Three-wheeled Autonomous Agent (Gnuman) With Roulette and Hypotrochoid Motion

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Abstract

Designed as an evolving humanoid research platform, Gnuman is a three-wheeled autonomous agent capable of roulette and hypotrochoid motion. The foundation comprises a drive mechanism that allows limitless rotation about each wheel's spin and steering axis without the traditional restriction of 'wind-up'. Founded on a 120° tripod configuration, the adaptive drive mechanism enables Gnuman to articulate through openings narrower than its 'footprint'. Gnuman will be expanded to incorporate three equally spaced limbs and redundant multidimensional vision. The symmetry of the design combined with a freely rotating torso provide for an agent that no longer has a front or back – the 'front' of Gnuman is defined as the direction it is traveling. This paper describes the progress and philosophy behind the design.

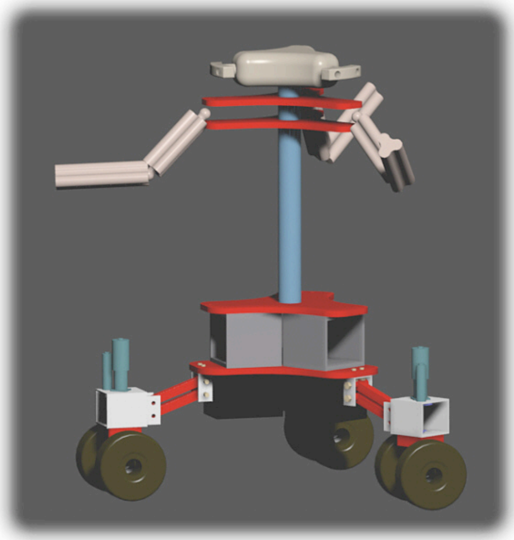

Figure 1: Machine Intelligence Lab's humanoid, *Gnuman*

1. Introduction

The University of Florida's Machine Intelligence Laboratory (MIL) is expanding its autonomous humanoid robot research. The design intent of *Gnuman* is to develop a foundation capable of supporting an array of advances that include vision, artificial intelligence, speech, voice recognition, tactile grippers, path planning, and human interaction. The bulk of this paper is contained in Section 2, which is dedicated to the implementation and capabilities of the platform.

2. Physical Structure

2.1 Overall Size

Based on a tripod, *Gnuman* has an adaptable footprint (Figure 2.) that varies from a minimum diameter of approximately 22 inches to a maximum of 30 inches. The variability in the footprint comes from a dual-purpose parallel-link leg structure (Figure 1). The leg structure allows for a semi-active suspension whose effect is a variable footprint. An additional byproduct of the suspension is variability in height, which is approximately 40 inches.

Maintaining the tripod theme are three arms space 120° apart, and a symmetric three sided head.

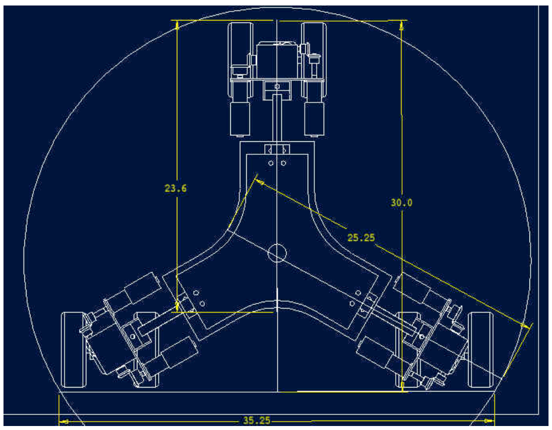

Figure 2. Footprint

2.2 Weight

Weight is an issue as power is limited to dual lead-acid batteries; projections are at 75 pounds. While the foundation is composed of steel and aluminum, the shoulder-girdle, arms, and head are composites.

2.3 Mobility

The premise for the design was to allow the base to articulate through an opening narrower than its footprint by incorporating unrestricted rotation of the drive wheels. To compliment the drive system, a modified triangle was decided upon (Figure 3.) The drive and platform combination enables *Gnuman* to duplicate the manipulation used when awkward furniture is rotated through a doorway.

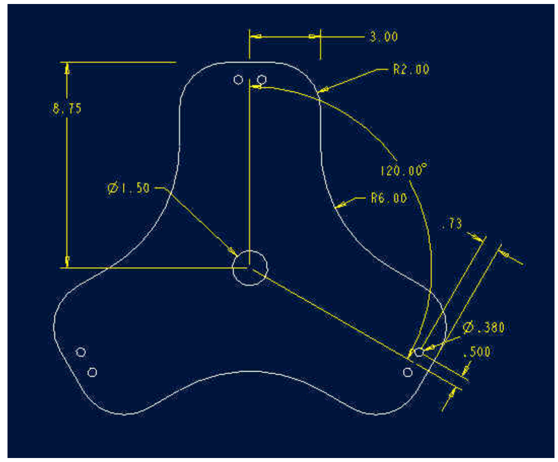

Figure 3. Top view. Modified triangle

2.3.1 The Main Bearing and Drive System

The drive system consists of three identical gearboxes, each composed of an independent drive motor and steering motor. The redundancy of six independently controlled motors gives *Gnuman* complete freedom of in-plane motion.

To accomplish complete independence, a floating drive shaft passes through and is supported by a bearing, which is also mounted in a bearing (the outer bearing) which becomes a drive shaft; the steering motor drives a gear mounted on the outer bearing (Figure. 4.) The combination of a drive shaft inside a drive shaft allows the wheels and steering to be independently driven with limitless rotation of both steering and drive.

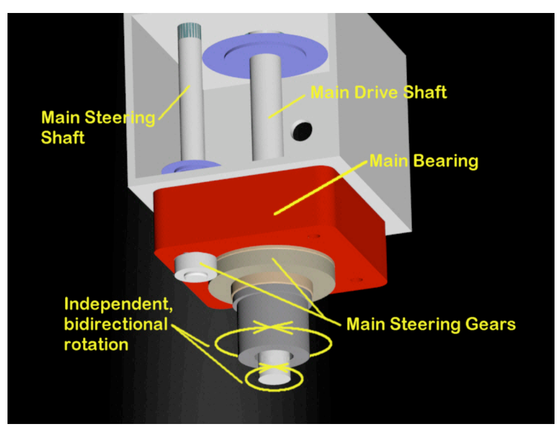

Figure 4. Main bearing and drive system

2.3.2 Roulette and Hypotrochoid Motion

The steering and drive redundancy combined with limitless rotations gives *Gnuman* the ability for extremely complex in-plane motion. Roulette motion (Figure 5) enables *Gnuman* to traverse a straight path while maneuvering around obstacles or through narrow openings, such as a doorway.

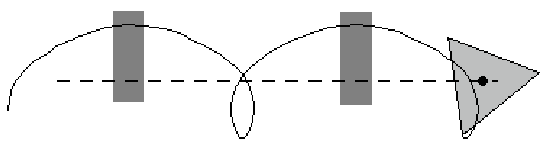

Figure 5. Top view. In-plane roulette motion through two openings narrower than footprint

The adaptability of the drive system also allows hypotrochoid motion (Figure 6) that is limited by the minimum radius of the circle being traversed.

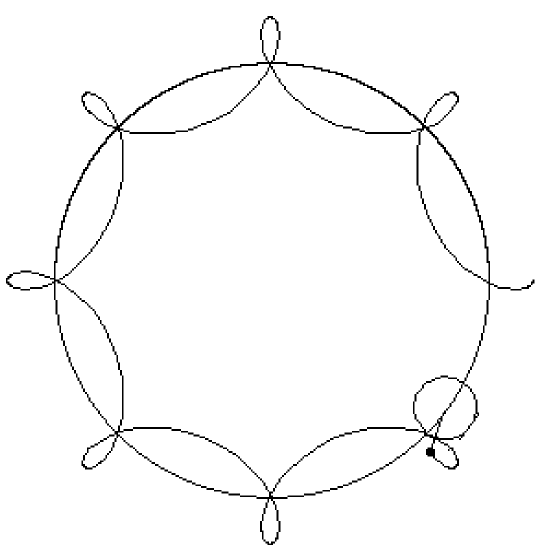

Figure 6. Top view. In-plane hypotrochoid motion

3. Controlling the Redundant Drive

The foundation of *Gnuman's* drive system is 6 independently controlled dc motors. The feedback network consists of 12 streams of data that monitor motor performance and drive train position.

The absolute position of the drive wheels was deemed unimportant so each drive motor was equipped with an incremental encoder that outputs a quadrature signal. Each steering motor makes use of an absolute encoder whose data is manipulated so that it supplies both a nine-bit absolute position (.703125 degree resolution) and incremental quadrature signal. Because of the 2:1 gear ratio on the steering (Figure 4), the absolute encoders indicates either the correct wheel assembly position or one that is 180 degrees out of phase. To address this aberration, a micro switch and a two-position cam was attached to each to each wheel assembly; the state of the micro switch determines the position of the wheel assembly, and the encoder determines the angle.

A dedicated motion-control processor is used on each motor. The processor takes the quadrature input then generates the necessary pulse width modulation (PWM) signal based on position, trajectory, acceleration, error from desired position, and PID correction. In addition to controlling the PWM, the dedicated processors report position errors that are monitored by the main microprocessor. As the errors are reported, the microprocessor determines the largest deviation and gives priority to that motor until it is within acceptable error.

4. User Interface

At this stage of development *Gnuman* interacts with the outside world by a menu driven interface. The output is to a four-line LCD panel and input is by a sixteen key keypad (Figure 7). During testing, an analog joystick provided input for a single drive motor and its companion steering motor.

5. Conclusion

5.1 Future Development

Gnuman is an ongoing project. Speech and voice recognition will replace the current user interface. Seven degree of freedom shoulders and arms (Figure 1) are in the design stage as are highly tactile and dexterous hands (not shown). 360 degree, three-dimensional vision is being investigated, as is the wireless communication that will allow *Gnuman* to face one direction while the base maneuvers around obstacles.

Full implementation of roulette and hypotrochoid behavior is progressing, as is the second-generation gearbox and semi-active suspension.

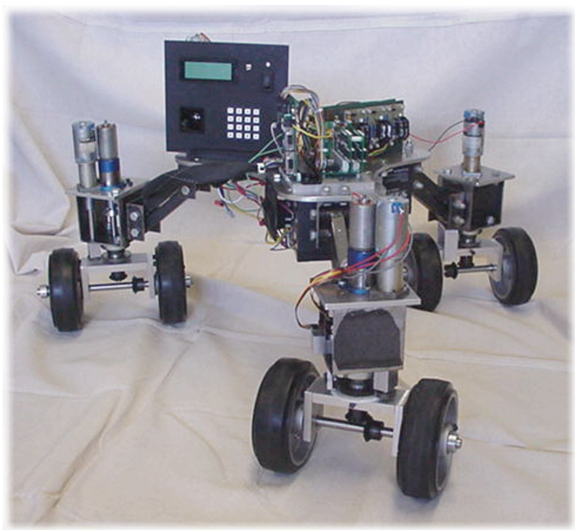

Figure 4: Current state of development

5.2 Summary

Intended as a research platform to push the bounds of humanoid development, *Gnuman* is in its infancy. Combining roulette and hypotrochoid motion allows for very complex path generation and following. Larger, all-terrain versions of *Gnuman* could be used to manipulate around hazards few humans are willing to traverse. Properly equipped, future versions could aid in locating, marking, and manipulating around some of the 80 million landmines spread throughout the world.

6. References