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A comparison of the motion scenarios for the SPHERO robot based on b-splines and it's real output

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Motivation

- NURBS – a tool for CAD/CAM

- Line segment for CA**D**
  - Linear parametrization is sufficient
- Line segment for CA**M**
  - Newton laws cannot be omitted
- For the description of proper solutions proper devices are necessary

- **Screen is not a proper device to explain problems within CAM (parametric smoothness)**

Used tool

SPHERO robot

1. Halme, A., Schonberg, T., Wang, Y. (1996), Motion Control of a Spherical Mobile Robot, 4th IEEE Workshop on Advanced Motion Control. Mie. Japan. 1996, 1, pp. 259-264
2. Hou, K., Sun, H., Jia, Q., Zhang, Y. (2012), An Autonomous Positioning and Navigation System for Spherical Mobile Robot, Procedia Engineering 29 (2012), pp. 2556-2561
3. Joshi, V.A., Banavar R.N., Hippalgaonkar, R. (2010): Design and analysis of a spherical mobile robot, Mechanism and Machine Theory 45 (2010), pp. 130-136
4. M. Kamaldar, M., Mahjoob, M.J., Yazdi, M.H., Vahid-Alizadeh, H., Ahmadizadeh·S (2011), A Control Synthesis for Reducing Lateral Oscillations of a Spherical Robot, International Conference on Mechatronics, Istanbul, Turkey, 2011, pp. 546-551
5. Rhodri H. Armour, R.H., Vincent, J.F.V., (2006), Rolling in Nature and Robotics: A Review, Journal of Bionic Engineering 3 (2006) pp.195-208
6. https://en.wikipedia.org/wiki/Inertial_measurement_unit cited [2018-02-14]
7. http://sdk.sphero.com/ cited [2018-02-14]

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6. https://en.wikipedia.org/wiki/Inertia
7. http://sdk.sphero.com/ cited [2018-0

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[1] A. Koshiyama and K. Yamafuji, "Design and Control of an All-Direction Steering Type Mobile Robot" The International Journal of Robotics Research. Vol.12, no.5, pp.411-9, 1993

[2] A. Halme, P. Jakubik, T. Schönberg, M. Vainio, "The Concept of Robot Society and Its Utilization" Proc. of the 1993 IEEE/Tsukuba International Workshop on Advanced Robotics - Can robots contribute environmental detorioration? - Tsukuba, 1993

[3] Y. Wang, "Spherical Rolling Robot", Automation Technology Laboratory, Helsinki University of Technology, report, Oct. 1994

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6. https://en.wikipedia.org/wiki/Inertia
7. htt 2018-(

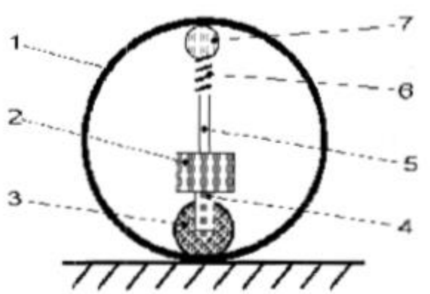

Fig.1 Structure of the Rolling Robot.1. robot body (case), 2. controlling box, 3. driving wheel, 4. steering axis, 5. supporting axis, 6. spring, 7. balance wheel

6. References

[1] A. Koshiyama and K. Yamafuji, "Design and Control of an All-Direction Steering Type Mobile Robot" The International Journal of Robotics Research. Vol.12, no.5, pp.411-9, 1993

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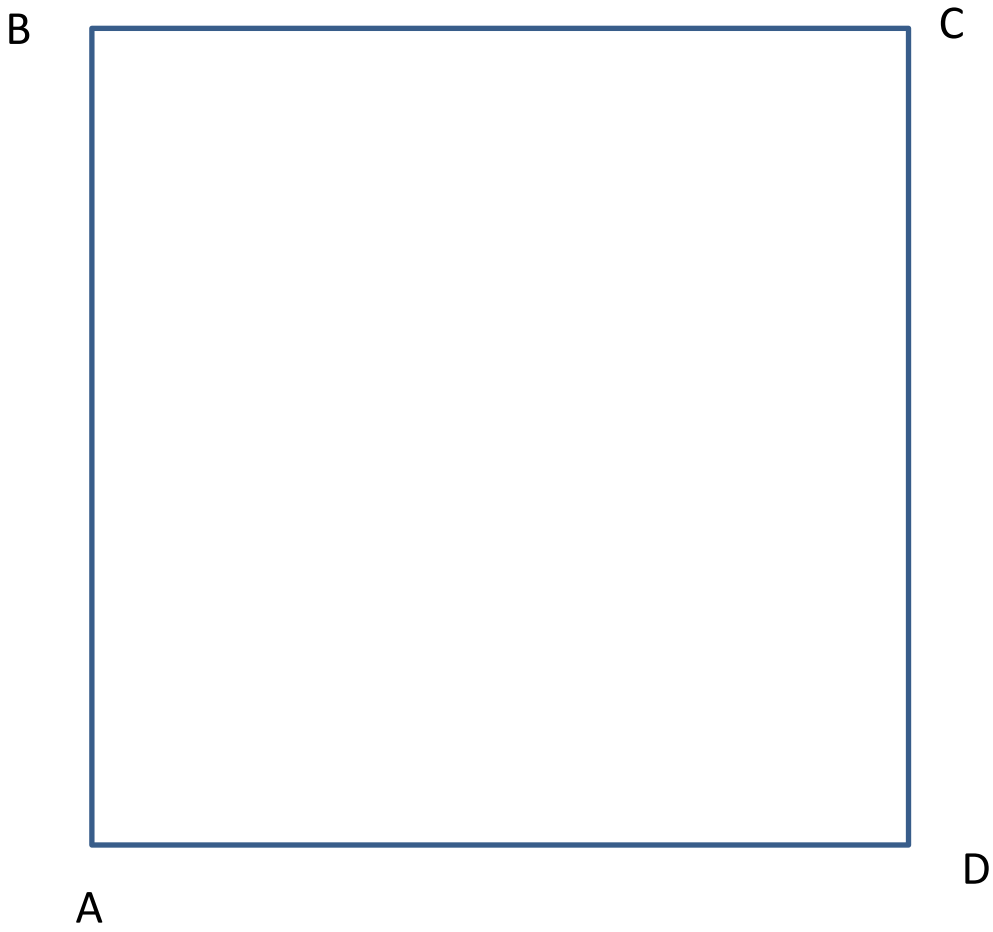
Motion scenarios and geometry



Line segment

$$P(t) = A + t\left(B - A\right)$$

$$P'(t) = \left(B - A\right)$$

$$P''(t) = 0$$

Line segment

$$P(t) = A + t(B - A)$$

$$P'(t) = (B - A)$$

$$P''(t) = 0$$

$$F(t) = m\,a = m\,P''(t)$$

Line segment

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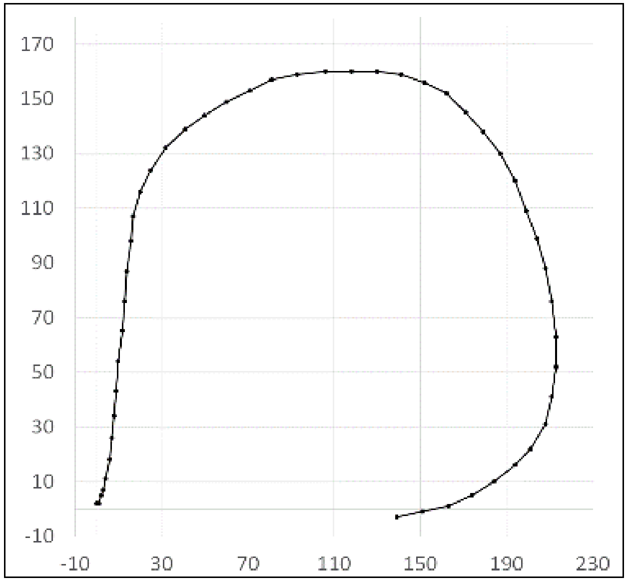
$$P''(t) = 0$$

$$F(t) = m\,a = m\,P''(t)$$



Motion scenarios (NURBS)

Bézier3

B-Spline2 (quadratic Bézier)

B-Spline3

Motion scenarios (NURBS)

Bézier3

$$P''(t) = \mathbf{TDDM\Pi} = \begin{pmatrix} 1 & t & t^2 & t^3 \end{pmatrix} \begin{pmatrix} 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 6 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} P_0 \\ 3(P_1 - P_0) \\ 3(P_0 - 2P_1 + P_2) \\ P_3 - 3P_2 + 3P_1 - P_0 \end{pmatrix} = \mathbf{T} \begin{pmatrix} 6(P_0 - 2P_1 + P_2) \\ 6(P_3 - 3P_2 + 3P_1 - P_0) \\ 0 \\ 0 \end{pmatrix}$$

B-Spline2 (quadratic Bézier)

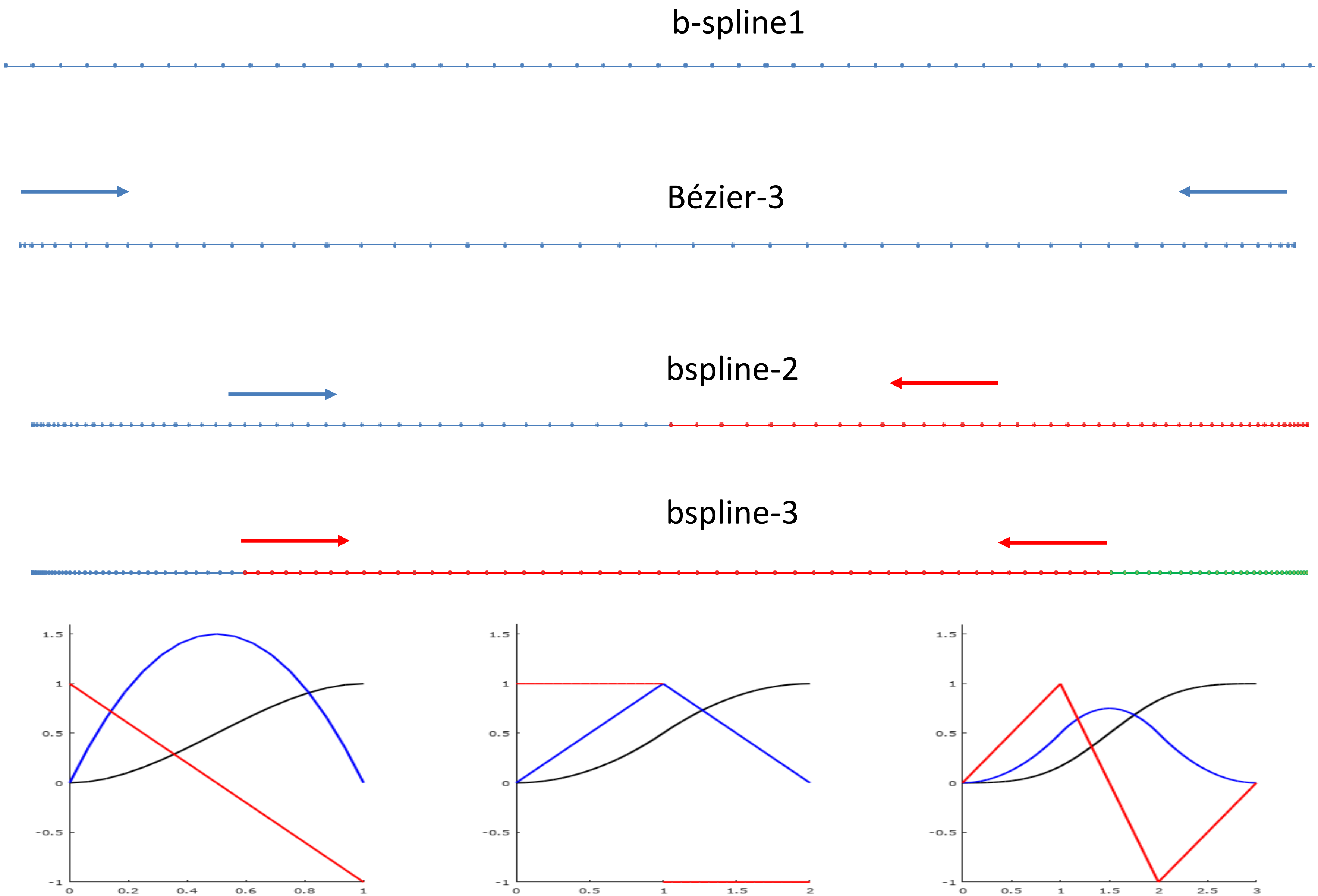
$$P''(t) = \mathbf{TDDM\Pi} = \begin{pmatrix} 1 & t & t^2 \end{pmatrix} \begin{pmatrix} 0 & 0 & 2 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} P_0 \\ 2(P_1 - P_0) \\ P_0 - 2P_1 + P_2 \end{pmatrix} = \mathbf{T} \begin{pmatrix} 2(P_0 - 2P_1 + P_2) \\ 0 \\ 0 \end{pmatrix}$$

B-Spline3 (Coons)

$$P''(t) = \mathbf{TDDM\Pi} = \begin{pmatrix} 1 & t & t^2 & t^3 \end{pmatrix} \begin{pmatrix} 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 6 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \frac{1}{6} \begin{pmatrix} P_0 + 4P_1 + P_2 \\ 3(P_2 - P_0) \\ 3(P_0 - 2P_1 + P_2) \\ P_3 - 3P_2 + 3P_1 - P_0 \end{pmatrix} = \mathbf{T} \begin{pmatrix} P_0 - 2P_1 + P_2 \\ P_3 - 3P_2 + 3P_1 - P_0 \\ 0 \\ 0 \end{pmatrix}$$

$$\mathbf{D} = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 3 \\ 0 & 0 & 0 & 0 \end{pmatrix} \qquad \mathbf{DD} = \begin{pmatrix} 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 6 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

Motion scenarios and geometry



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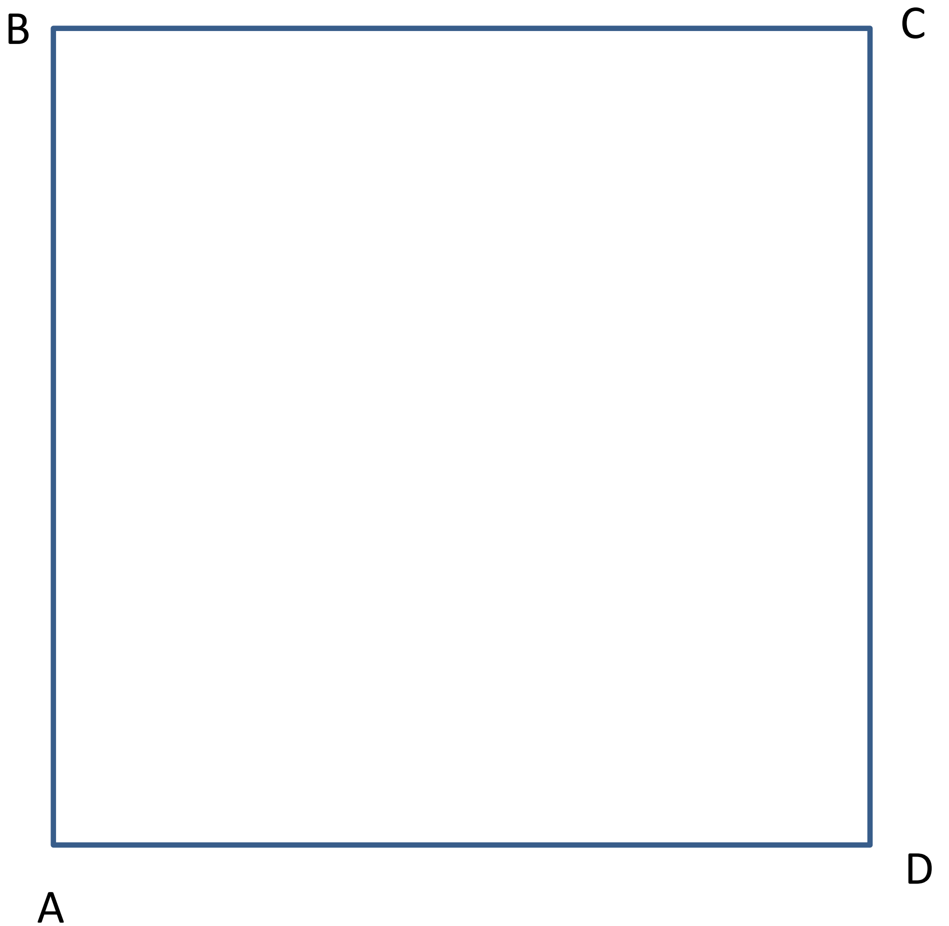
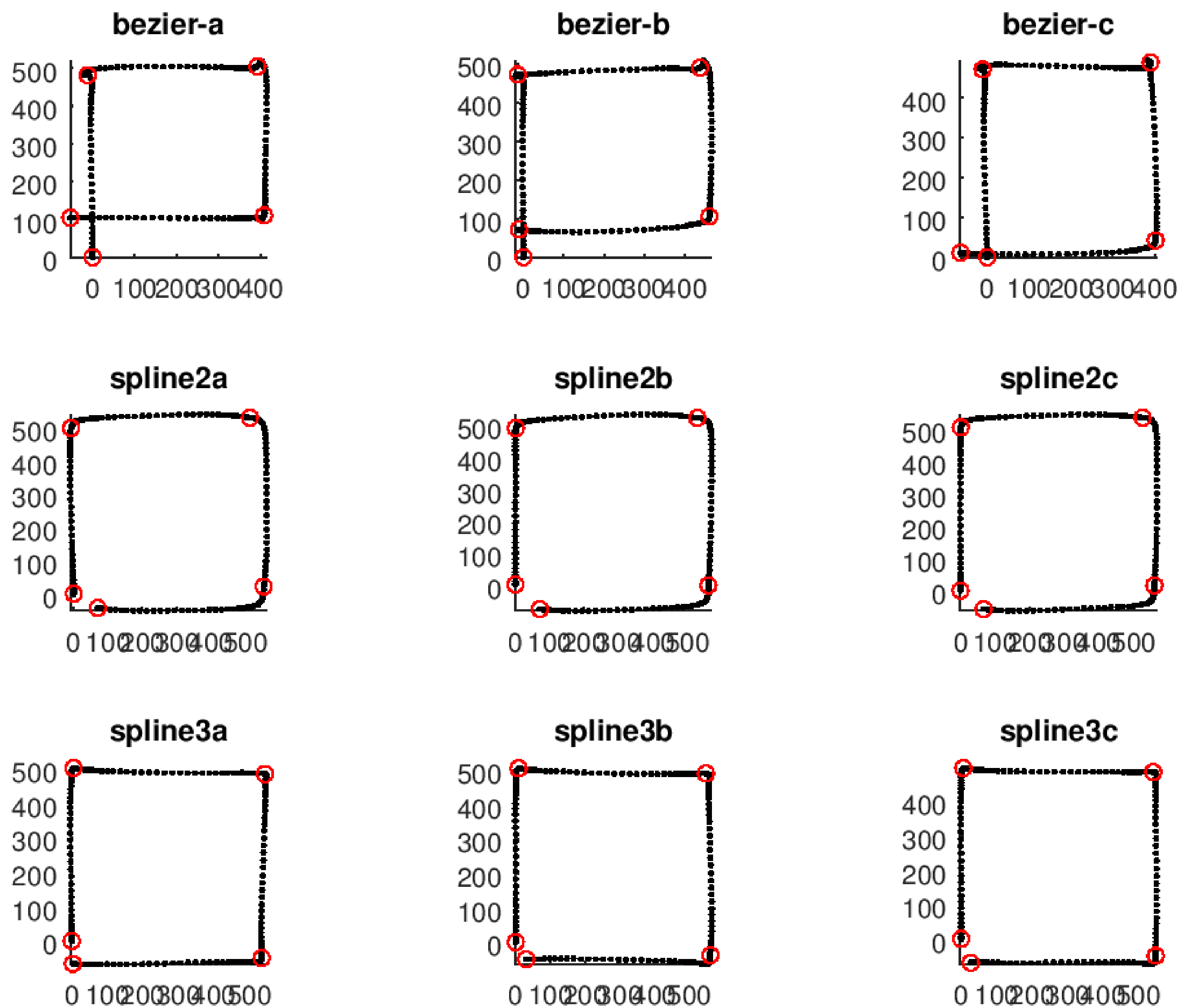


Real trajectories



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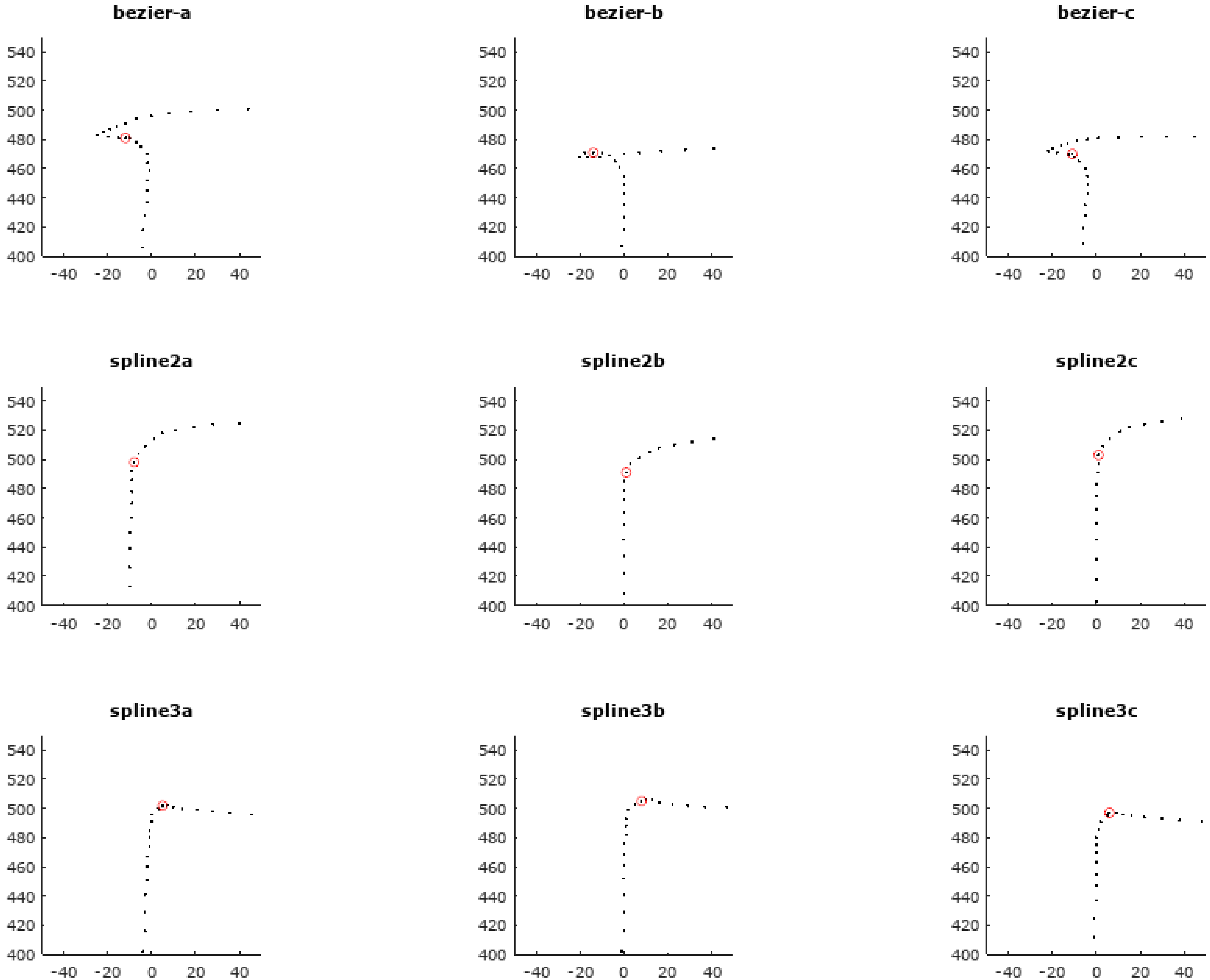
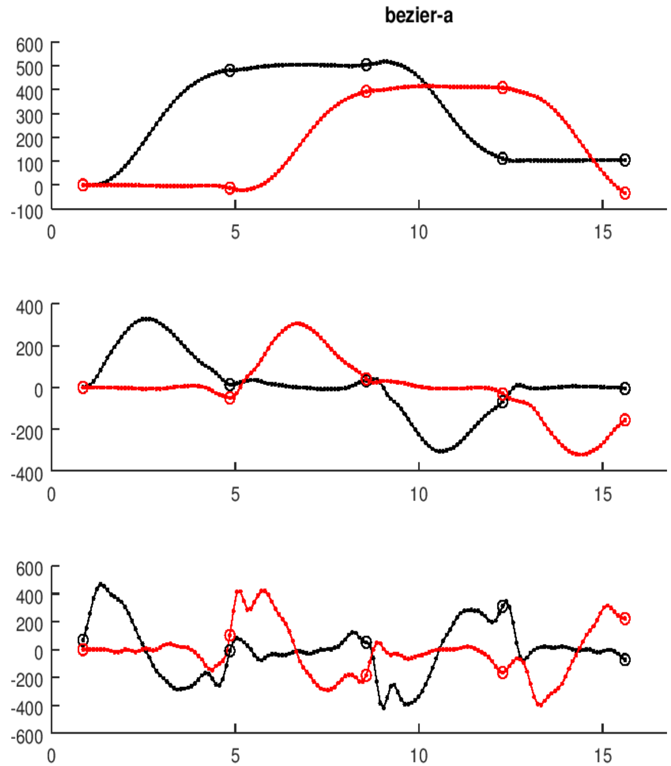
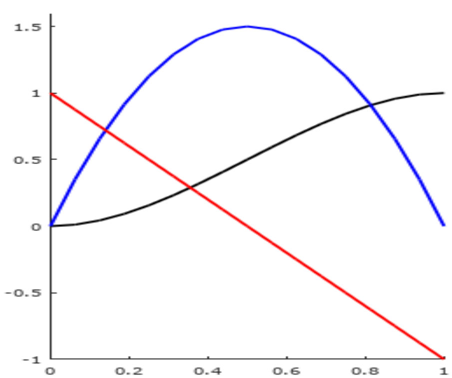


Real trajectories – analysis





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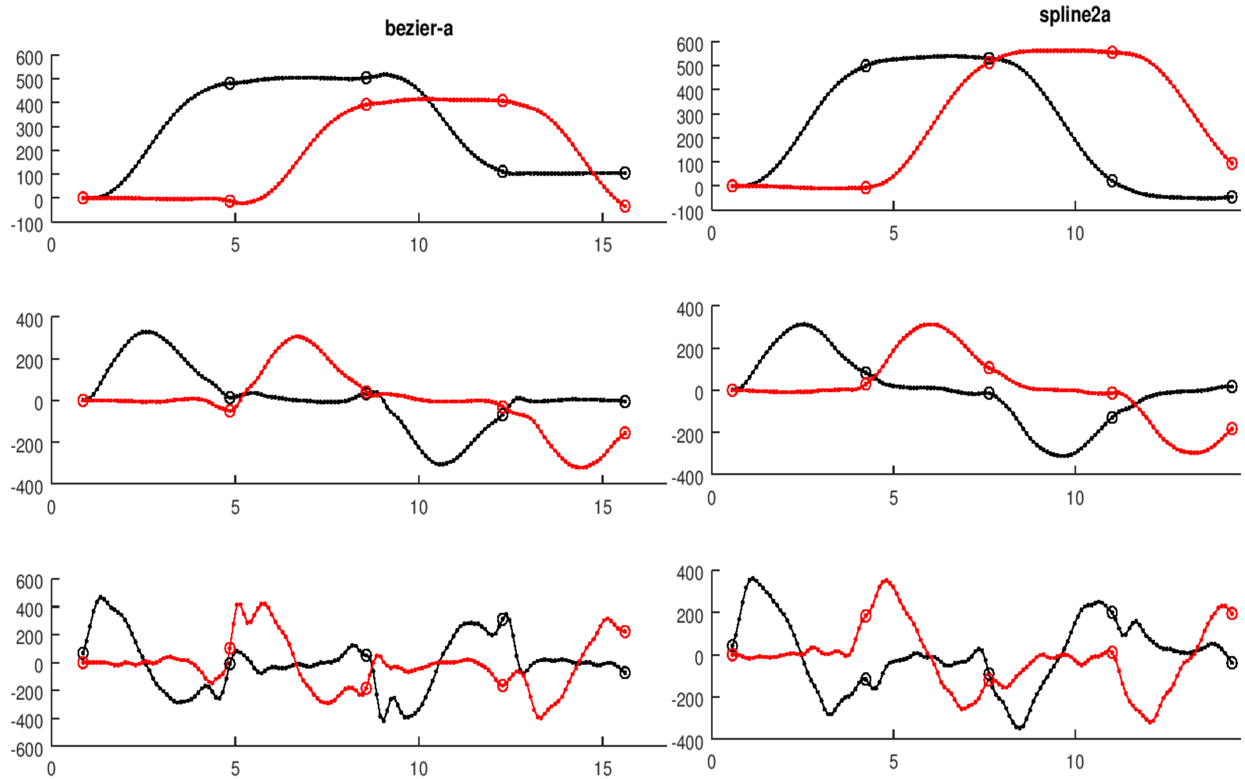

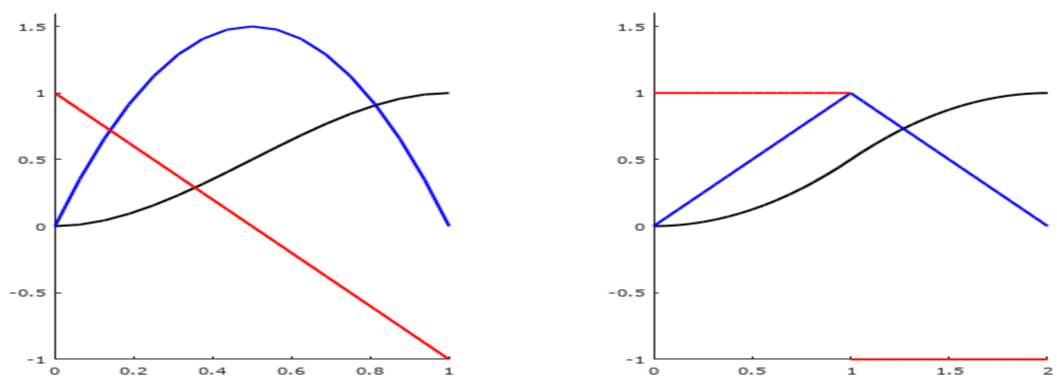

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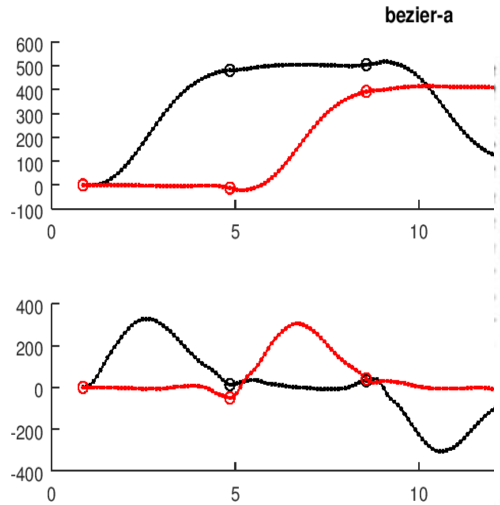

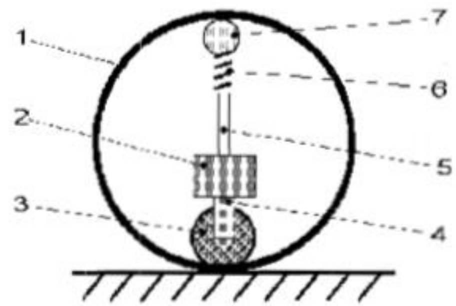

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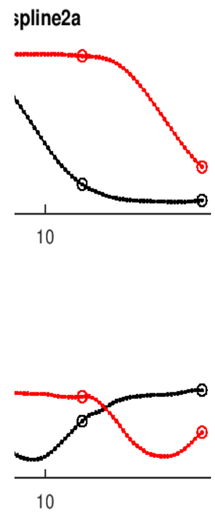

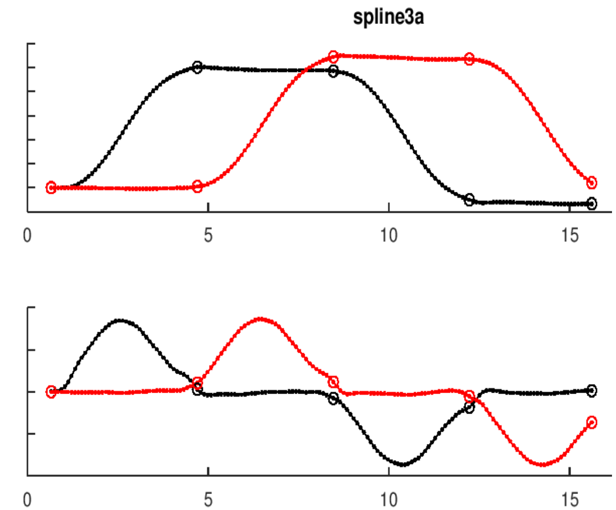

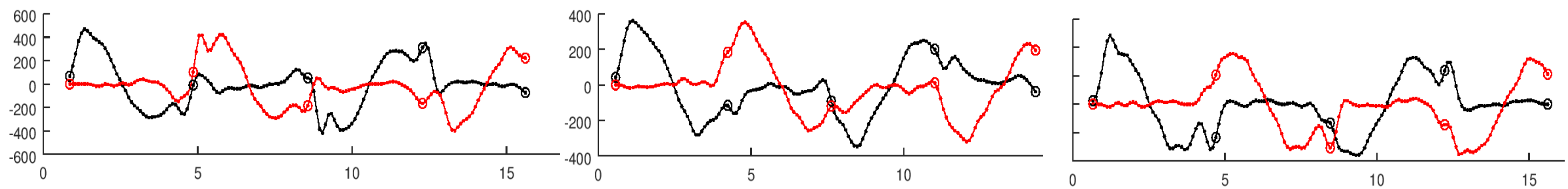

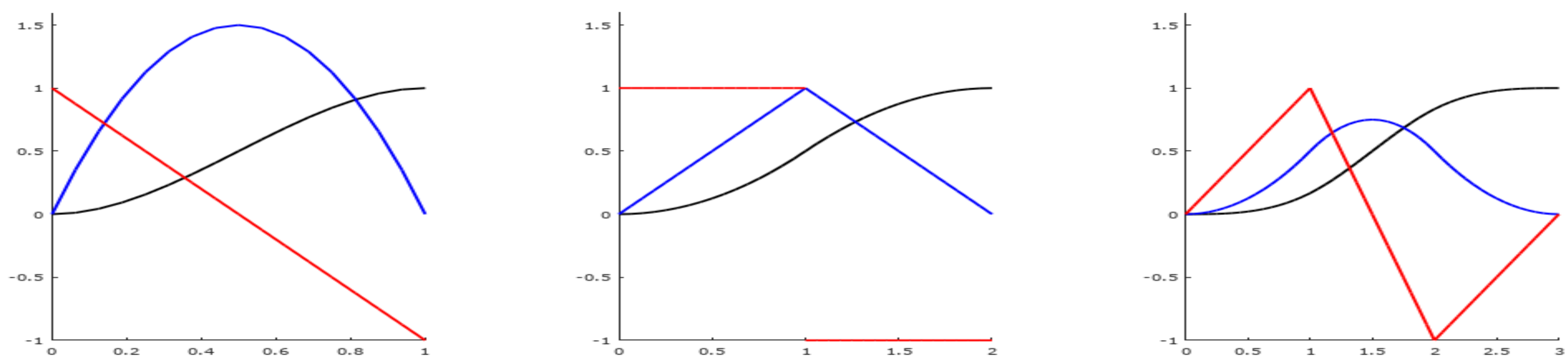

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Thanks for your attention

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