Mathematical Modeling Of Ball Balancing Robot: A Review

Mr. Sagar S Kadam[1], Prof. Gajanan N. Thokal[2], Prof. Shishirkumar. N. Kadam[3]
[1, 2, 3] Dept of Mechanical Engineering
[1, 3] PHCET Rasayani.
[2]PIIT New Panvel

Abstract- *In the past decade, there has been much more research in ball balancing robots which actively stabilize themselves. Various models and controllers have been applied to control the dynamics of ball balancing robots. Ball balancing robots motion is arbitrary without changing the direction of the wheels, because they have three DOF-motion on a two dimensional plane. Sometimes this system is unstable, when active control is not applied to the wheels on the ball. In this paper the review of mathematical modeling of ball balancing robot is represented.*

Keywords- Ball balancing robot, Mathematical modeling.

I. INTRODUCTION

The Ball balancing robots works on the principle of an inverted pendulum. It shows a dynamically-stable mobile robot design to balance on a single spherical wheel. Single contact point of ball balancing robot with the ground is useful for Omni-directional, manoeuvrable and organic in motion, compared to other ground vehicles. It is also suitable for navigability in narrow, crowded and dynamic environments.

Traditional wheeled mobile robots are equipped with two independent driving wheels. Since these robots have two degrees of freedom (DOFs), they can rotate about any point, but cannot perform immediate motion in every direction. To overcome this type of motion limitation, Omni-directional mobile robots were proposed.

II. LITERATURE SURVEY

[1].The first BBR is developed in 2006 by Prof. Ralph Hollis at Carnegie Mellon University (CMU), Pittsburgh, in the United States and it was patented in 2010.The CMU Ball balancing robots is built to be of human size, both in height and foot print. Prof. Hollis and his group at CMU demonstrated that the ball balancing robots can be robust to disturbances including kicks and shoves, and can also handle collisions with furniture and walls.

They showed that a variety of interesting human-robot physical interaction behaviors can be developed with the ball balancing robots and presented planning and control algorithms to achieve fast, dynamic and graceful motions using the ball balancing robots. They also demonstrated the ball balancing robots capability to autonomously navigate human environments to achieve point-point and surveillance tasks. The robot has about human size with the aim to let it interact with humans. Later also arms were added to the BBR.

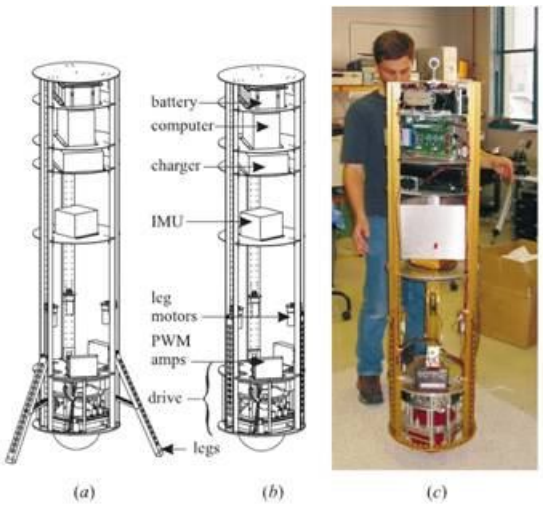

Figure 1 First BBR developed at CMU, Pittsburgh.

Structure of the report BBR is that is has three legs for static stability and that it has a drive mechanism that consists of four rollers: two active rollers, driven by DC motors, that actuate the ball and two spring-loaded passive rollers opposite the drive rollers, that apply a force to the ballot maintain contact between the drive rollers and the ball. That implies that the robot cannot rotate around the vertical axis.

A pair of two degrees of freedom (DOF) arms was added to the CMU Ball balancing robots in2011 making it the first and currently, the only ball balancing robots in the world with arms .Later, the two passive rollers were replaced by two active rollers, due to unequal friction for forward and backward motion and also a drive system was added for

rotation around the vertical axis. This means that in total 5DC motors were needed, which is quite expensive. A lot of research has been done on this BBR.

[2]. The Tohoku Gakuin University (TGU) in Japan developed a BBR in 2008. . Prof. Kumagai and his group demonstrated the capability of ball balancing robots to carry loads and be used for cooperative transportation. They developed a number of small ball balancing robots and demonstrated cooperative transportation using them.

[3]. This one is small compared to the BBR of CMU, but special about this BBR is that it can perform the same motion (including rotation around the vertical axis) with only three motors connected to three Omni-wheels that drive the ball. Also this robot can carry loads of at least 10 kg. A group of researchers independently presented the design for a human-reliable ball balancing robots wheelchair that balances on a basketball named B. B. Rider . However, they reported only the design and never presented any experimental results
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[4]. László Havasi from Hungary independently introduced another ball balancing robots called ERRO Sphere . The robot did not reliably balance and no further work was presented.

[5]. The University of Adelaide (UA) in Australia developed a BBR using LEGO Mind storms NXT in 2009. It is a small robot of about 20 cm high, completely built of LEGO. It has only two wheels to drive the ball.

[6].Tomás Arribas (Spain) developed the first ball balancing robots using LEGO Mind storms NXT in 2008 as the Master Project at University of Alcala. He developed a simulation project with Microsoft Excel to easily simulate the system.

As part of the research carried out inside the Space Research Group of the University of Alcalá (SRG-UAH), Spain, the work team, specialized in optimal control and planning applied to non-linear dynamic systems, published in 2012 the article called "A Mono ball Robot Based on LEGO Mind storms "This article describes the math model and trajectory control as a baseline to unstable and non-linear control systems.

[7]. Yorihisa Yamamoto (Japan) inspired by Tomás Arribas's project, developed a ball balancing robots using LEGO Mind storms NXT in 2009 He created a detailed demo to build, model and create controllers using MATLAB.A group of mechanical engineering students at University of Adelaide (Australia) developed both a LEGO Ball balancing robots and a full-scale Ball balancing robots in 2009 . A group of students from ITMO University (Russia) introduced an algorithm and constructed a Ball balancing robots based on Lego NXT robotics kit which performed stability with only two actuators used.[36] There are a number videos on YouTube that present several ball balancing robots developed around the world. Several of them have been developed using LEGO Mind storms NXT While several other custom designs use Omni-wheels to actuate the ball

[8]. Ball balancing robots have also appeared in the Science Fiction World. Pixar's Wall-E (2008) movie featured M-O (Microbe Obliterator), a ball balancing robots cleaning robot. Syfy's Caprica TV series (2010) featured Serge, a ball balancing robots butler robot.

[9]. The National Chung Hsing University in Taiwan developed a BBR in 2012, similar to the one of the TGU. It also has three Omni-wheels and is of about the same height.

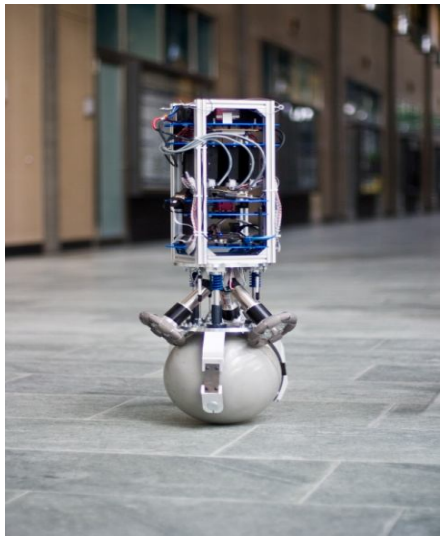

Figure 2 Re-zero Robot

[10]. TH Zurich in Switzerland developed a BBR, called Re-zero in 2010.Like the robot of TGU, it has three Omni-wheels to drive the ball. It has a high dynamic robustness, achieves a linear speed of up to 2 m/s and a tilt angle of 20.

III. CONCLUSION

This paper reviewed the research work had been done regarding methods of mathematical modelling of ball balancing robot. In two dimensional mathematical modeling effect of inertia forces has been neglected, so three dimensional mathematical modeling is required . In case of control system addition of kalman filter is required to filter the signals from various devices.

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