The Rapid Prototyping of a Mobile Robot With One DWT Using Lego Components

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1. Introduction

The dual-wheel transmission (DWT) was disclosed in a patent [1], as shown in Fig. 1, details of the underlying design rationale being available in [2]. We report here on the design and assembly of the rapid prototype of a wheeled mobile robot (WMR) with one DWT, as shown in Fig. 2. This robot is built upon seven modules, as shown in Fig. 3: module 1 comprises the motors; module 2 is the upper part of the transmission; module 3 is its lower counterpart; module 4 comprises the wheels; module 5 comprises the sun gears and the central bearing; module 6 is the connector of the upper part and the central bearing; and module 7 is the connector of the lower part and the central bearing. We describe below the assembly of each module, and then the assembly of all these modules into the robot.

Here, we regard the whole DWT as an assembly of modules (M), submodules (SM), subsubmodules (SSM), and subsubsubmodules (SSSM), which is indicated by numbers i-j-k: i is the number of a module; j is the number of a submodule belonging to the module i; and k is the number of a subsubmodule belonging to the submodule i-j.

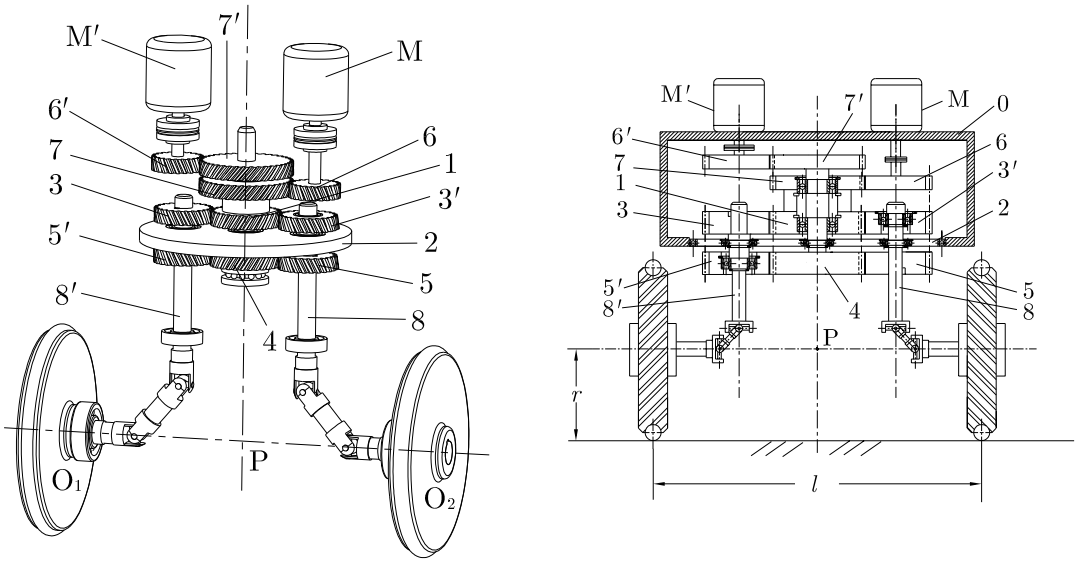
This report begins with the whole DWT, then the modules, the submodules and subsubmodules. Finally, we introduce the Lego pieces. However, the procedure to build a DWT must be done inversely, i.e., begin with Lego pieces, the subsubmodules, and, finally, assemble the whole system.

Preparation: We need the Lego pieces from the following packages:

- Lego Mindstorms, Robotics Invention System 2.0;
- two Cross Axles packs;
- one Gear Wheel pack;
- Lego 4496 box (for bricks);
- six AA 1.5V batteries.

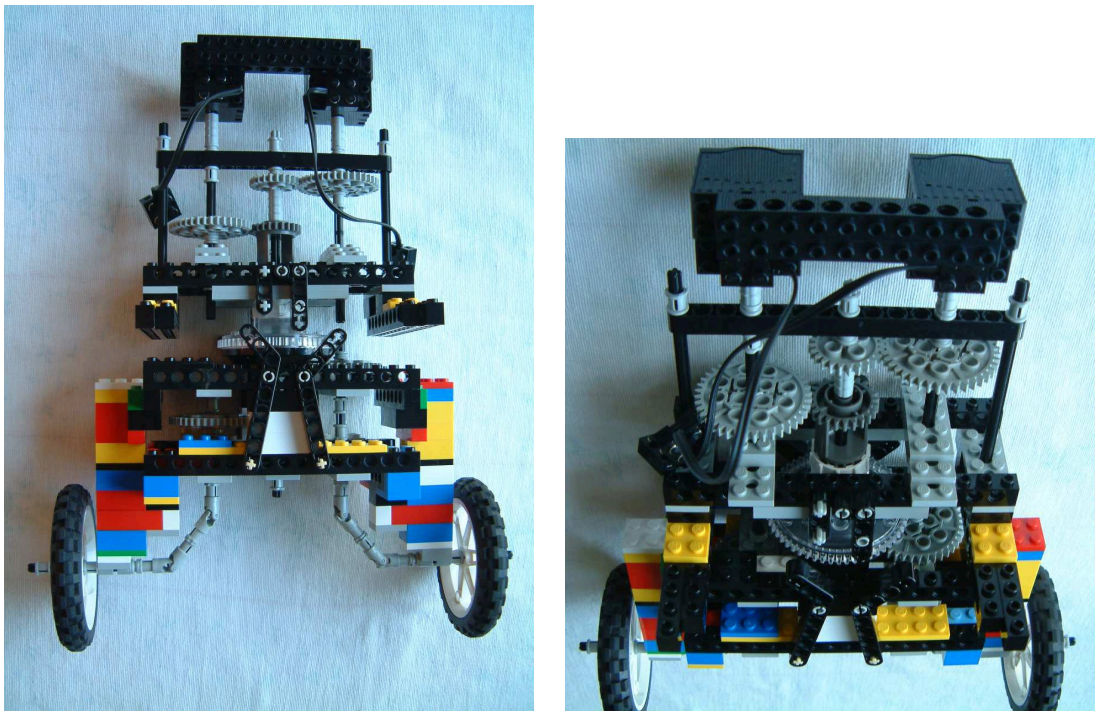
2. Assembly of Module 1

We first introduce the assembly of the motors. Shown in Figs. 4 are the front and rear views of this assembly. We need the Lego pieces shown in Fig. 5 to build this module. In Fig. 5, there are two couplings, two motors, two beams, and two wires, each with end-plates. Notice that the wire plates must be connected to the motors in the right way, as shown in Fig. 4(a).



(a) (b)

Figure 1. A layout of the DWT: (a) a perspective view; (b) a section view



(a) (b)

Figure 2. A wheeled mobile robot with one dual-wheel transmission: (a) front view; and (b) top-front view

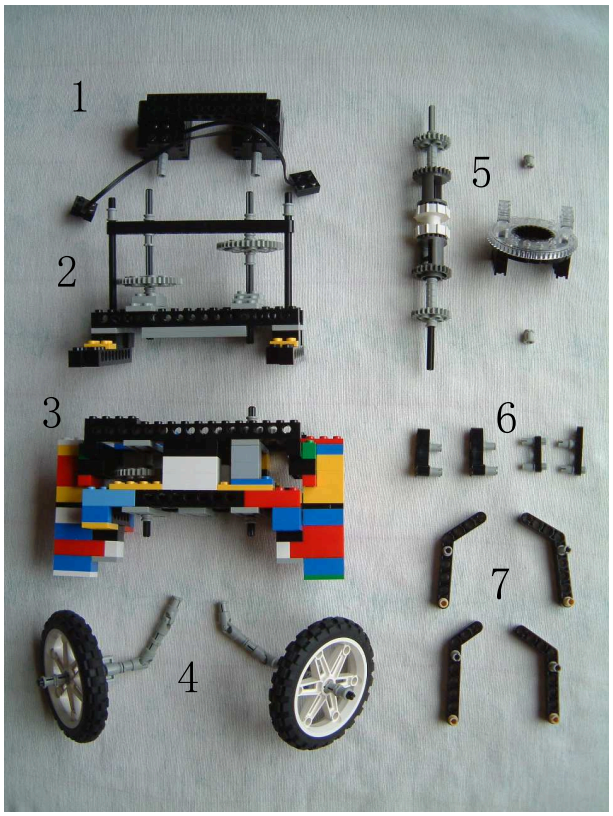
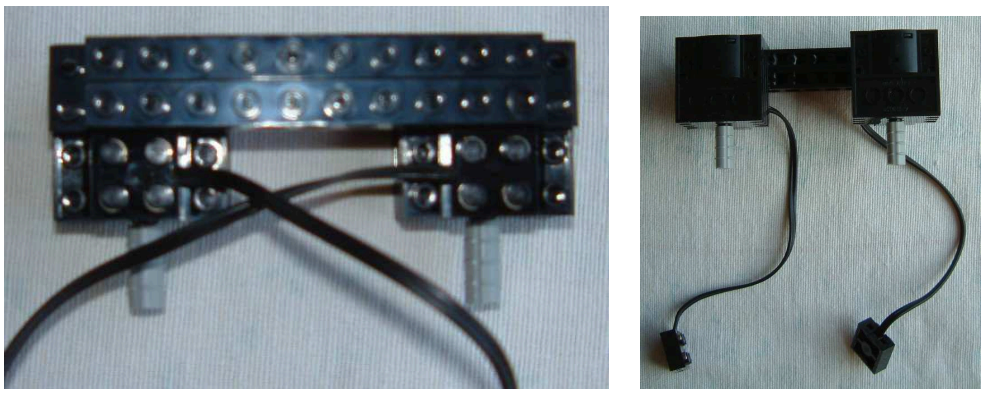


Figure 3. Seven parts in the wheeled mobile robot



(a) (b)

Figure 4. The motor assembly: (a) front view; and (b) rear view

3. Assembly of Module 2

Shown in Fig. 6(a) is the upper part assembly, which contains three submodules, as displayed in Fig. 6(b). SM 2-1 is the gears; SM 2-2 is the bottom frame; and SM 3-2 comprises the beams. We further display the assembly of these three submodules in detail.

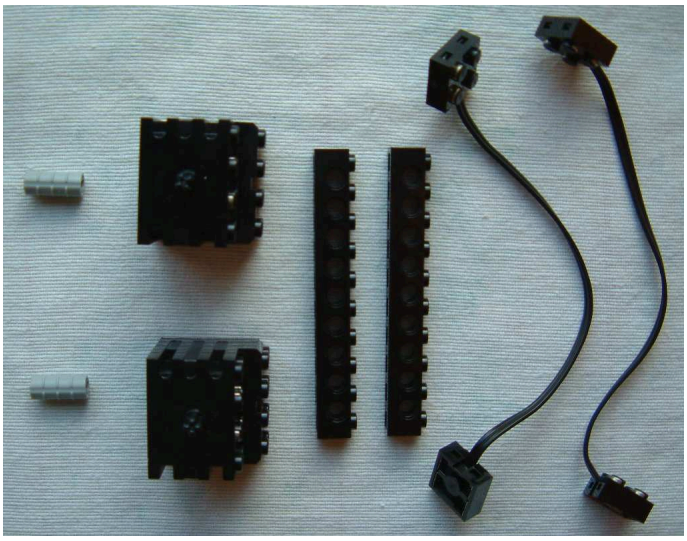
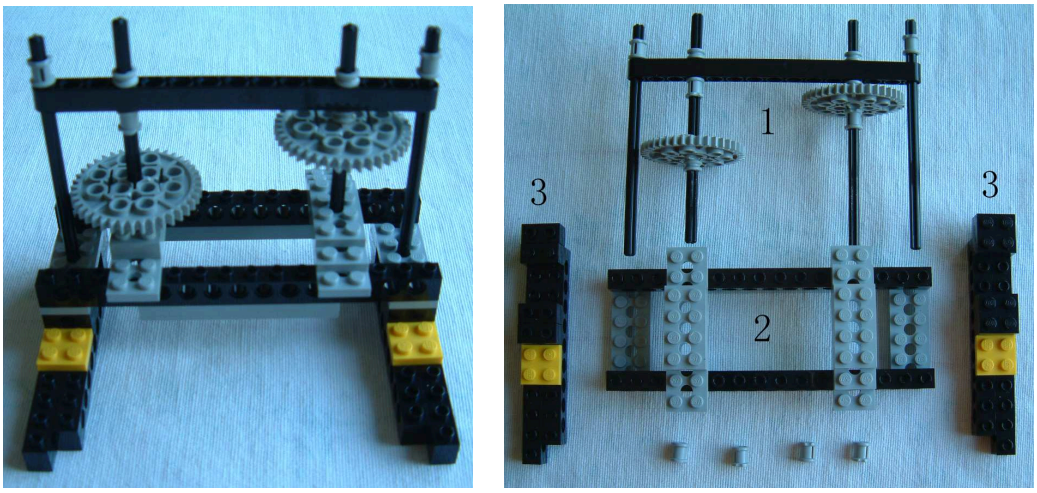


Figure 5. Lego pieces used to build the motor assembly



(a) (b)

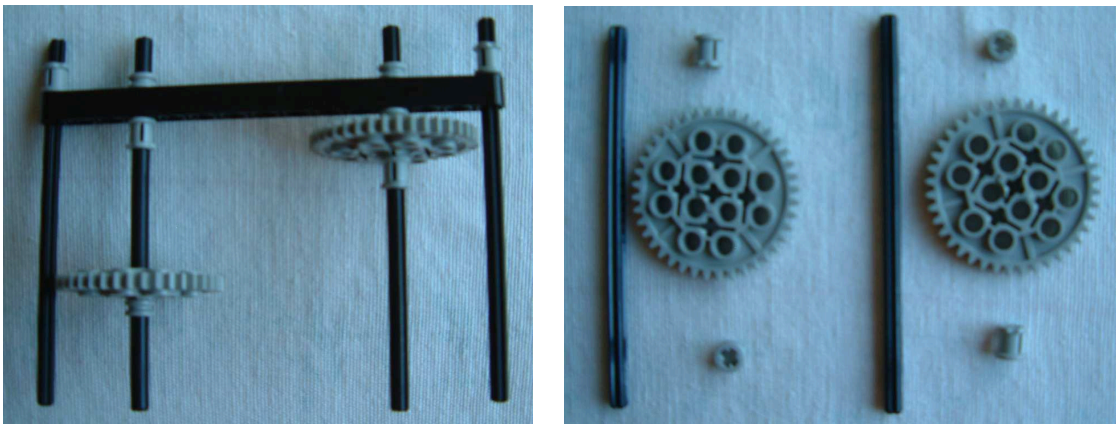
Figure 6. Module 2: (a) the upper part assembly; and (b) the submodules in this assembly

3.1. Assembly of Submodule 2-1

Shown in Fig. 7 is the assembly of SM 2-1 and the Lego pieces required for two gear shafts. To correctly assemble the components, the lockers must be assembled at the right position on each shaft, as shown in Fig. 7(a).

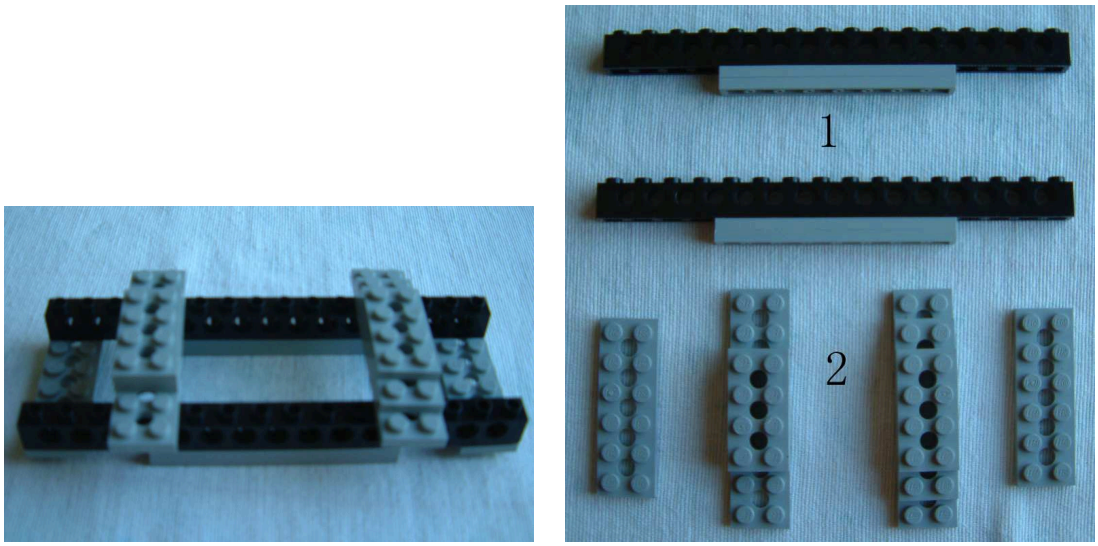
3.2. Assembly of Submodule 2-2

Shown in Fig. 8 are the SM 2-2 assembly and its two subsubmodules, 2-2-1 and 2-2-2; the assembly of 2-2-1 and 2-2-2 is illustrated in Figs. 9(a) and (b), respectively.



(a) (b)

Figure 7. Module 2: (a) the submodule 2-1 assembly; and (b) the Lego pieces used for the two gear shafts



(a) (b)

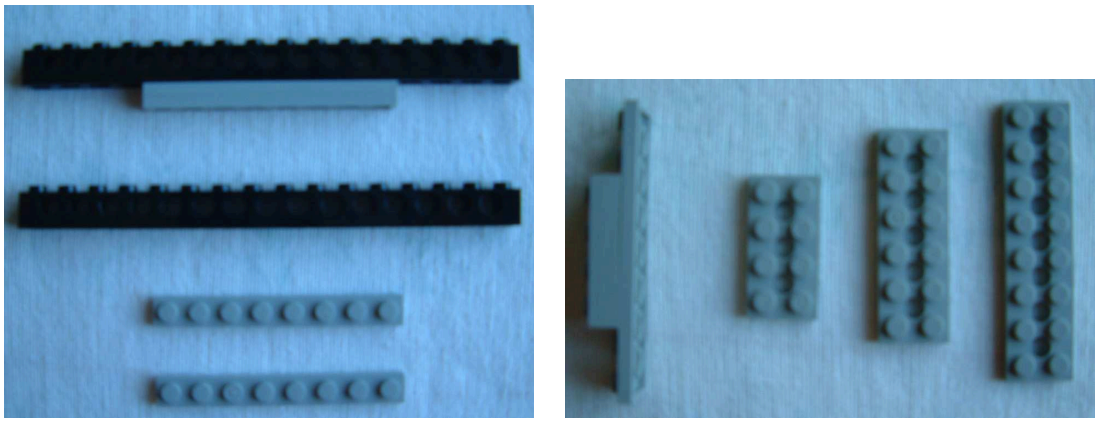
Figure 8. Module 2: (a) the submodule 2-2 assembly; and (b) its two subsubmodules

3.3. Assembly of Submodule 2-3

The submodule 2-3 assembly and the Lego pieces required are illustrated in Fig. 10.

4. Assembly of Module 3

Shown in Fig. 11(a) is the lower transmission assembly, which contains two submodules, displayed in Fig. 11(b). SM 3-1 is the gear transmission, SM 3-2 being the bottom frame. We further illustrate the assembly of these two submodules in detail.



(a) (b)

Figure 9. Module 2: (a) the subsubmodule 2-2-1 assembly; and (b) the subsubmodule 2-2-2 assembly

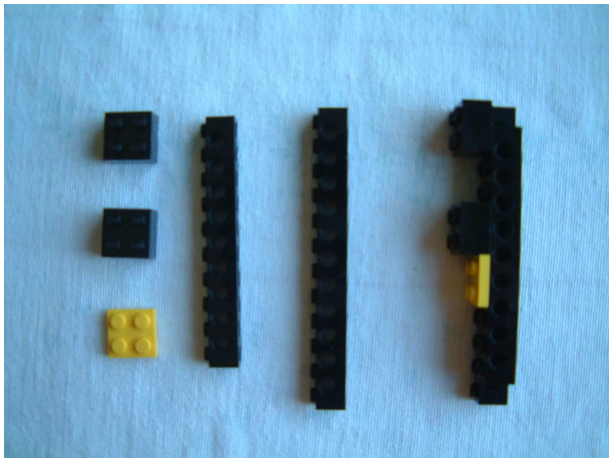


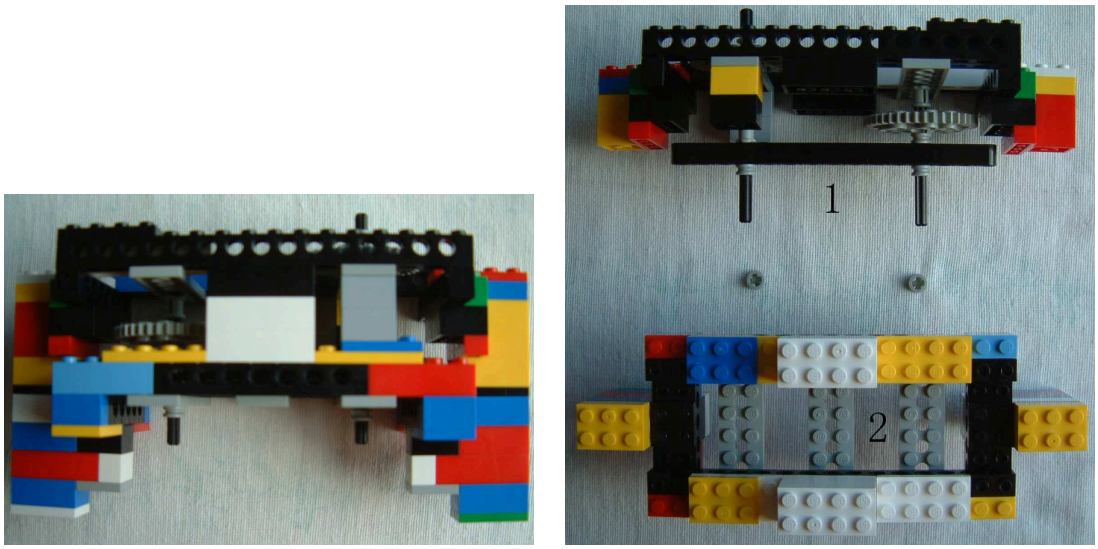
Figure 10. Module 2: the submodule 2-3 assembly

4.1. Assembly of Submodule 3-1

Submodule 3-1 is composed of two subsubmodules, 3-1-1 and 3-1-2, and the gears and the shafts, as shown in Fig. 12. SSM 3-1-1 is composed of the Lego modules and SSM 3-1-1-1, as shown in Figs. 13. SSM 3-1-1-1 comprises the Lego pieces shown in Fig. 14(a). The assembly of SSM 3-1-2 is illustrated in Fig. 14(b).

4.2. Assembly of Submodule 3-2

SM 3-2 is made of two subsubmodules, 3-2-1 and 3-2-2, as shown in Fig. 15. SSM 3-2-1 is composed of the Lego pieces and SSSM 3-2-1-1 and 3-2-1-2, as shown in Figs. 16(a). SSSM 3-2-1-1 comprises the Lego pieces shown in Fig. 16(b), while SSSM 3-2-1-2 is made of the Lego pieces shown in Fig. 17(a). The assembly of SSM 3-2-2 is illustrated in Fig. 17(b).



(a) (b)

Figure 11. Module 3: (a) the assembly of the lower transmission; and (b) the submodules of this assembly

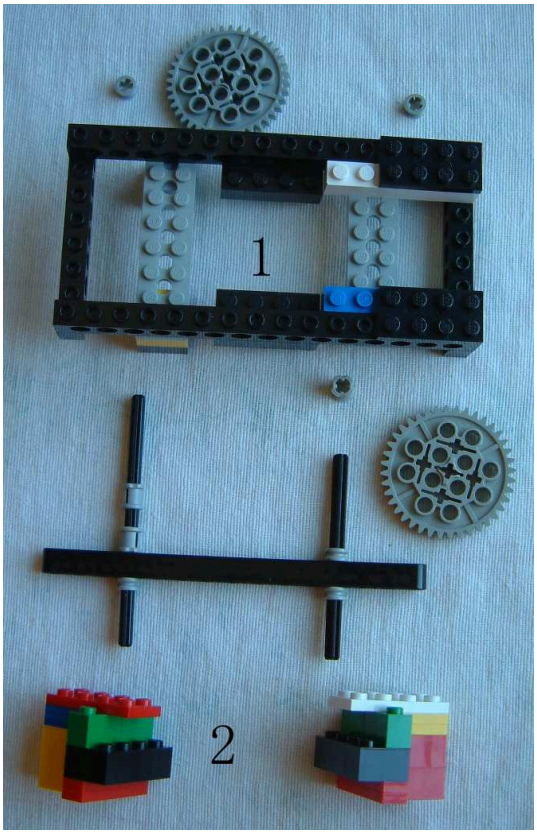
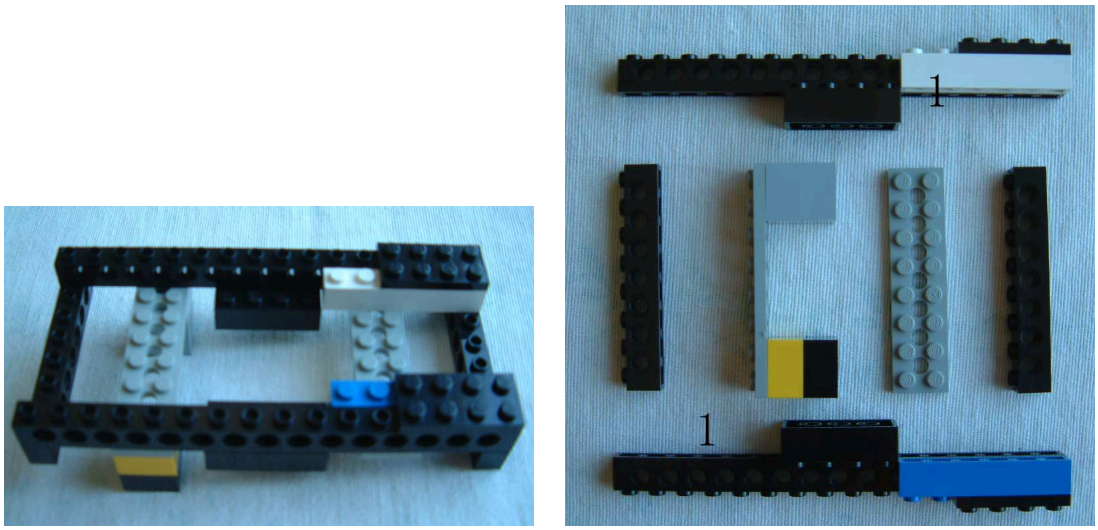
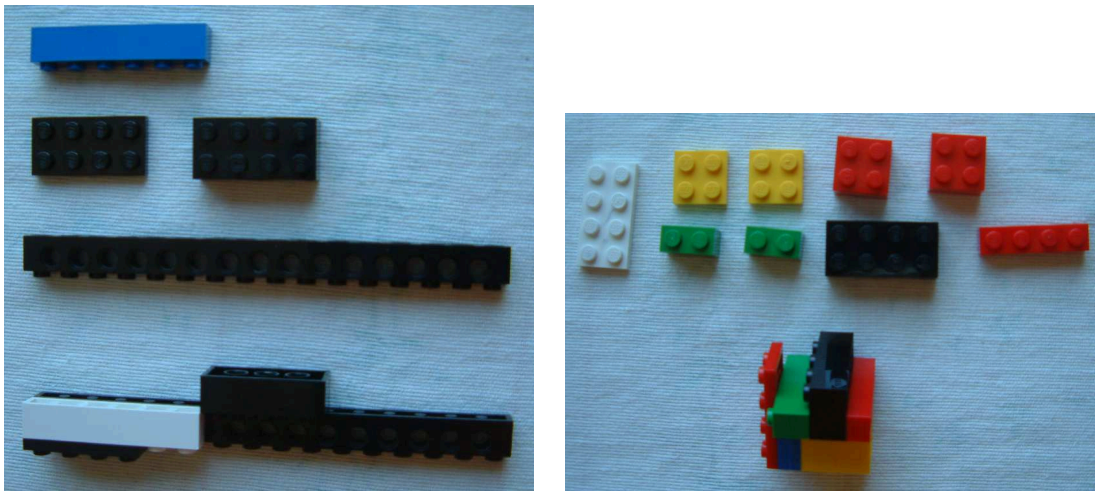


Figure 12. Module 3: the subsubmodules of submodule 3-1



(a) (b)

Figure 13. Module 3: (a) the assembly of the subsubmodule 3-1-1; and (b) its subsubsubmodules



(a) (b)

Figure 14. Module 3: (a) the assembly of the subsubsubmodule 3-1-1-1; and (b) the assembly of the subsubmodule 3-1-2

5. Assembly of Module 4

The assembly and the Lego pieces of M 4, the wheels, is illustrated in Fig. 18.

6. Assembly of Module 5

The assembly of M 5 is illustrated in Fig. 19. The Lego pieces of the sun gears and each gear shaft are further shown in Figs. 20(a) and (b), respectively.

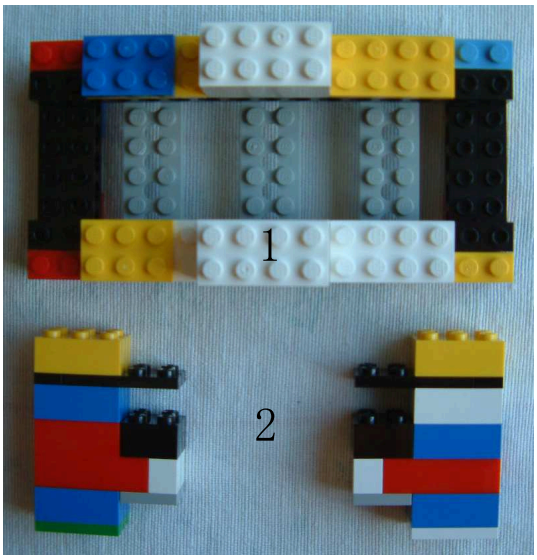
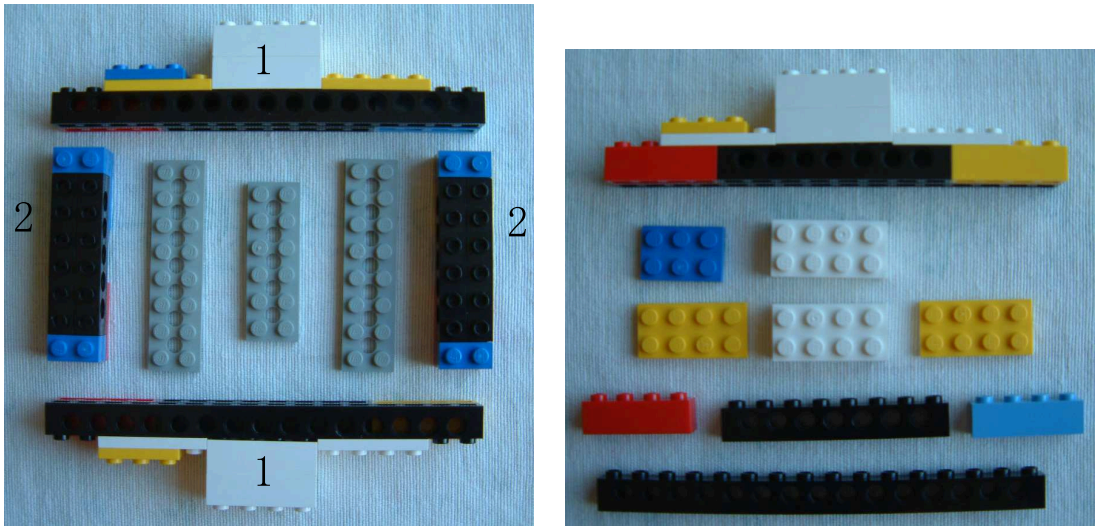


Figure 15. Module 3: the subsubmodules of submodule 3-2



(a) (b)

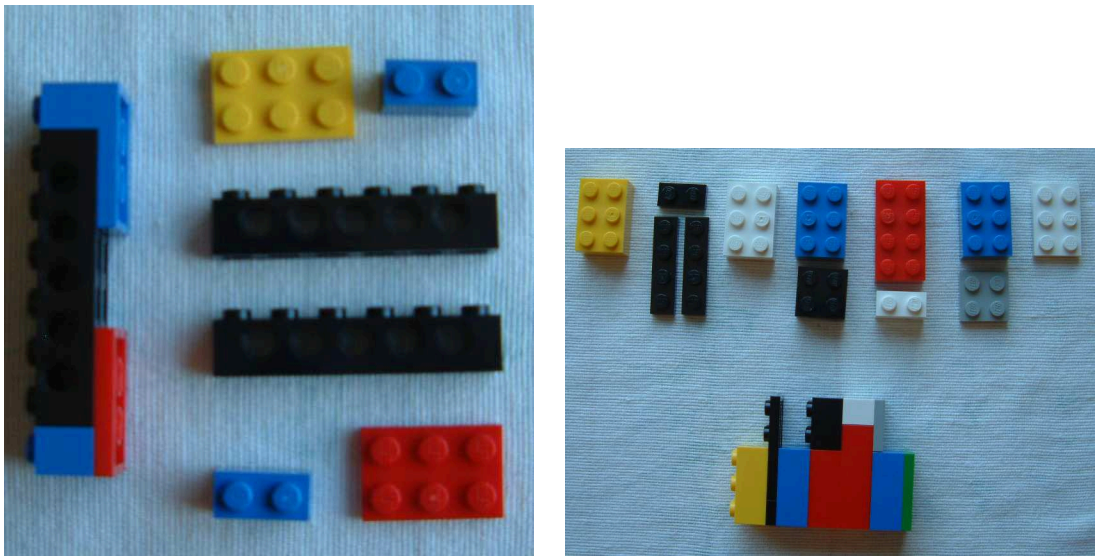
Figure 16. Module 3: (a) the subsubsubmodules of subsubmodule 3-2-1; and (b) the subsubsubmodules of subsubmodule 3-2-1-1

7. Assembly of Module 6

The assembly of M 6 is illustrated in Fig. 21(a) and (b).

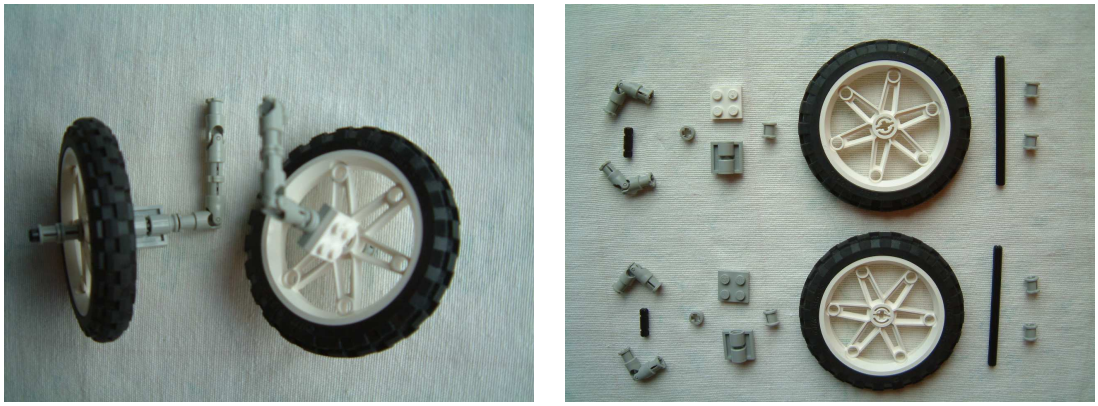
8. Assembly of Module 7

The assembly of M 7 is illustrated in Fig. 22(a) and (b).



(a) (b)

Figure 17. Module 3: the Lego pieces of (a) subsubsubmodule 3-2-1-2, and (b) subsubmodule 3-2-2



(a) (b)

Figure 18. Module 4: (a) the assembly of the wheels; and (b) the Lego pieces of this assembly

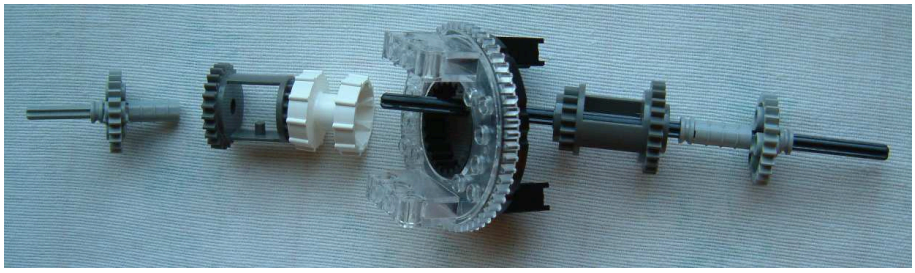
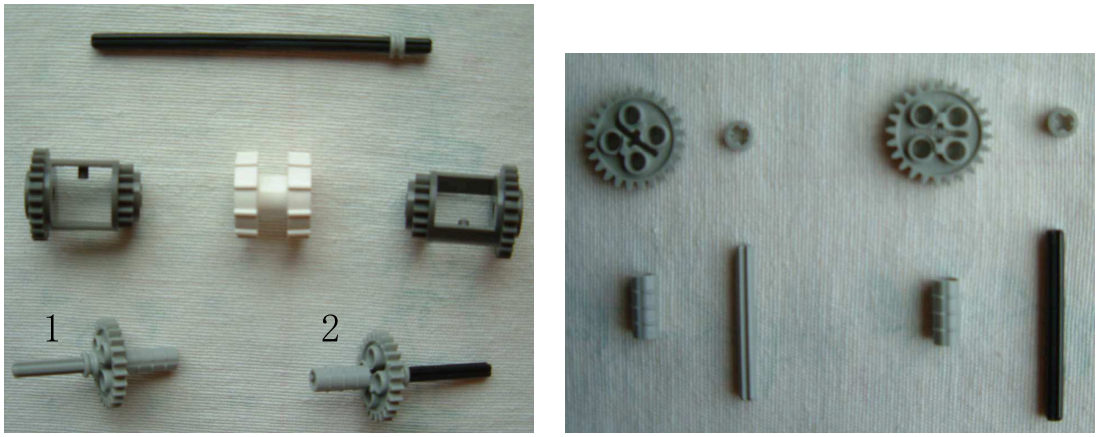
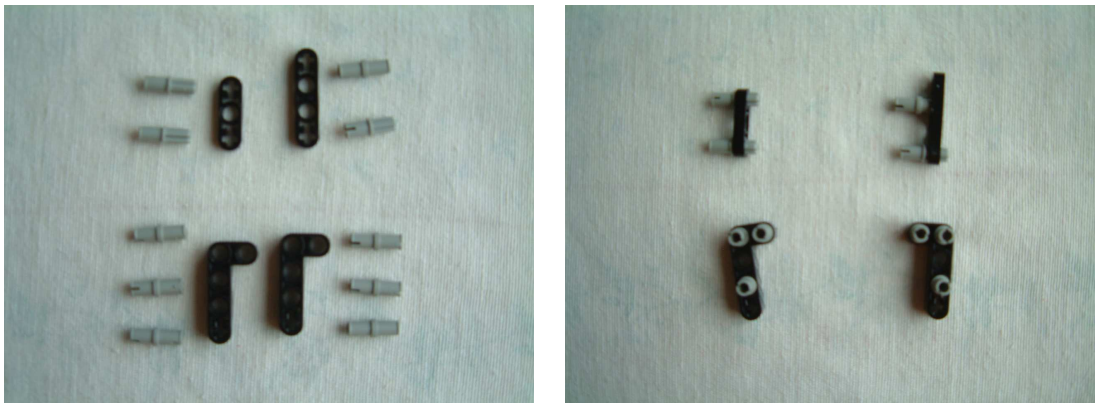


Figure 19. Module 5: the parts of the sun gears and the bearing



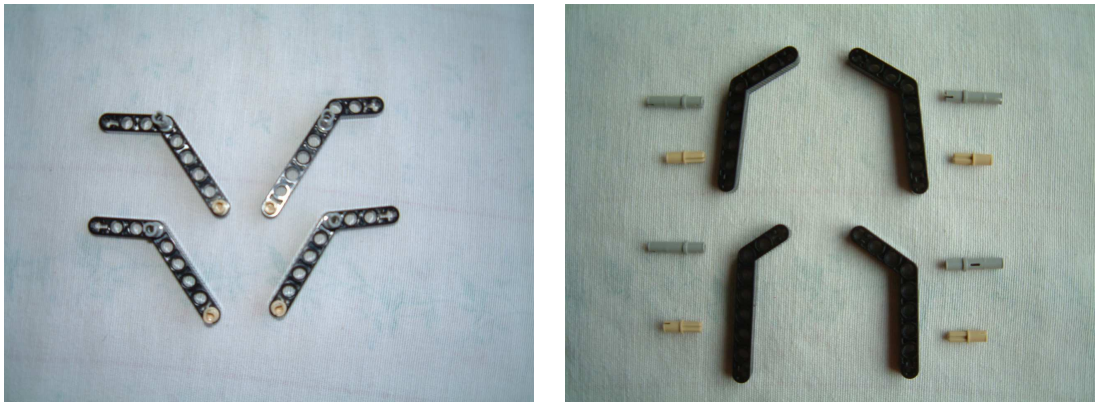
(a) (b)

Figure 20. Module 5: (a) the components of the sun gear; and (b) the components of submodules 5-1 and 5-2



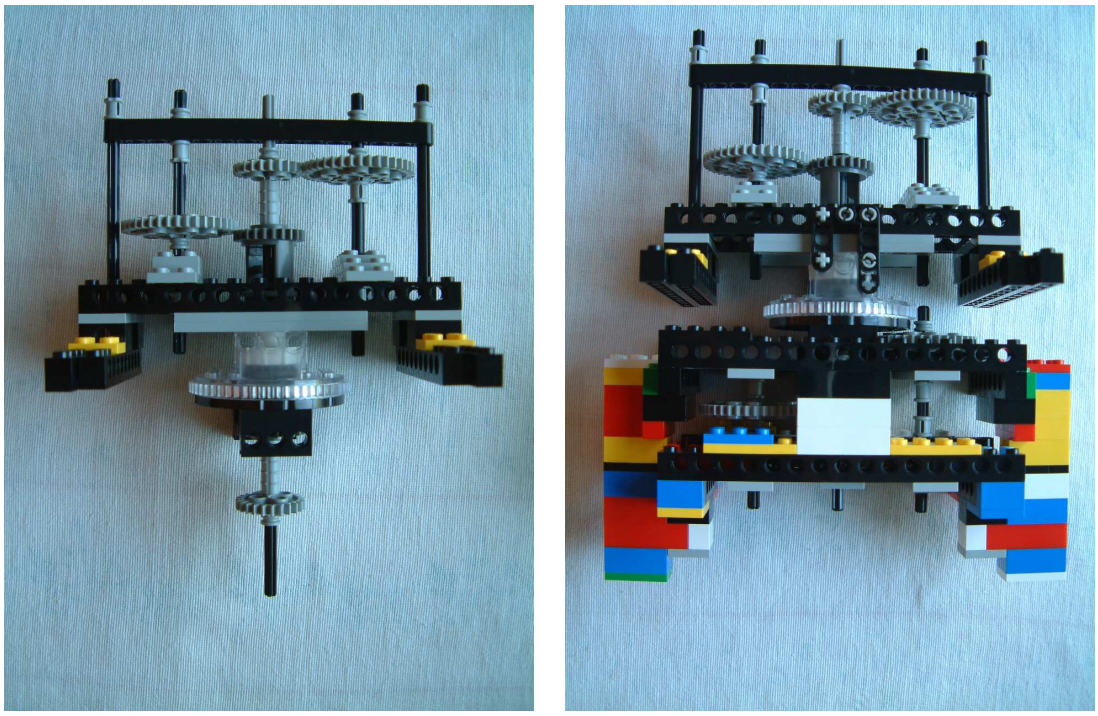
(a) (b)

Figure 21. Module 6: (a) the assembly of the connectors of the upper transmission; and (b) its Lego pieces



(a) (b)

Figure 22. Module 7: (a) the assembly of the connectors of the lower transmission; and (b) its Lego pieces



(a) (b)

Figure 23. (a) The assembly of the upper transmission with the sun gears, and (b) the assembly of the lower transmission into the system

9. Assembly of the Whole Robot

After each module is ready, we can begin to assemble the whole DWT. First, we assemble the upper transmission with the sun gears and the central bearing, as shown in Fig. 23(a). Second, the lower transmission is assembled into the system, as shown in Fig. 23(b). Then, the wheels are assembled, as shown in Fig. 24(a). Finally, we connect the motors to the input shafts, as illustrated in Fig. 24(b), thereby completing the assembly of the whole DWT.

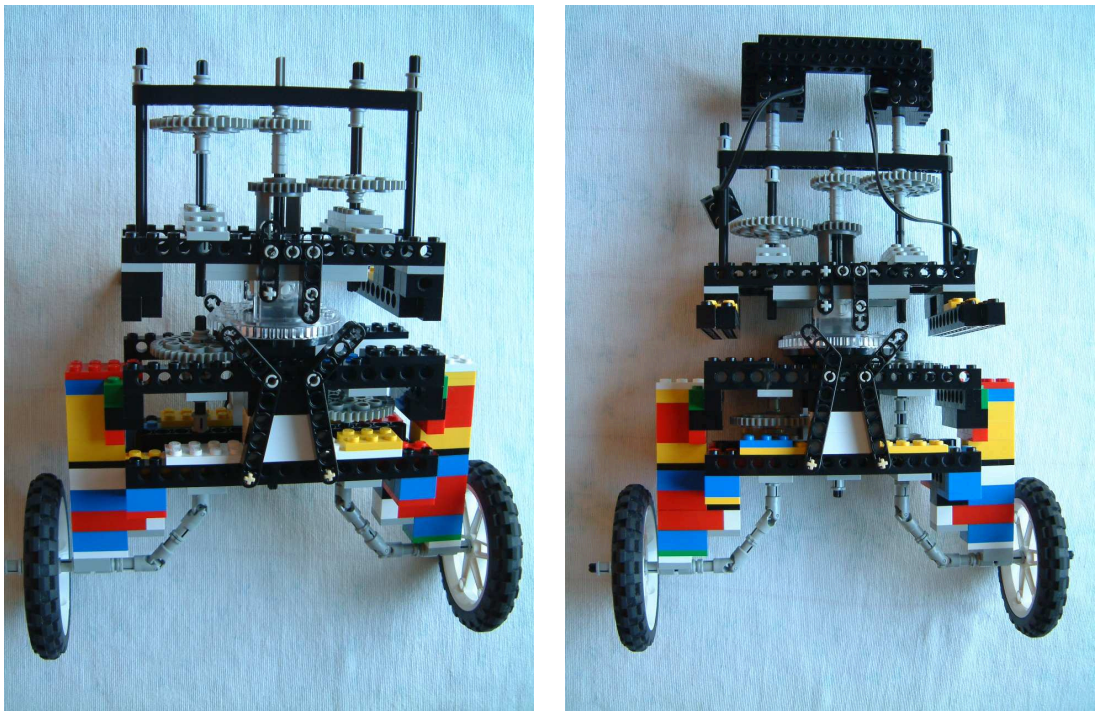
10. Remarks

The prototype of the DWT can be significantly simplified, if suitable Lego components are available.

References

[1] J. Angeles. *Driving and Transmission Unit for Use in Rolling Vehicles* . in U.S. Patent No. US 6,948,576 B2, Sept. 27, 2005.

[2] J. Angeles. An innovative drive for wheeled mobile robots. *IEEE/ASME Transactions on Mechatronics*, 10(1):43–49, 2005.



(a) (b)

Figure 24. (a) The assembly of the wheels into the system; and (b) the whole DWT