3D-printed Robots for Digital Education – case studies

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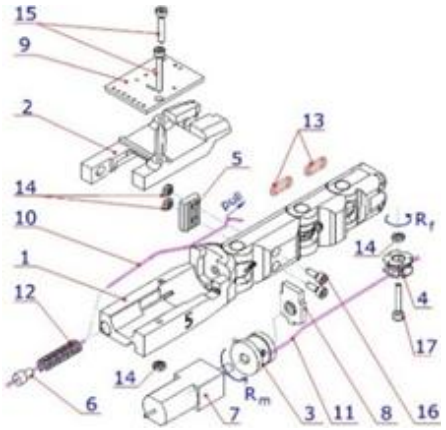
1. Introduction

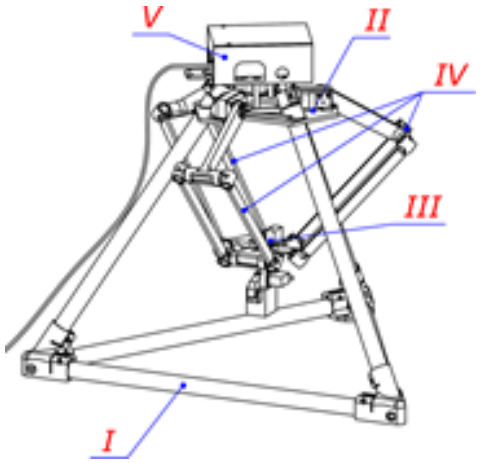
- Digital and automated technologies into all spheres of society poses new challenges to education;
- The development of 3D printing technologies has led to new constructive solutions for creating objects with complex shapes at low cost;
- Growing interest in additive manufacturing technology and specifically 3D-printed robots at different levels of the educational process;
- Despite the vast literature on the subject, there will still be room for the creation of effective learning robots with different characteristics for making education more visual and accessible.

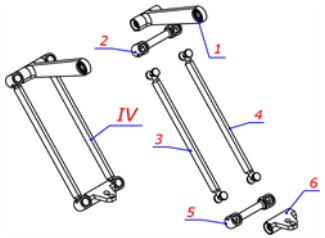
2. Technical description of 3D-printed educational robots

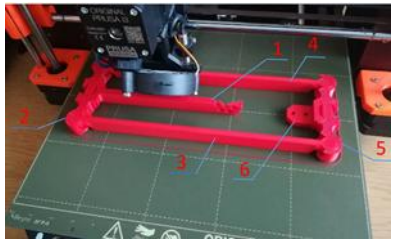
2.1. 3D-printed humanoid hand



2.2. 3D-printed DELTA robot

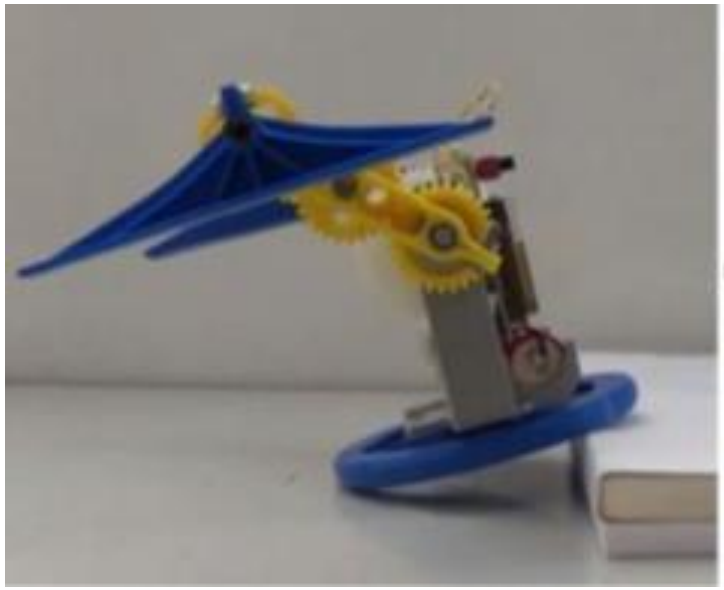


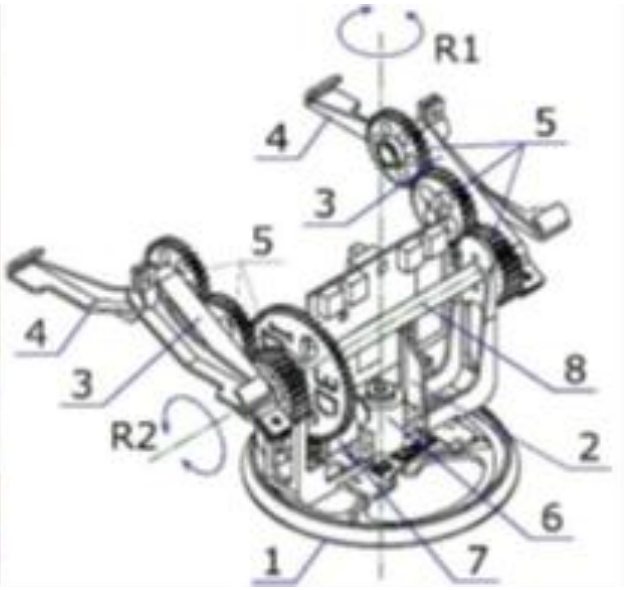




2.3. Walking robot „Big Foot“

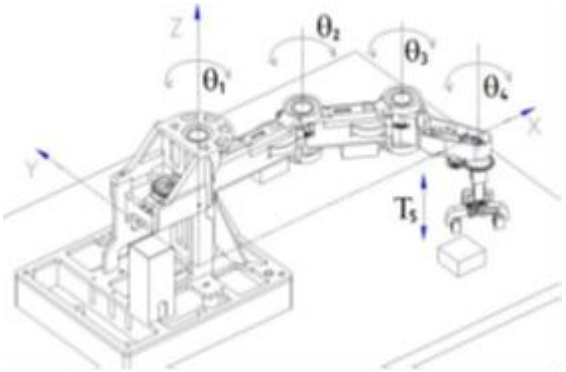
- Walking robot based on a minimalistic approach;
- The robot has a simple mechanical structure using only 2 motors;
- Can walk, rotate around its central axis and climb high obstacles;
- Different sensors, depending on the purpose.

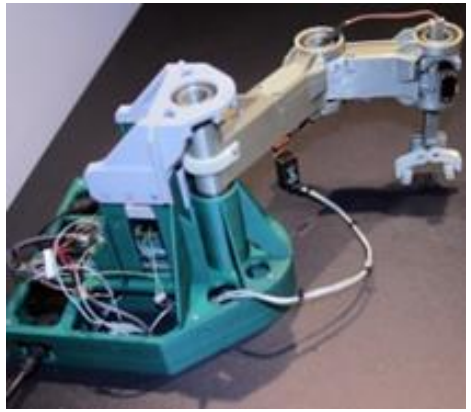




2.4. 3D-printed modular planar robot

- Its main movements are rotations about parallel vertical axes;
- Has a vertical translation driven by the rack and the gripper





3 Case Studies – goals and objectives

Table 1. Application of the 3D-printed robots in education

It is useful when studying:	3D-printed humanoid hand	3D-printed DELTA robot	Walking robot „Big Foot“	3D-printed modular planar robot
DoF of robots	Yes	Yes	Yes	Yes
Robot kinematics	No	Yes	Yes	Yes
Grasping objects	Yes	Yes	No	Yes
Movements along a complex trajectory	No	Yes	No	Yes
Walking mechanisms	No	No	Yes	No
Concept for redundancy	Yes	No	No	Yes
Overcoming or avoiding obstacles	No	No	Yes	Yes
Supporting the education and rehabilitation of children with special needs	No	No	Yes	No
3D printing already assembled parts	Yes	Yes	No	No

Case Study 1 - 3D-printed humanoid hand

The 3D-printed humanoid hand has found applications in the educational process of :

- the master's program "Mechatronics, Robotics and Mechanics" at Sofia University and a dissertation on the topic: "Design and control of a 3D-printed humanoid hand“;
- The PhD student created a program for performing sign language with the prototype;
- A second program for gripping cylindrical and spherical objects is also created;
- Functional experiments with PhD students from the Institute of robotics are conducted;
- To study and demonstrate different principles of gripping objects by a humanoid hand;

Case Study 2 - 3D-printed DELTA robot

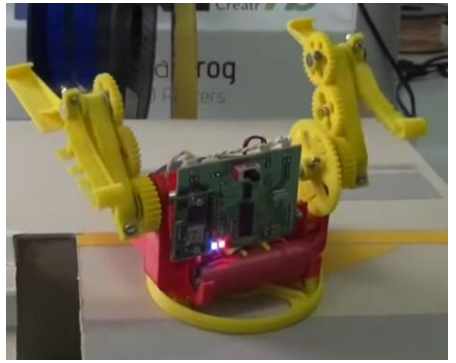
The model is a good example for studying: DoF, kinematics, gripping and manipulation of objects and movement along a trajectory. This model has found application in a :

- Diploma thesis on the topic "Control of a Delta Robot“ - development of the robot and developed software for its control;
- A web-based user interface has been developed, which:

- allows each of the motors to be controlled independently;
- to upload a sequence of joint coordinates to the Arduino controller's memory, -

- The use and demonstration of this specific type of robot contribute to the diversity in the studied designs and developed control algorithms.

Case Study 3 - Walking robot „Big Foot“ -

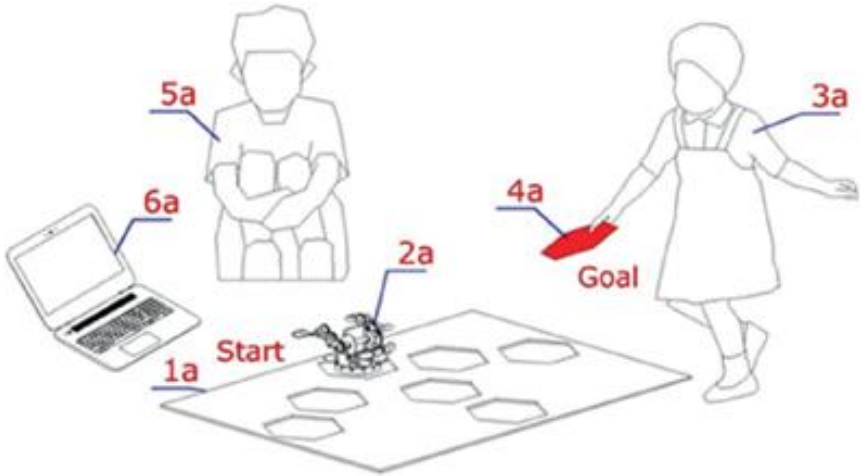


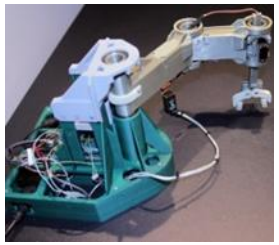
The walking robot is used as an example of applying a *minimalistic approach*. The possibility of realizing multiple movements and achieving different goals using *only 2 DoF* is demonstrated in video [32]. The robot is useful in studying:

- The kinematics of walking mechanisms and methods for overcoming high obstacles;
- Development of specialized games for training children with special needs. With the help of the robot, children improve their ability to navigate in space, learn directions, shapes and colours easily and joyfully by controlling the robot;
- The interaction of children with the walking robot improves their social and communicative skills, learning new things and developing skills in handling technical devices.

- Students from 8th to 12th grade from the National Professional High School of Computer Technologies and Systems, Pravets, Bulgaria, participate in the development of the software and hardware for controlling the walking robot. This stimulates the students' creativity and develops their technical skills;

- A scenario with the robot “Big Foot” for pedagogical rehabilitation of children with specific needs has been developed. The concept of the scenario is based on the interaction between two children and the walking robot





Case Study 4 - 3D-printed modular planar robot

- This planar robot is used for the development of a student's thesis on the topic: "Control of a SCARA robot for picking up objects moving along a conveyor line" - the student examines the basic methods for solving the forward and inverse kinematics problems necessary for controlling a SCARA-type educational robot;
- A sensor system has been designed to detect an object moving along a conveyor;
- An algorithm for robot movement in automatic mode has been developed.

4. Discussion

Specific advantages:

- Printing already assembled mechanical parts significantly reduces the number of parts in a robot model and eliminates the need for its assembly (CS1 and CS2);
- The ability to create parts with complex shapes, including internal cavities, reduces the number of elements used (CS2 CS3 and CS 4) and allows the creation of specific “feet” for the walking robot (CS3) with which it overcomes high obstacles;
- the application of a minimalistic approach to the design of the walking robot “Big Foot” leads to practical applications with minimal effort. The small number of DoF of the robot makes it useful for studying various aspects of the mechanics and control of robots. Therefore, the robot is applicable to students of different ages and students with specific needs.

The challenges are related to:

- The need for an initial investment to purchase 3D printers, consumables for them, electronic components and software;
- The relatively low accuracy of the models;
- The low strength and resistance to temperature changes;
- The limitations in the dimensions of the robot models caused by the limited volume of the 3D printer;
- The lower reliability and shorter life compared to industrially produced robots;
- The need for teachers to improve their qualifications in the field of additive technologies.

5. Conclusion

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LINKS

https://www.youtube.com/watch?v=ePiC0b5xf40

https://www.youtube.com/watch?v=zyVM0bgJaNs

https://www.youtube.com/watch?v=Q5F-d3yTs4w

https://www.youtube.com/watch?v=RYRJZcYdIX0&t=2s

https://www.youtube.com/watch?v=LtTwBEoB-mc&t=187s

https://www.youtube.com/watch?v=YJNcIyzSqOI

https://www.youtube.com/watch?v=CGsUJX_4H0o

https://www.youtube.com/watch?v=6XNhMk1xJKU

https://www.youtube.com/watch?v=EE2thTRve9U

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