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Design and Experiments of a Foldable Wheeled-Mobile Robot

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Abstract: Mobile robots are used in a wide range of applications such as outdoor and indoor tasks. Even though, several design configuration exist for such applications, still extreme operations may require new type of design. An example for an extreme operations is that a mobile robot needs to be moved on a curved path in a confined space. In order to accomplish the task, mobile robot requires new type of body. This study proposes a new type of design of a mobile robot, which has a foldable chassis. The folding angle of the chassis could be adjusted according to the desired road conditions such as L-shaped road. After fabricating the proposed mobile robot, experiments are performed to determine the kinematic behavior capability of the foldable wheeled-mobile robot motion on a L-shaped path. The results demonstrate that the proposed design is feasible, and foldable wheeled-mobile robot can be used on curved paths.

Keywords: Design, Mobile robot, Foldable chassis, Curved path

Introduction

Mobile robots are used in a wide range of applications from human missions in hazardous areas (such as space research) to home care robots (such as autonomous vacuum cleaners). Mostly in mobile robotics, wheels are essential for the locomotion. Either changing the number of the wheels or the wheel geometry are the main design parameters of the mobile robots. This is because wheels yield a drawback on the mobile robots. That is the unbalanced motion when the mobile robots encounter rough roads or complex paths (Rubio et al. 2019). One way to overcome this problem is to design a deformable wheel (Lee et al., 2013a, 2013b, 2014) or customizable wheel (Guan et al. 2014). Although deformable or customizable wheel for the mobile robots exist for rough surface operations, still for extreme operations new types of mobile robots may be required. An example for such an application area is that a mobile robot could be able to move on a curved road. In order to be able to move on a curved road, mobile robot chassis should be able to fold with a customizable angle. We propose a structural design for a new type of mobile robot. This study deals with designing and fabricating a foldable mobile robot to be able to move on curved surfaces. The design comprises a foldable chassis where the folding angle could be adjusted according to the desired road conditions. Experiments are performed to show the kinematic behavior capability of the foldable wheeled-mobile robot motion on a curved surface. The results show that the proposed design is beneficial and feasible, and foldable wheeled-mobile robot can be used on curved paths instead of non-foldable mobile robots.

Structural Design

The structural design of the foldable wheeled-mobile robot and manufactured one are shown in Figure 1 and Figure 2, respectively. The mobile robot consists of four wheels where each wheel is connected to a direct-current (DC) motor. The motion of the mobile robot is achieved by driving the DC motors. The DC motors and the wheels are connected to the chassis with a rigid attachment. Two different chassis are designed to have a foldable configuration. The two chassis are connected to each other with revolute joints. Hence, one chassis can

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be rotated with respect to the other one, which results in the allowable folding condition. Torsional springs are used to have a quick return from foldable configuration. Rotational motion of one chassis is achieved by a servo motor system, to which a pulley is attached. A rigid rope is used to make a connection between the pulley and the foldable chassis of the mobile robot. Therefore, with an activation of the servomotor, one chassis of the mobile robot can be rotated with a desirable angle. The maximum angle of the folding is approximately 70^0. A typical folding configuration and structural components of the foldable mobile robot are shown in Figure 1.b and Figure 1.c., respectively.

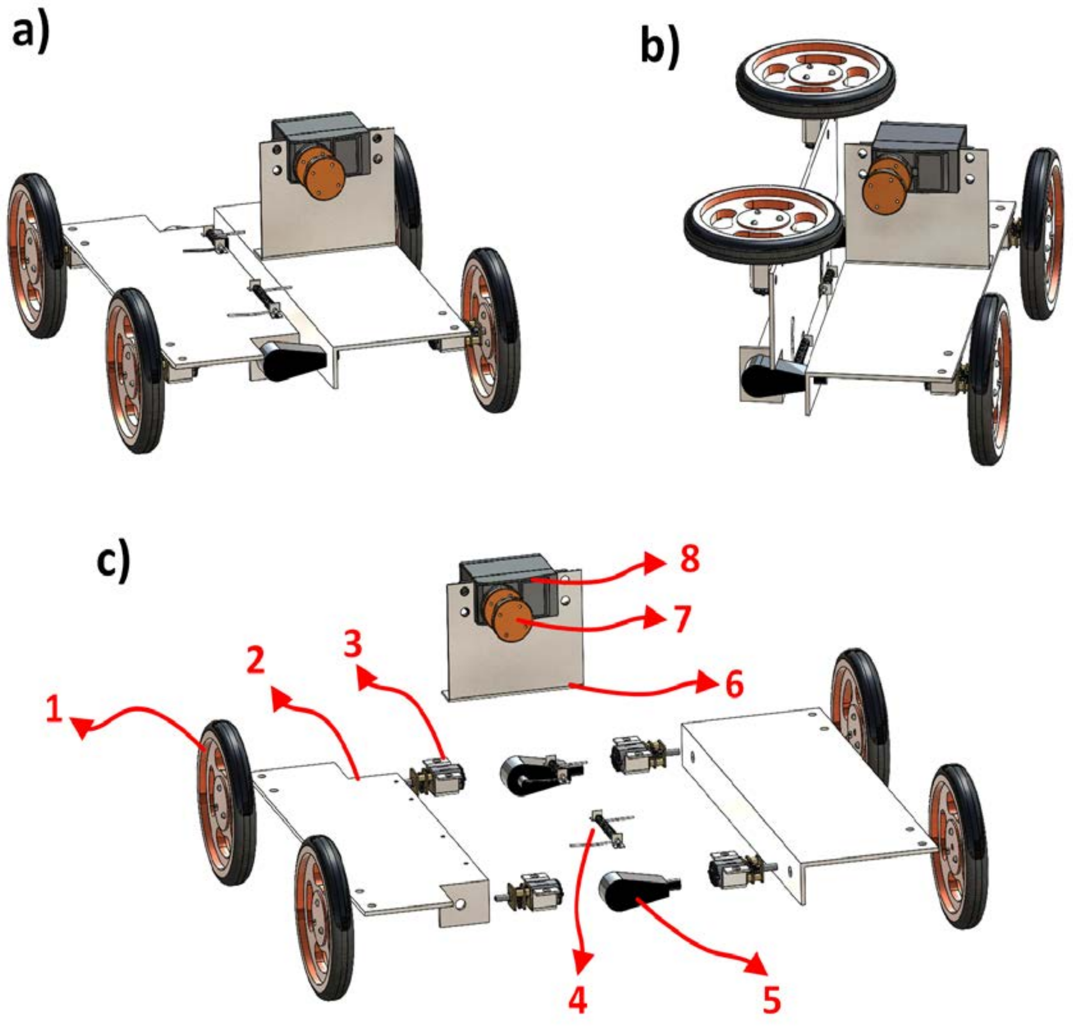

Figure 1. Structural design of the foldable mobile robot. a) General view, b) View of the folded condition, c) Components of the foldable mobile robot: 1- Wheels, 2- Chassis, 3- DC Motors, 4- Torsional spring, 5- Revolute joint, 6- Rigid support, 7- Pulley, 8- Servo motor.

Experiments

Two different kinds of experiments were performed. These are movements of the mobile robot on a flat road and on a curved road. The first experiment is to observe the similarity between a typical mobile robot and the foldable mobile robot kinematic behavior, even though two different chassis are coupled via revolute joints. The second experiment is to show the locomotion capability of the foldable wheeled-mobile robot on a L-shaped surface, where the two roads are perpendicular to each other. The snapshot of the videos of the first experiment was given in Figure 3. The results show that despite there being a foldable configuration of the mobile robot, still the kinematics of the foldable mobile robot is similar to the one with non-foldable one. This suggests that the foldable mobile robot can be used instead of a non-foldable one.

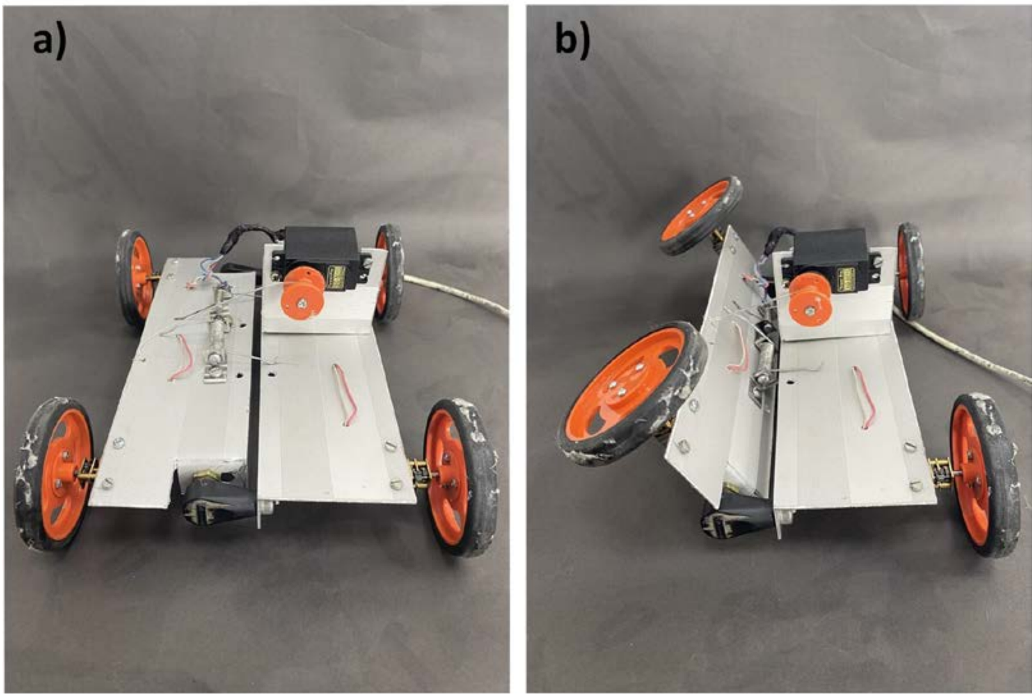

Figure 2. Manufactured foldable wheeled-mobile robot.

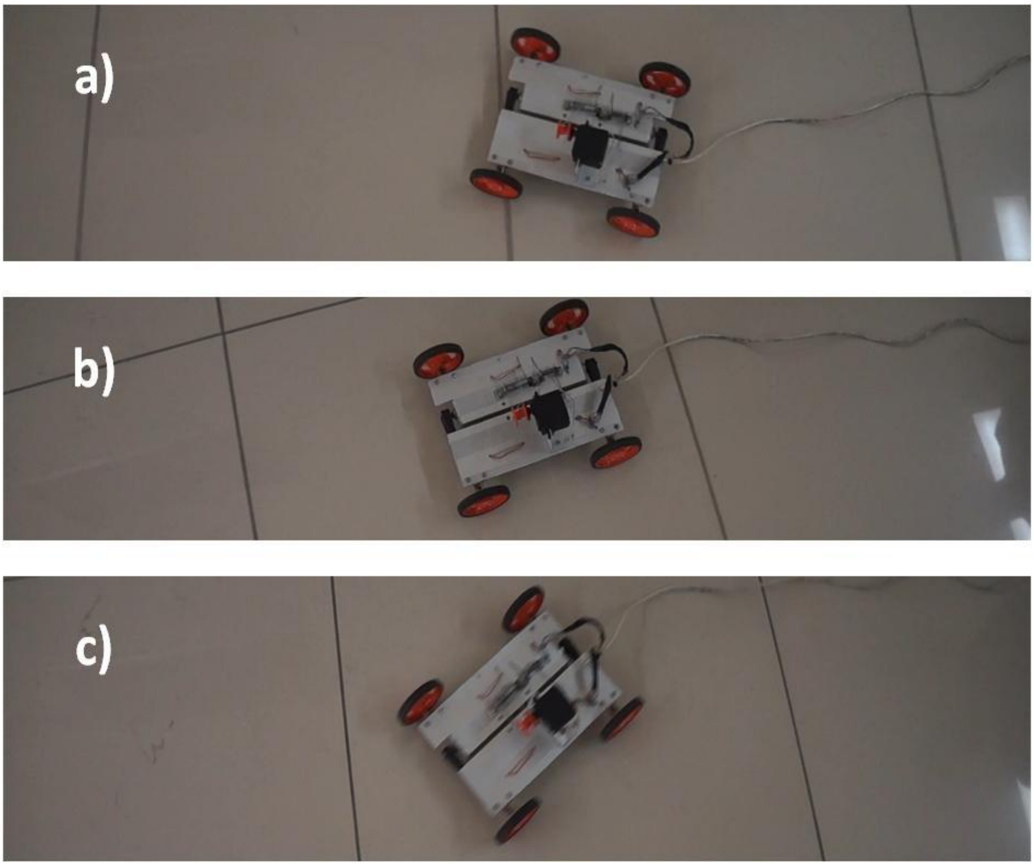

Figure 3. Snapshot of the first kind experiment. a) Translational motion, b) Beginning of the turning motion, c) End of the turning motion.

Figure 4, Figure 5 and Figure 6 show the results of the second kind experiment. Second kind of experiment was completed in three stages. The first stage corresponds to the transition of the foldable mobile robot motion from flat surface to curved surface. The second stage is to check the stability of the translational motion of the foldable mobile robot on the curved surface. In the final stage, this time, the kinematic stability of the translational motion of the foldable mobile robot during its transition from the foldable configuration to the nominal (flat) configuration, while the mobile robot moves on the curved surface, is observed.

Figure 4 depicts the transition from nominal configuration to the foldable configuration to move on the L-shaped surfaces. The result demonstrates that the foldable configuration allows a stable kinematic behavior, which corresponds to the transition from flat surface to curved surface during translational motion of the foldable mobile robot. This yields that the proposed design is feasible for the motion of the mobile robot on a curved surface.

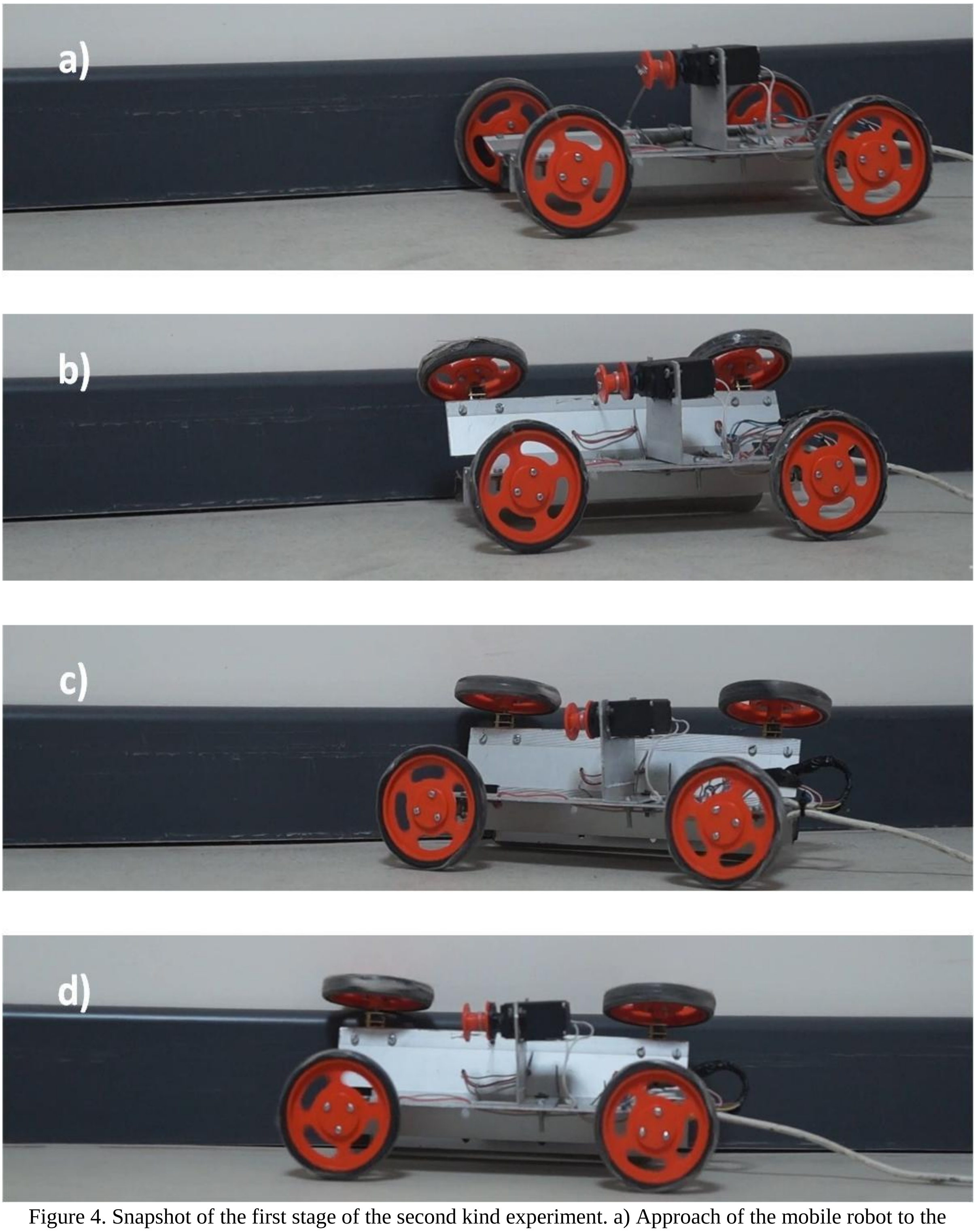

Figure 4. Snapshot of the first stage of the second kind experiment. a) Approach of the mobile robot to the curved surface, b) Transition from nominal to foldable configuration, c) Beginning of the movement on the curved surface, d) Translational motion on the curved surface.

Figure 5 shows the translational motion of the foldable mobile robot on the L-shaped curved surface. The results indicate that the foldable mobile robot can move on a straight path on the curved surface without loss of its kinematic stability. Hence, this yields that the foldable configuration of the mobile robot is feasible and beneficial in terms of the kinematic behavior capability of the mobile robot on the curved surface.

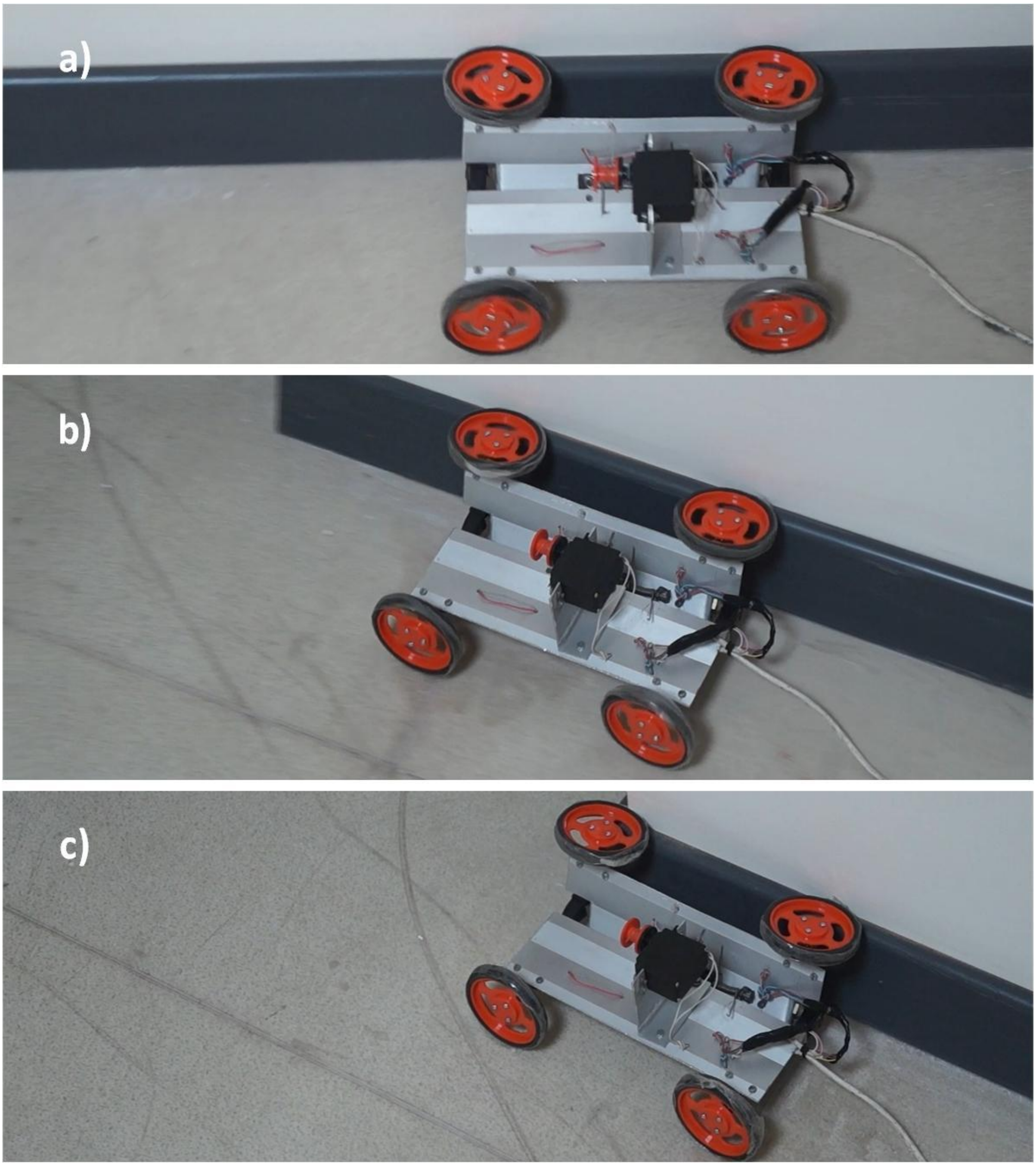

Figure 5. Snapshot of the second stage of the second kind experiment. a) Approach of the mobile robot to the curved surface, b) Transition from nominal to foldable configuration, c) Beginning of the movement on the curved surface, d) Translational motion on the curved surface.

Figure 6 gives the progress of change of the body of the foldable mobile robot from the foldable configuration to the nominal configuration during the crossing from the L-shaped curved surface to flat surface. The results demonstrate that there is no loss of kinematic stability of the foldable mobile robot while the path of the mobile robot shifts from the curved surface to the flat surface. As a result, the foldable configuration of the mobile robot has no effect on the stability of the translational motion of the mobile robot. This suggests that the foldable design of a mobile robot is attainable for the motion on the curved surfaces.

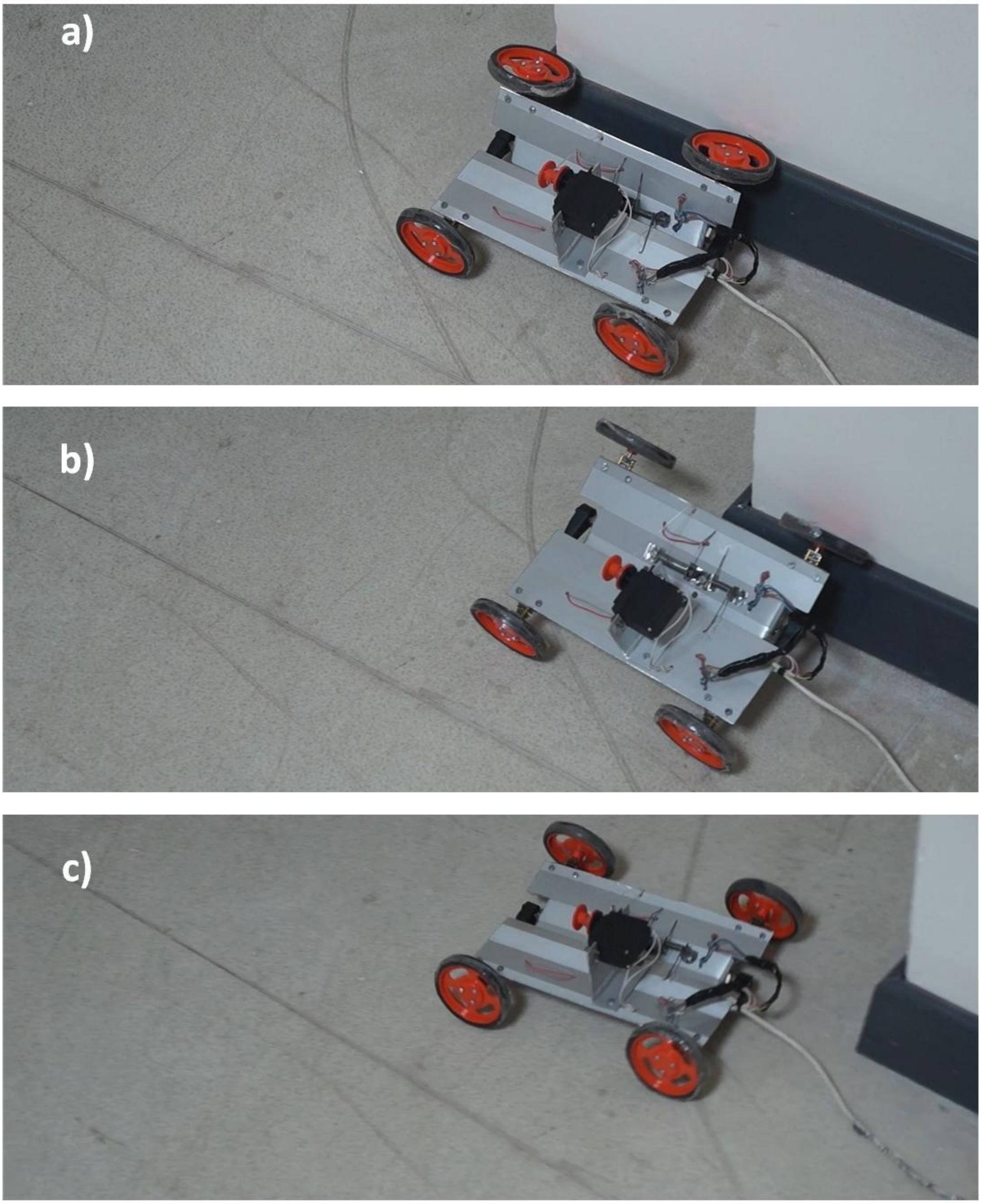

Figure 6. Snapshot of the final stage of the second kind experiment. a) Approach of the mobile robot to the edge of the curved surface, b) Transition from foldable to nominal configuration, c) Motion on the flat surface after the motion on the curved surface.

Conclusion and Recommendations

In this study, for extreme road conditions such confined spaces, a design for a mobile robot with a foldable configuration was proposed. After structural design was completed, the mobile robot was manufactured and kinematic performance of the foldable mobile robot was evaluated experimentally. The experimental results show that the proposed design is feasible, and the foldable mobile robot can be used in complex paths. We recommend using the foldable mobile robot for confined spaces, which may have complex roads.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

Acknowledgements or Notes

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