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非ホロノミック運動ロボットの姿勢制御シミュレーション

Attitude Control Simulation of Nonholonomic Motion Robot

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1. Introduction

A nonholonomic robot has a feature of less fuel consumption when an attitude is changed. However, the attitude may be changed around two or more axes simultaneously if the rotational moment is not cancelled. The attitude change around multiple axes is difficult to control the attitude. Therefore, a method of changing the robot attitude around one axis is investigated. To know the attitude change, an open source dynamics simulation library named Open Dynamics Engine (ODE) is used. A robot has eight rotatable frames so that the moment about the axes excluding the focusing axis can be cancelled. The results of motion simulation are reported in this paper.

2. Model

The robot model is shown in **Figure 1**. The robot has eight rotatable frames. To cancel the moment, a pair of frame rotates in the opposite angle direction. To enhance the moment, the pair rotates in the same angle direction.

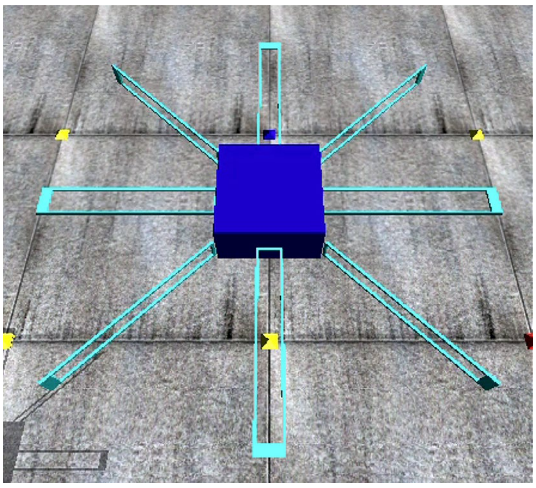


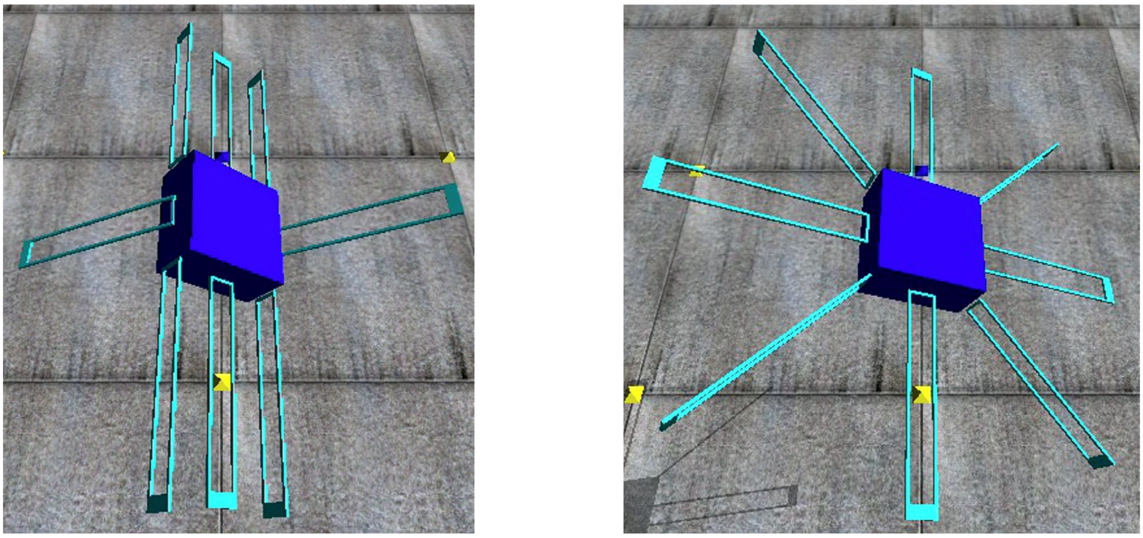
Figure 1. Robot model. The eight frames are rotational. The body attitude changes when the frame rotates due to reaction.

3. Simulation

ODE is an open source and can calculate robot motion based on the dynamics. The ODE also calculates the effect of friction. A motor can be added on a hinge. All function we need are implemented in the ODE. The ODE API can be called from C/C++ language. the ODE is suitable for users who can compile C/C++ codes.

4. Results

The typical motion result is shown in **Figure 2**. Figure 2(a) shows a snapshot of rotation process, and Figure 2(b) is the final attitude after rotation stops. The angles about x-axis, y-axis and z-axis are 0.0°, 25.26°, 0.0°, respectively. The frame length affects the attitude change, namely, the longer frame achieves the larger attitude change.



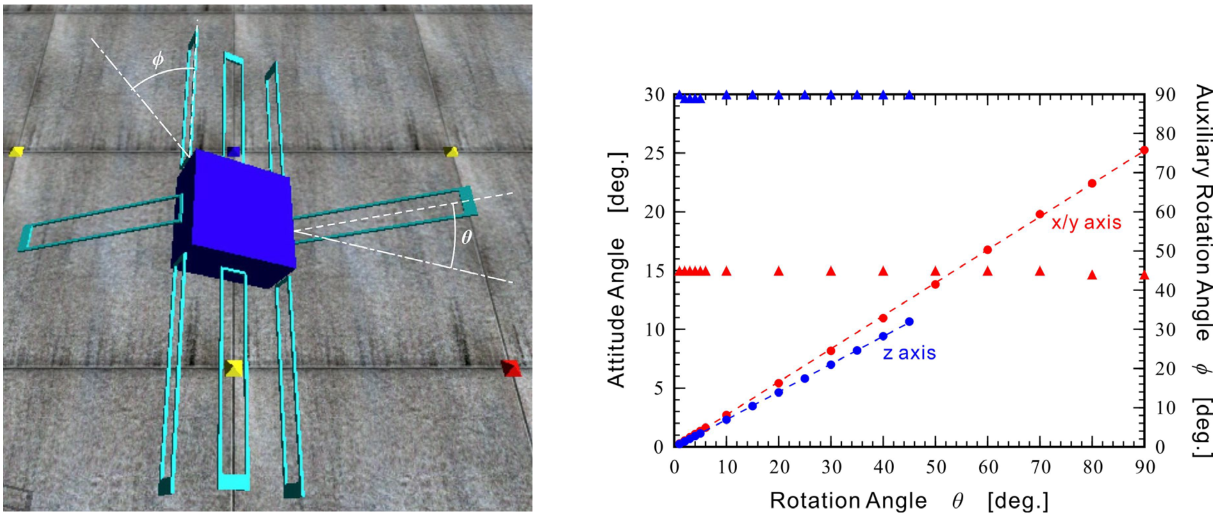
(a) Rotating Frames (b) Final Attitude

Figure 2. Attitude Changing. (a) a snapshot of changing process, (b) final attitude after rotation stops. The robot rotates about the y-axis. The angles about other axes are not changed within the calculation precision.

In order to control the attitude as we want, a control law is required. Therefore, we investigated dependency of attitude angle change on the rotation angles. At first, no compensation was added to the rotation angles. As a result, the dependency was not linear. To improve the linearity, we introduced an auxiliary angle ϕ. This angle was slightly changed so that the dependency could become more linear. The law is shown in **Figure 3**. This figure indicates that linear attitude change can be achieved by optimizing the rotation angle. In addition, any angle within the maximum change angle per one cycle can be achieved. If larger attitude change is required, that can also be achieved by two or more cycles motion.

5. Conclusions

A robot model is prepared for the dynamics simulation. By rotating a pair frame in the opposite angle direction, the rotational moment can be cancelled. On the other hand, by rotation a pair frame in the same direction, the rotation angle can be enhanced. The control law is introduced by considering those characteristics. The attitude angle can be changed linearly against the frame rotation angle.



(a) Angles Definition (b) Control Law

Figure 3. Attitude Control Law. (a) angles definition, (b) finely tuned control law for *x*-/*y*- axes and *z*-axis. By slightly changing the auxiliary angle ϕ, the attitude angle linearly changes against the rotation angle θ.