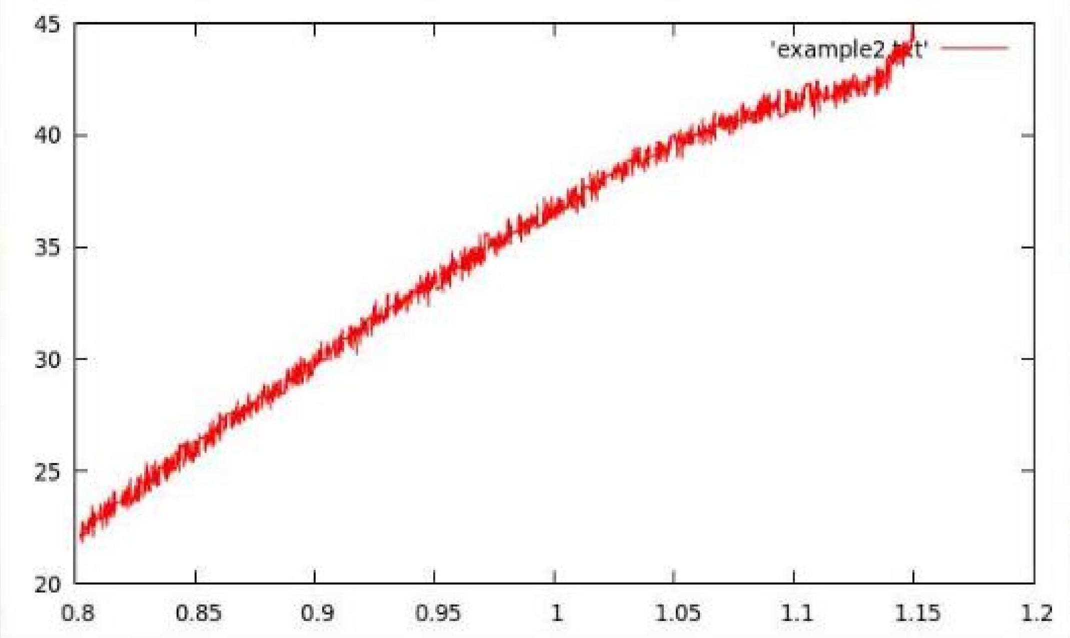


Where to write? (1)

- Determine the table's position
  - Left endeffector at a starting position: y =(0.6, -0.1, 1.1);
  - Go down step by step;
    - Read the torques u and the Jacobian J;
    - Compute force via $\boldsymbol{f} = \left(\boldsymbol{J}^{\#}\right)^{\boldsymbol{T}} \boldsymbol{u}$, where $\boldsymbol{J}^{\#} = J^T (JJ^T)^{-1}$;
    - Save $\boldsymbol{y}$ and corresponding $\boldsymbol{f}$;

Where to write? (2)

- Analyze the data;
  - $\boldsymbol{f} = 63.714 \, * \underbrace{y(2)}_{\text{Value on z axis w.r.t base frame}} - 28.8;$
  - determine the table's height.



How to write? (1)

- Torque control;
- Robot dynamics: $\boldsymbol{u} = \underbrace{M\ddot{q}^*}_{\text{Provided in the code}}$, neglecting F;
- Torque for pushing: $\boldsymbol{u} = J^T f$;
- Necessary torque: $\boldsymbol{u} = \boldsymbol{M}\ddot{\boldsymbol{q}} + \boldsymbol{J}^T\boldsymbol{f}$.

How to write? (2)

- Desired acceleration $\ddot{\boldsymbol{q}}^*$: $\ddot{q}^* = \underbrace{\ddot{q}^{ref}}_{=0} + K_p\left(q^{ref} - q\right) + K_d(\underbrace{\dot{q}^{ref}}_{=0} - \dot{q})$;
- Compute the reference joint vector q^{ref}:
  - Inverse kinematics: $\boldsymbol{q}^* = \underset{q}{\operatorname{argmin}} \|\phi(q) - y^*\|^2 + \|q - q_0\|^2$;
  - Linearization of $\phi(q)$ at q_0: $\phi(q) \approx y_0 + J(q - q_0), y_0 = \phi(q_0)$;
  - Solution: $\boldsymbol{q}^* = q_0 + J^{\#}(y^* - y_0)$.

How to write? (3)

- “Small step” approach → target interpolation;

Input: initial state q_0, desired y^*, methods ϕ^{pos} and J^{pos}
Output: trajectory $q_{0:T}$

Set $y_0 = \phi^{\text{pos}}(q_0)$ *// starting endeff position*
for $t = 1 : T$ **do**
  $y \leftarrow \phi^{\text{pos}}(q_{t\text{-}1})$ *// current endeff position*
  $J \leftarrow J^{\text{pos}}(q_{t\text{-}1})$ *// current endeff Jacobian*
  $\hat{y} \leftarrow y_0 + (t/T)(y^* - y_0)$ *// interpolated endeff target*
  $q_t = q_{t\text{-}1} + J^\sharp(\hat{y} - y)$ *// new joint positions*
  Command q_t to all robot motors and compute all $T_{W \to i}(q_t)$
end for

Lecture 5 (*Kinematics*), **Robotics Course**
https://ipvs.informatik.uni-stuttgart.de/mlr/15-Robotics/05-kinematics.pdf

How to write? (4)

- Configuration close to the initial one, q_0:
  - $\underset{\substack{\downarrow \\ q_{t+1}^{ref}}}{q^*} = \underset{\substack{\downarrow \\ q_t^{ref}}}{q'} + J^{\#}(\underset{\substack{\downarrow \\ y_{interm}}}{y^*} - \underset{\substack{\downarrow \\ y_t}}{y'}) + \left(\mathrm{I} - J^{\#}\mathrm{J}\right)\mathrm{h}$, where $h = q_0 - \underset{\substack{\downarrow \\ q_t}}{q'}$

Team Kugelschreiber
and Baxter
thank you
for the attention!