On Time Parameterizations of User Demands in Mechatronics

10th PhD Workshop - Hluboká nad Vltavou

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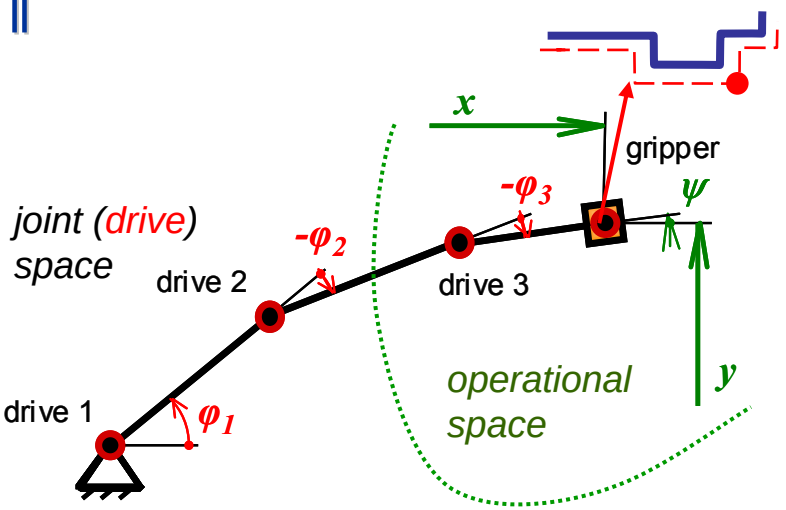
On Time Parameterizations of User Demands in Mechatronics

Outline:

- User Demands in Mechatronics (Intro)
- Concepts of Time Parameterization
- Dynamical point of view of time parameterization
  - Range-Space Modification - example
  - End-Point Modification - example
- Kinematical point of view of time parameterization
- Several Notes as Conclusion

User Demands in Mechatronics

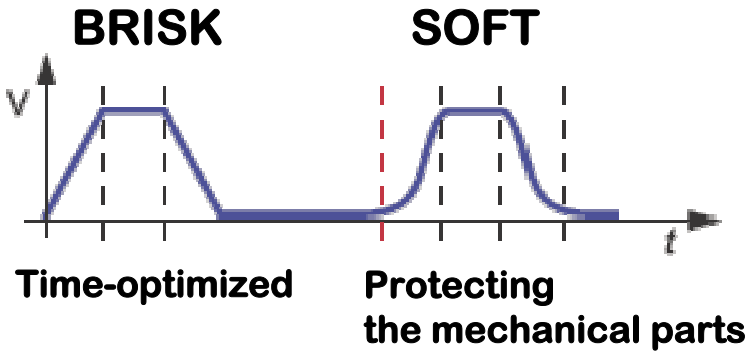
- ***mechatronic system***

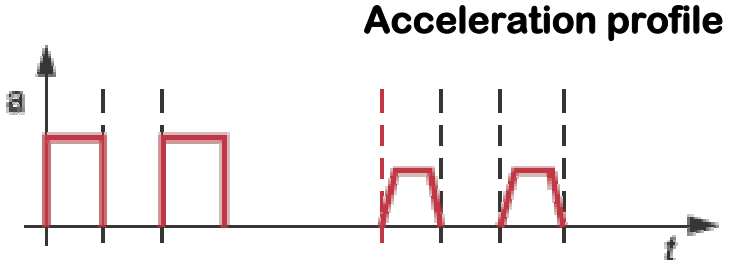


- *mechanical elements*
  (beams, joints, gears, grippers)
- *electro-mechanical*
  (drives, sensors)
- *electrical*
  (control units)

- ***combination of technological demands and construction limits of the system:***

  to accomplish assigned path
  or to reach predetermined key point
  with certain velocity
  and acceleration profiles . . .





Concepts of Time Parameterization

- ***kinematical point of view***
  ⇨ ***curve-based planning***
  - **length of path**
  - **approximate time for execution of path**
  - **geometrical parameter**

  (selection of acceleration polynomial with border conditions:

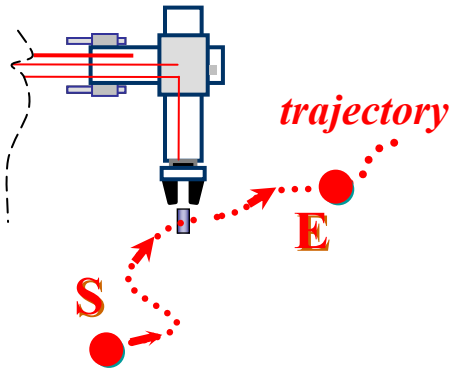
  $p = s(t)$
  $\dot{p} = v(t)$
  $\ddot{p} = a(t)$

  s, v, a → 3rd order / s, v, a, a' → 5th order)
  in 1D – *parameter t (time)*

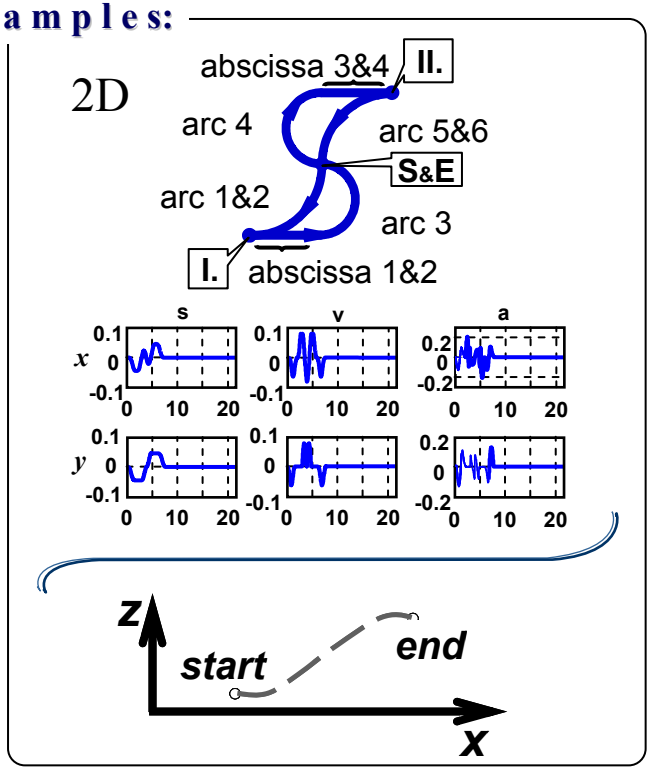
  - **coordinates and their time derivatives** ***(param. p(t))***
    - *abscissa*
    - *circle / ellipse arc*
    - ...

    *(*2D, 3D *parametric curves)*
    - 2D, 3D *general curves (selection from table by parameter)*
- ***dynamical point of view***
  ⇨ ***range space design***
  ⇨ ***point-to-point design***
  - **free ranges and Start and End points are given**

    or
  - **only Start and End points are given**
  - **timing via specific modifications of predictive control algorithms**
    ⇨ coordinates and their time derivatives



Examples:



Dynamical point of view of time parameterization
via Predictive Control:

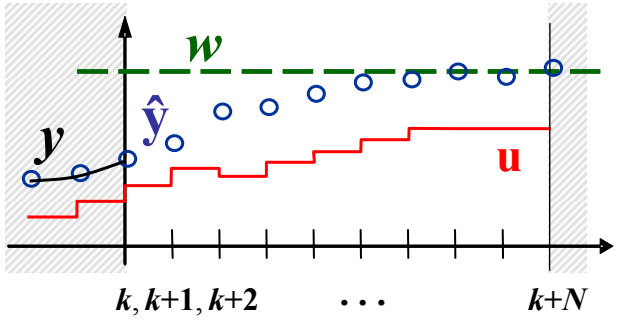
Model + Cost function (criterion):

$$\hat{\mathbf{x}}_{k+1} = \mathbf{A}\,\mathbf{x}_k + \mathbf{B}\,u_k$$
$$\hat{y}_{k+1} = \mathbf{C}\,\hat{\mathbf{x}}_{k+1}$$

$$J = \sum_{j=k}^{k+N} \left((\hat{y}_{j+1} - w_{j+1})^T Q_y \, (\hat{y}_{j+1} - w_{j+1}) + (u_j - u_{j-1})^T Q_u \, (u_j - u_{j-1}) \right)$$

Equations of predictions $\Rightarrow$ $\hat{\mathbf{y}} = \mathbf{f} + \mathbf{G}\,\Delta\mathbf{u}$

$$\hat{\mathbf{y}} = [\hat{y}_{k+1}, \cdots, \hat{y}_{k+N+1}]^T, \quad \mathbf{u} = [u_k, \cdots, u_{k+N}]^T$$



Minimization of quadratic criterion:

$$\min_{u} J = \min_{u} \mathbf{J}\,\mathbf{J}, \quad (\min_{u} \textit{(quadratic form)}), \quad u_{opt} = \arg\min_{u} \mathbf{J}$$

Range-Space Modification

$$J_k = \sum_{j=k}^{k+N} \{ \| (\hat{y}_{j+1} - r_{a\,j+1}) \mathbf{Q}_{\mathrm{ra}} \|^2 + \| (\hat{y}_{j+1} - r_{b\,j+1}) \mathbf{Q}_{\mathrm{rb}} \|^2 + \| \mathbf{u}_j \mathbf{Q}_{\mathrm{u}} \|^2 \}$$

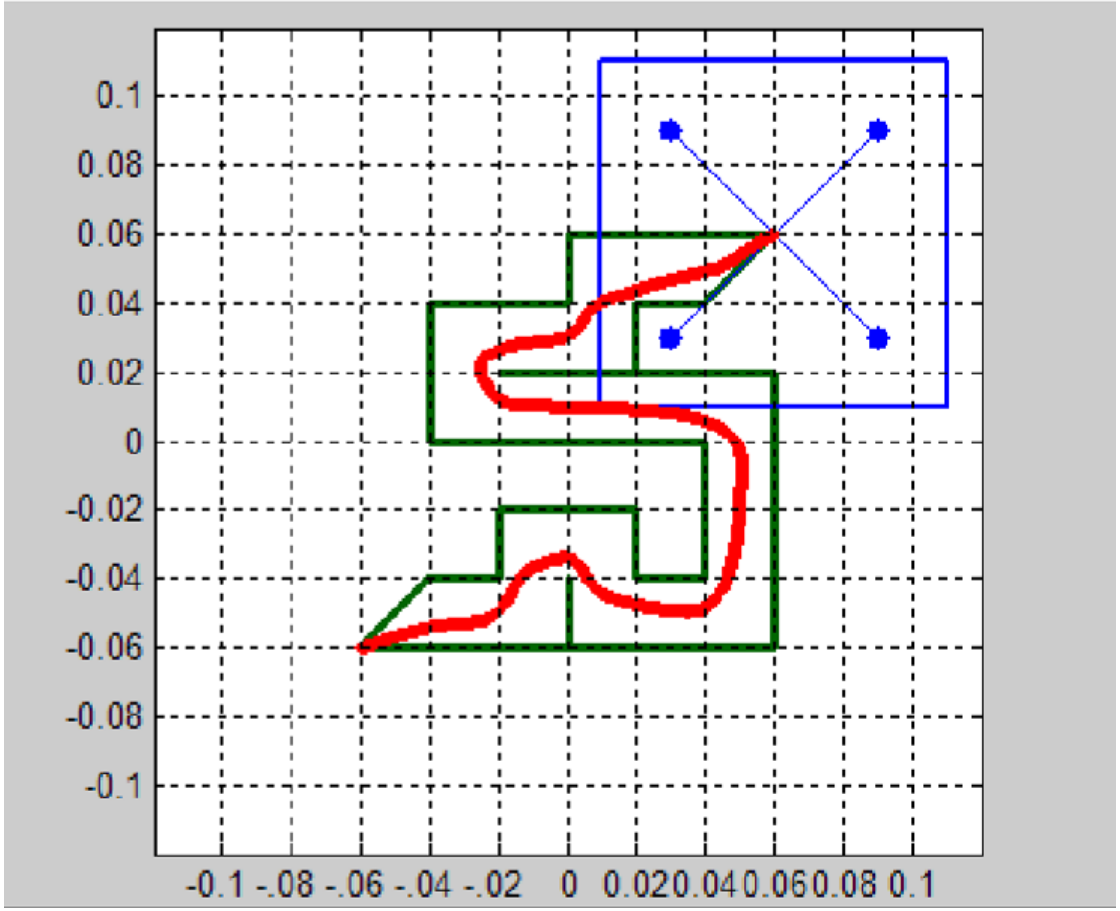
End-Point Modification

$$J_k = \sum_{j=No+1}^{k+N} \{ \| (\hat{y}_{k+j} - w_{k+j}) \overline{\mathbf{Q}}_y \|^2 + \| \mathbf{u}_{k+j-1} \overline{\mathbf{Q}}_{\mathrm{u}} \|^2 \}$$

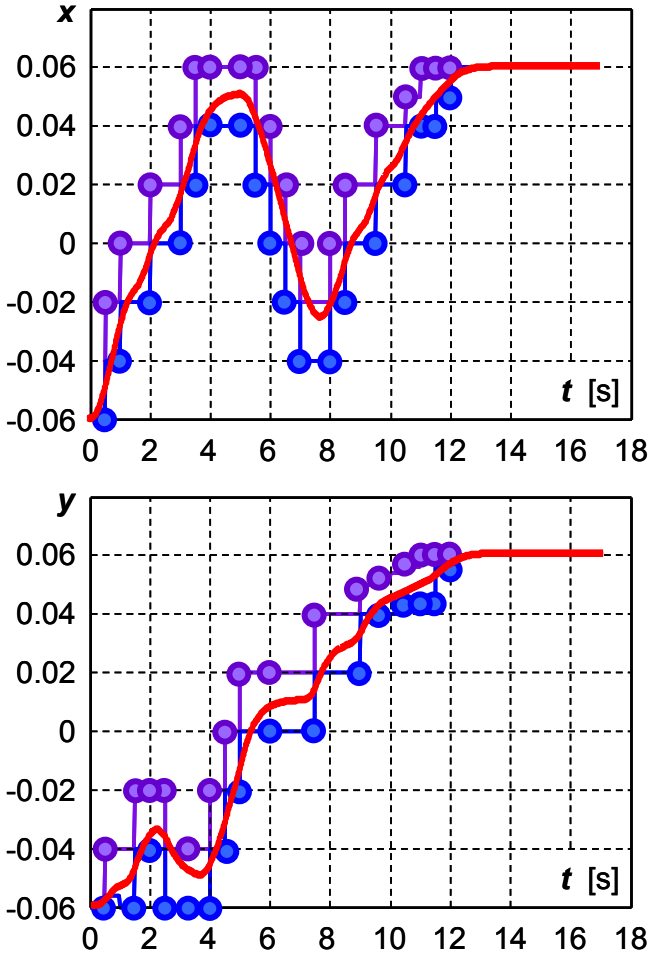
w = const.

Range-Space Modification - example

xy- graph: motion of a robot movable platform

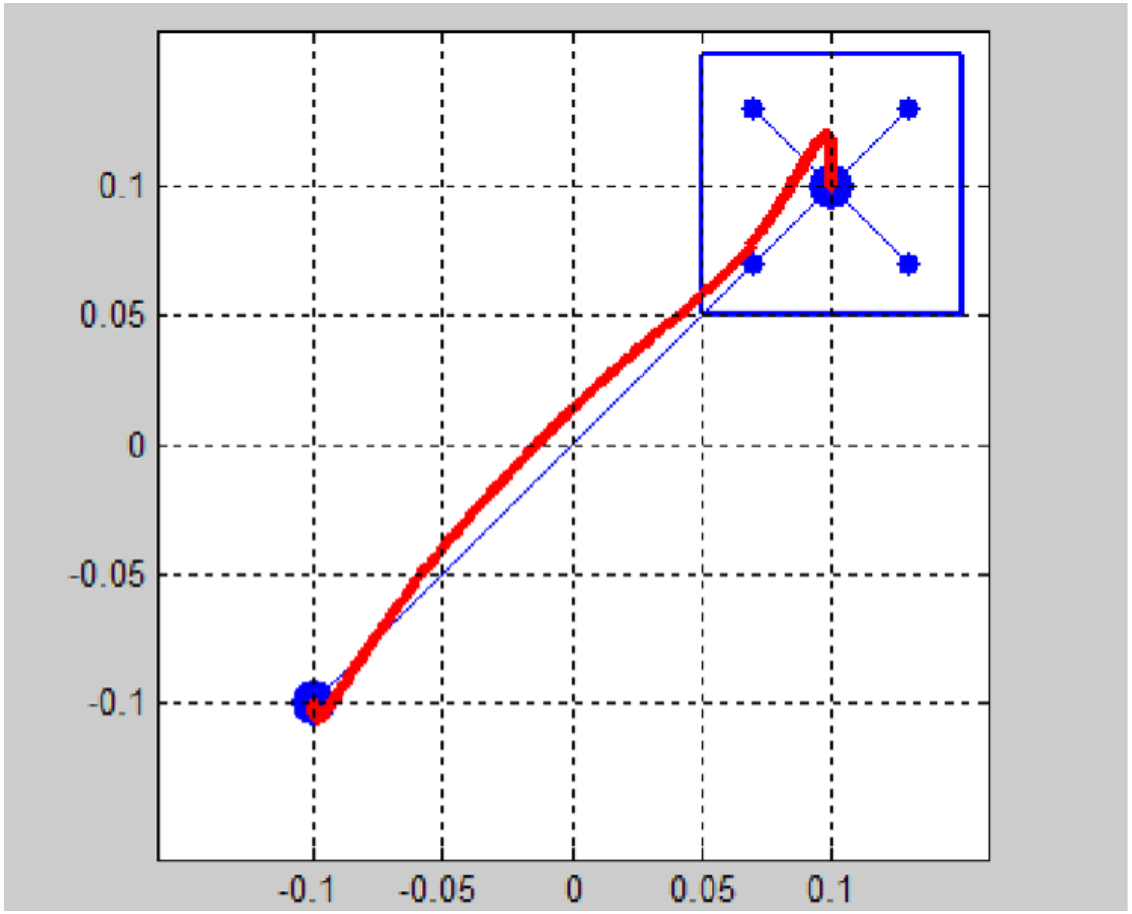


time – graphs: $x(t)$, $y(t)$

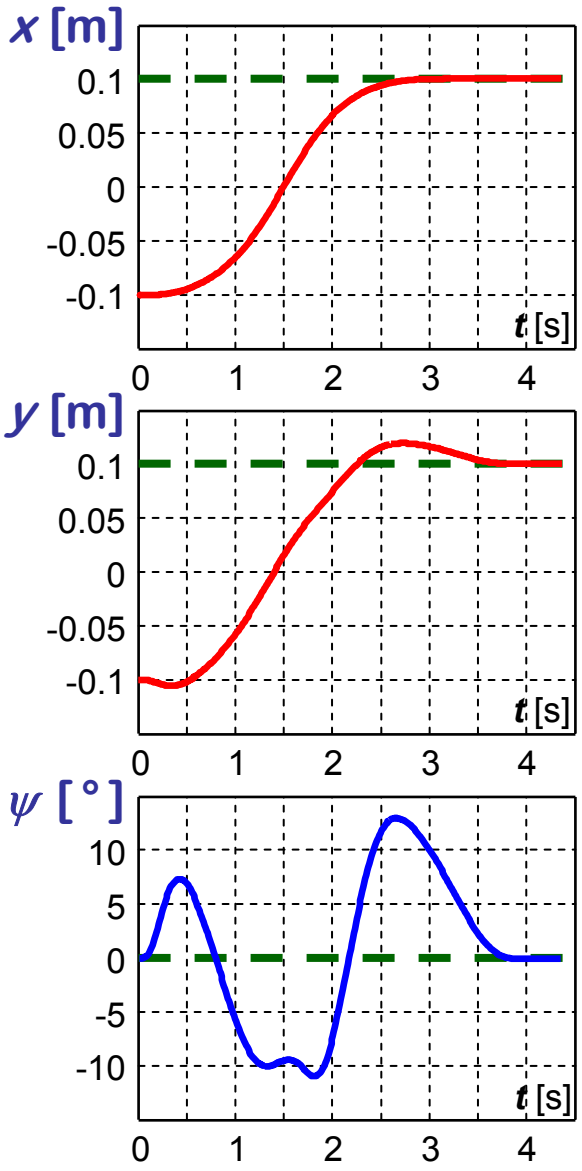


End-Point Modification - example

xy- graph: vertical motion of a robot movable platform



time graphs →



Several Notes as Conclusion

- *Suitable time parameterization can provide:*
  - *safe utilization of machinery*
  - *optimal duration of the motion process*
  - *optimal path of the machinery motion*

- *In the presentation, there were addressed:*
  - *kinematical approach*
    based on analytical geometry and kinematical laws
  - *dynamical approach*
    realized by specific control tasks
    and using appropriate dynamical models of systems

- *The procedures of time parameterization together with path optimization are continuously under development due to continuous efforts to minimize production costs at keeping the profit from number of products*

  ⇨ *minimize operational time*
  (path optimization . . .)
  ⇨ *maximize machinery use*
  (velocity and acceleration profile optimization)

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Thank you for your attention

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