Simple robots in physics education: deterministic laws and predictability

Bulcsú SÁNDOR

Department of Physics, Babeș-Bolyai University, Kogălniceanu 1, Cluj-Napoca, Romania

Abstract. We study simple controllers for robotic locomotion as prototypical examples of deterministic equations of motions. The proposed didactic activity enables students to investigate predictability of the generated dynamics in a technology-enhanced active learning scenario.

1 Introduction

To elucidate general misconceptions among secondary school students concerning random and deterministic processes in nature, new teaching and learning approaches should be employed [1], which clearly distinguish between concepts as deterministic systems, chaotic dynamics and predictability [2]. Maintaining the motivation and commitment of students during such didactic activities is an increasingly challenging taks. Studies demonstrate, however, that integrated approaches based on robotics not only generate a high degree of student engagement [3] but also contribute to an increase of achievement scores in informal learning environments [4]. In order to enhance the students' motivation, we propose to invesitgate locomotion modes of simple robots generated by deterministic controller schemes.

2 The research

In this work, we explore a didactic activity based on programmable wheeled robots in order to demonstrate the deterministic aspect of equations of motion and to investigate the predictability of the resulting dynamics. This active-learning scenario allows the students to study the dynamics of robotic locomotion generated by control laws implemented by themselves and hence to comprehend the relations between mathematical expressions and real physical motion.

1.1 Experimental setup

Nowadays, a complete zoo of wheeled robots are available, developed specifically for STEM acitivities. Here we consider Lego Mindstorms and Arduino compatible Polulu Romi robots (see the left panel of Fig. 1), since both of them provide user friendly programming interfaces with wifi connection, hence secondary students with basic programming skills can easily implement simple algorithms on their own.

To control robotic locomotion, we propose simple update rules for the angle of the wheel, based on the recently introduced dynamical systems framework [5], considering four qualitatively different cases:

a) uniform linear motion,
b) uniform circular motion,
c) linear motion with constant accelaration,
d) chaotic dynamics generated by non-linear update map (see the right panel of Fig. 1).

The path visited by the robot in the above cases is reconstructed using two complementary approaches: by recording the internal measurements of the rotational angle of the wheels, and by estimating the robot's position from video recordings from above the plane of locomotion.

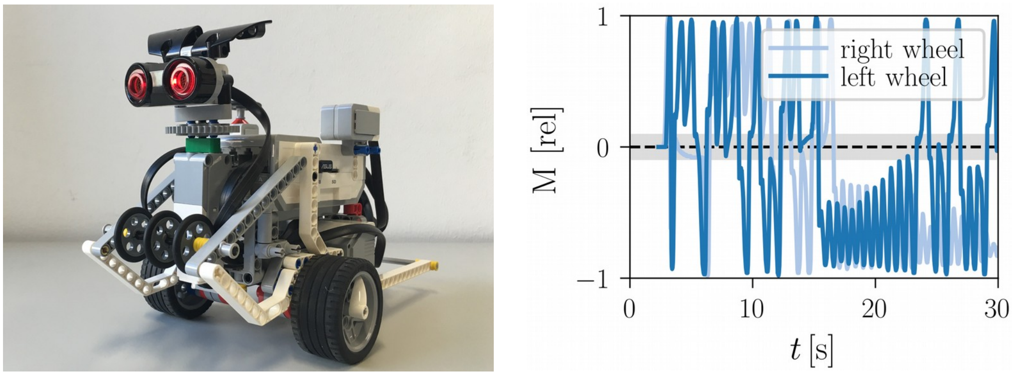

Fig. 1 Physics teaching using Lego robots. *Left*: Picture of the two-wheeled Lego robot. The controllers for the motors are implemented as simple update maps. *Right*: Chaotic time-series of the normalized control signal of the motor (for right and left wheels), relative to the maximum values.

1.2 Integrated didactic activity

The experimental framework is prepared before the activity. The students have to modify the core code according to the studied motion type, and conduct a series of experiments following the instructions provided by the teacher. As a first step the students estimate the final position of the robot for the four different cases of locomotion. After discussing and interpreting these results, the experiments are repeated for pairs of initially very close wheel-angle settings. Adopting the classical definition of predictability for nonlinear systems [1,6], the four scenarios are characterized as predictable regular motion, respectively non-predictable chaotic dynamics. To study the effectiveness of the intervention, pretest and postest achievement scores are compared.

2 Conclusion

The employed experimental setup and didactic activities designed to study predictable and non-predictable deterministic dynamics in active-learning scenarios prove to impact positively both comprehension and student motivation.

Acknowledgments

The project is funded by the Content Pedagogy Research Program of the Hungarian Academy of Sciences.

References

[1] D. Stavrou, R. Duit, & M. Komorek, A teaching and learning sequence about the interplay of chance and determinism in nonlinear systems. Physics Education, 43(4) (2008) 417–422.
[2] T. Tél, & M. Gruiz, Chaotic Dynamics: An Introduction Based on Classical Mechanics. Cambridge University Press, 2006
[3] R. D. Beer, H. J. Chiel, & R. F. Drushel, Using Autonomous Robotics to Teach Science and Engineering. Commun. ACM, 42(6) (1999) 85–92.
[4] Brockington, G., Schivani, M., Barscevicius, C., Raquel, T., & Pietrocola, M, Using robotics in kinematics classes: exploring braking and stopping distances. Physics Education, 53(2) (2018) 025012.
[5] Sándor, B., Nowak, M., Koglin, T., Martin, L., & Gros, C. . Kick Control: Using the Attracting States Arising Within the Sensorimotor Loop of Self-Organized Robots as Motor Primitives. Frontiers in Neurorobotics, 12 (2018) 40.
[6] Wernecke, H., Sándor, B., & Gros, C., How to test for partially predictable chaos. Scientific Reports, 7(1) (2017) 1087.