Hamster Wheel: A Multidiscipline Educational and Race Toy

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ABSTRACT
This paper introduces a novel and tangible educational or race toy, called Hamster Wheel, which is an approach and interface to illustrate multidiscipline science and technology in an intuitive and economic fashion, and encourage any age's people to explore science. The multidiscipline to be learnt through this toy includes kinematics, control engineering, discrete mathematics, computer and mechanical engineering. Through the play of this toy, users can efficiently and effectively gain applied multidiscipline knowledge with fun. Using this toy as race mechanism encourages people to explore and enhance the insight of this knowledge.

Author Keywords
Educational toy, race toy, multidiscipline, kinematics, control engineering, discrete mathematics, computer engineering, mechanical engineering.

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interface.

INTRODUCTION
Toys with some adjustable factors, which influence the toy's behavior and performance, always attract the attention of people with curiosity and sprit of science exploration. Their curiosities drive them interact with the toy to see what the results are when they adjust the factors. If the determination of these factors reflects some application of sciences and engineering technologies, and meanwhile the interaction is easily accessible, the quickly responding results can help people to efficiently and effectively gain applied knowledge. These kind toys are suitable for educational purpose [1]. If the performance measurement is move speed, these toys are also suitable for race use.

DESCRIPTION
I here introduce my designed toy, called Hamster Wheel, on which multidiscipline knowledge are applied and intuitively illustrated. The applied multidiscipline includes kinematics, control engineering, discrete mathematics, computer engineering, and mechanical engineering. This toy is of simple structure and low cost. It can further be developed as a race toy if more construction components are available for user to choose, and a convenient programming device is accompanied. .

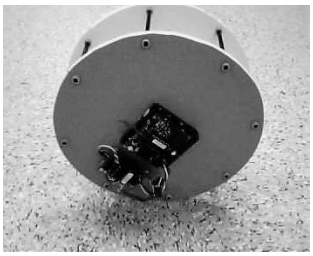

Figure 1. Hamster Wheel Outlook

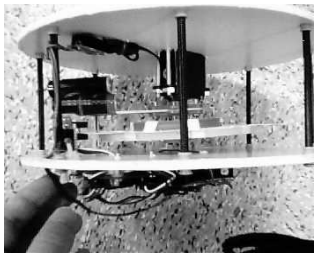

Figure 2. Hamster Wheel Inside Look

As its name implies, Hamster Wheel, shown in the Figure 1 and Figure 2, is a rotating toy which looks like a hamster pet wheel, but not hung on a trestle. Instead it rolls on floor. Due to the gravity and friction forces, the rotation of the pendulum, illustrated in Figure 3, drives the wheel to move forward or backward similarly to that a hamster pet scrambles in its wheel.

The pendulum is driven by a microchip controlled servo motor. The lift of pendulum within 90 degree range always tries to force the wheel move, whereas the move of wheel always lowers the position of pendulum. The physical structure of Hamster Wheel is a typical and complicated kinematics system (detailed modeling and analysis should be refereed to [2]). Several forces are involved in the movement of wheel (see Figure 4).

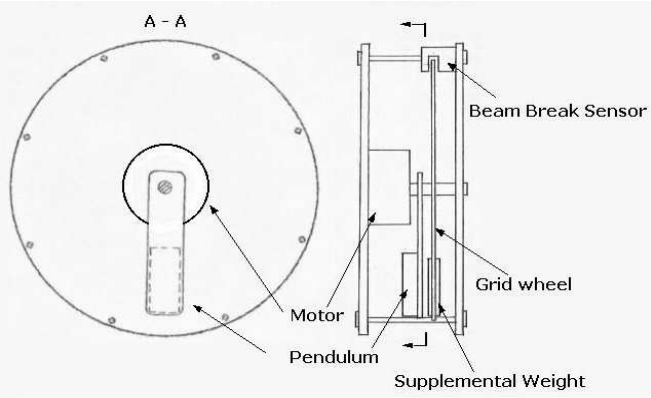

Figure 3. Hamster Wheel Structure

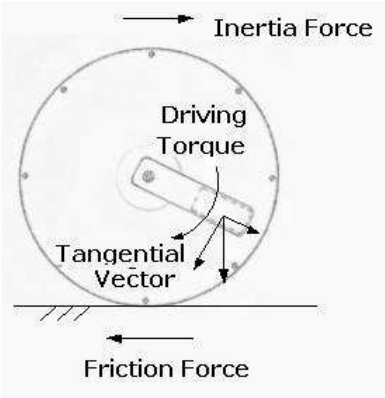

Figure 4. Kinematics Illustration

These forces include pendulum gravity, friction force between wheel periphery edge and floor, whole wheel inertia force, motor driven force etc. The key force is the tangential fraction force vector of pendulum gravity, which produces the wheel rotation torque. The magnitude and direction of this toque is varied depending on where the pendulum is. The torque causes the wheel move speeding up, down or even oscillation.

If we want the wheel move at certain constant speed, there must be a feedback to control the pendulum. The feedback is the wheel rotation speed relative to ground detected by a sensing system. The sensing system shown in Figure 5 is a shaft encoder, which contains an infrared beam break counter sensor and a hollowed engrave grid wheel. The grid wheel keeps still relative to ground during the Hamster Wheel rotate due to the effect of its supplement weight, such that the counter sensor is able to detect the rotation speed of Hamster Wheel relative to ground.

On another hand, a fast computing microprocessor based computer system is necessary for pendulum motion control and sensing signal process. The motion control codes contain the servo motor driver and target speed value. The signal processes deal with the calculation of rotation speed in term of the counter value from the infrared beam break sensor.

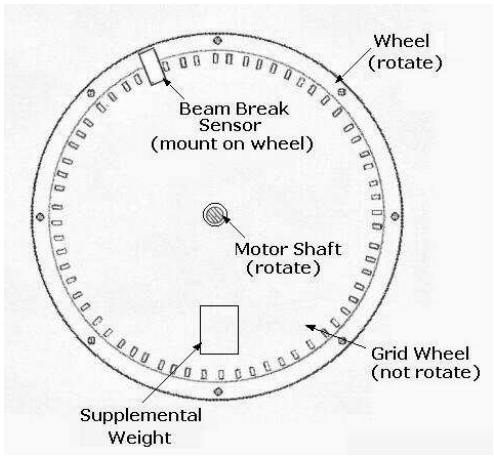

Figure 5 Sensing System

All above components work together and form a closed loop control system, as shown in Figure 6

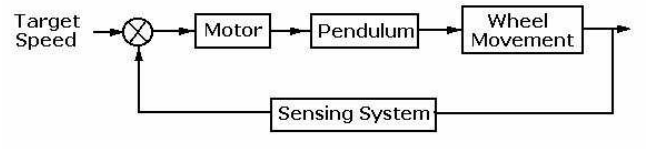

Figure 6 Closed Loop Control System

In this closed loop control system, the signal of difference between target and measured rotation speed controls the motor to keep the pendulum at certain position, which makes Hamster Wheel move stably at target speed.

From the control engineering theory [3], we know that only a well configured or designed system can make this system work stably. Otherwise the oscillation occurs. For this system, the appropriate configuration is a challenge. Several factors, which can be manipulated or observed by users, affect the system's performance. Through the manipulation or observation, users are able to gain applied multidiscipline knowledge with funs. It is the point that could attract users with strong curiosity and spirit of science exploration to play with.

USER STUDY

In our preliminary user study by showing demo, we found that people at first are very curious how Hamster Wheel could move at constant speed without any driving wheel, and after observing its intuitive, simple and clever structure they quickly gain some applied multidiscipline knowledge which they need taking longer time to learn from textbook. User study also showed that people are willing to

participate in race competition if they have available materials.

CONCLUSION

Below factors apparently affect the behavior or performance of Hamster Wheel:

- Mass and dimension of wheel
- Mass and position of pendulum
- Weight balance condition of wheel
- Performance of microcontroller system
- Response time specification of motor
- Fineness and quality of sensing system
- Surface conditions of wheel periphery edge and floor

By manipulating some factors, being ware of conditions and observing the result, users can gain some applied multidiscipline knowledge.

ACKNOWLEDGMENTS

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