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Self-docking for Robots and Drones

Introduction

Self-docking robots and drones propose higher levels of autonomous performance in terms of power, mobility, stability and functionality. The wide range of commercial applications has increased the need for proliferation of self-docking technology. This paper is a review of hardware and software technology for self-docking robots and drones. Sensors, electromagnetism, and object recognition algorithms are discussed.

Commercial Applications of Self-docking Robots

Recharging

Robots and especially drones have short battery lives. The use of self-docking technology for recharging elongates operation time. H3 Dynamics's product DRONEBOX allows drones to survey in remote locations because drones can land on and dock to a recharging platform by themselves [1]. The platform functions as a command center for self-deployment and landing. The price of DRONEBOX is not listed on H3 Dynamic's website because it is mostly sold for industrial inspection. For a domestic use product, self-docking vacuums are popular. Strata Home released MP SmartVAC 2.0 that goes to its charger when its battery is low, worth 200 dollars$ [2]. In addition to the existing products, Amazon filed a patent for using existing streetlights as docking and recharging stations for delivery drones in the future [3].

Delivery

For delivery drones and robots, Soundararajan [4] proposes that a delivery receptacle uses a locking mechanism on the door or chute through which the package is deposited. That is to say, the door and the chute serve as docking stations, and the delivery receptacles need to perform self-docking. This is a prototype under development, so there is no price associated.

Mid-air Refueling

Self-docking and refueling in mid-air provide a solution to unmanned aerial vehicles' (UAV) short power endurance. Daniel Wilson from The University of Sydney used a combination of Infrared cameras, GPS, and inertial sensors to allow accurate positioning of two UAVs for airborne docking [5]. The price is not listed because this project is under the research and development stage.

Underlying Technology

Distance Sensors

Distance and angle between adjacent robotic modules are measured by position sensors, such as Infrared and Ultrasonic sensors. As presented in [6], the sensors should be light-weight, robust, cost effective, and quick in response. The Infrared sensor (SHARP GR2Y0A21YKOF) tested in [7] has a range of 10 centimeters to 80 centimeters, and the Ultrasonic sensor (HC SR-04) has a range of two centimeters to 10 centimeters. Docking distance should be within the visible range of the sensors. Won *et al.* [8] shows, at a certain distance, the signal strength of the Infrared sensor is the strongest when receiver and emitter are aligned. This lays the foundation for the alignment control algorithm.

Electromagnetic Docking

Electromagnets are used in self-docking because magnetic forces compensate for small misalignments. Since current controls electromagnets' polarities, docking and undocking can be controlled by current direction. Electromagnets can be employed to alleviate the burden of a docking controller. As Won *et al.* shows in [8], permanent magnets and electromagnets are implemented on opposite sides of the robotic module. Current is only needed at the moment of docking and undocking, and for the rest of the time the modules are connected due to permanent magnets. This design results in low power consumption.

Computer Vision Object Recognition

Object recognition is employed to locate docking destinations. A marker on the destination simplifies the object recognition algorithm. A 3D fiducial marker together with Hessian-Laplace machine learning method are used to achieve accurate localization in [9] because Hessian-Laplace method is invariant to rotation, scale, and lighting changes. As stated in [9], it takes .8 seconds to match features on a Pentium III 600MHz computer.

Building Blocks for Implementation

Robots and drones employ distance sensors, electromagnets and object recognition methods to achieve accurate and controlled self-docking. The distance sensors should have stable performance across a range of distances and high sensitivity around the desired docking distance. The electromagnets need to be highly responsive to current change. And object recognition algorithms aim at low computation power.

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[3] Kelsey D. Atherton. (2016, July), *Amazon Patent Lets Drones Perch On Streetlight Recharging Stations* [Online]. Available: https://www.popsci.com/amazon-patent-puts-drones-on-streetlight-recharging-stations

[4] Soundararajan, *et al.*, "Mobile Delivery Receptacle," U.S. Patent 9,798,995, October 24, 2017.

[5] Daniel Briggs Wilson *et al.,* "Guidance and Navigation for UAV Airborne Docking", *Robotics: Science and Systems*, 2015.

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[7] S Adarsh *et al.,* "Performance comparison of Infrared and Ultrasonic sensors for obstacles of different materials in vehicle/ robot navigation applications" in *IOP Conference Series.: Materials Science and Engineering*, 2016 © IOP Publishing Ltd. Doi: 149 012141

[8] Peter Won *et al.*, "Development of an Effective Docking System for Modular Mobile Self-Reconfigurable Robots Using Extended Kalman Filter and Particle Filter", *Robotics*, vol. 4, pp. 25-59, 2015.

[9] Uri Kartoun *et al.*, "Vision-Based Autonomous Robot Self-Docking and Recharging" in *Automation Congress*, 2006 © IEEE. doi: 10. 1109/WAC.2006/375987.