The Autonomous Photovoltaic MarXbot

Florian Vaussard, Philippe Rétornaz, Martin Liniger, and Francesco Mondada

EPFL – STI – LSRO, Station 9, 1015 Lausanne, Switzerland
firstname.lastname@epfl.ch

Abstract. Domestic service robots are currently powered by the mains electricity. The growing multiplication of such devices negatively impacts our environment. In this study, we show the feasibility of harvesting energy from natural light in an indoor environment. The design of the harvester is carefully carried out using an experimental characterisation of several solar panels, while the boost converter is optimised to operate at low-light intensities and the robot is enhanced for low-power operations. The resulting harvester is then thoroughly characterised. Finally, a phototaxis experiment is conducted, proving the feasibility of recharging the robot solely by using this form of energy. The possibility of embedding energy harvesting in indoor mobile robots radically changes the potential impact of this technology in our society.

1 Introduction

Domestic service robots are a rapidly growing market. In 2010, at least 1.45 million units have been sold, mostly vacuum cleaners [1]. This is roughly a 40 % increase compared to the previous year. The total population can be estimated at around seven million units, even if this figure is subject to uncertainty.

All these devices are powered by batteries. In the best case, the robot can recharge itself using the mains electricity and a docking station. In the worst case, primary batteries must be periodically replaced. If these robots are in use only 1 % of the time, given the mentioned population, this equals 600 million hours of activity per year. If we take a reasonable power consumption of 10 W, this represents 6 GW h per year, or 510 *Tonne of Oil Equivalent* (TOE). Our long-term goal is to replace most of this power with renewable energy, for example by harvesting the energy from the surrounding environment.

In a previous study, we considered several types of energy, and showed how some of them are highly promising, such as indoor solar energy or mechanical work produced by humans [14]. The indoor environment is, however, demanding. Compared to outdoors, the house is protected against environmental phenomena, leading to scarce energy resources. In the case of a robot performing periodic tasks at a low duty cycle—like cleaning, watering the plants or patrolling—renewable energies can however account for a fair part of the total energy budget. This is what we want to assess in practice.

In this study, we present the results achieved using a prototype of a photovoltaic robot for indoor use. This energy was chosen for its high potential, especially near windows and other bright places exposed to the sun. A power density of at least $300\,\mathrm{W\,m^{-2}}$ behind a window was assessed during good weather in September using a solarimeter (46° of latitude). This is two orders of magnitude above the indoor lighting.

S. Lee et al. (Eds.): Intelligent Autonomous Systems 12, AISC 194, pp. 175–183.
springerlink.com

There are a number of challenges when scavenging the solar energy directly from a mobile indoor robot. In this study, we address the mechatronics integration, with the main purpose of efficiently moving and orienting the panel, so as to maximise the collected energy. Another problem is the localization of the best spots for being recharged. We show here a simple solution based on phototaxis. More complex situations will be addressed separately.

The key points of our design are first introduced. The prototyped harvester is then validated under well-known conditions. Finally, we prove the feasibility of recharging the robot, using an indoor experiment.

2 Prior Works

A number of outdoor robots are effectively using solar energy, the most notable ones being the three Mars rovers—Sojourner, Spirit, Opportunity—as well as the Antarctic rover "Cool Robot". The Mars rovers were fitted with expensive GaAs/Ge and triple-junction solar panels, placed horizontally on top of the robots and providing the necessary power for a few hours per day [12,13]. The operating point of the solar panels is approximated using environmental conditions and a priori knowledge.

"Cool Robot" is designed to operate in Antarctic conditions [7,8]. The power budget has been carefully modelled, including the snow-reflected component, providing a good margin for long-term polar experiments [6]. Such experiments, however, have yet to be conducted.

In the case of indoor robots, there exists only a few rigorous designs. Results are often restricted and inconclusives. Testing conditions are not always well defined, leading to non-reproducible experiments. Worthy designs include the miniature legged inchworm of Hollar [5]. It was able to move forward 3 mm in 30 minutes under the light provided by an optical fiber. The miniature robot "Alice" was also fitted with solar panels, operating under a 3000 ANSI lumens beamer [2]. Power densities of 7.1 and $27.8\,\mathrm{W\,m^{-2}}$ were achieved using crystalline silicon and thin film amorphous silicon cells. The overall power balance is, however, unknown.

The problem of the panel's orientation is often not considered by researchers, simplified to a horizontal placement. The tracked robot of Hartono is fitted with a fixed-tilt panel and four photodiodes at each corner [4]. These inputs are fed into a neuronal network, which controls the driving motors and switches between several survival strategies. This setup has been tested for 33 hours in uncharacterised outdoor conditions.

In summary, a rigorous design, validated by by a proof a concept experiment, was not yet demonstrated in the literature. We propose to fill in the gap in this study, using a simple approach to locate the energy source.

3 Design

Our design was driven by several key points. First, the system should minimise the consumed energy, while being able to move in an indoor environment. It should also maximise the illumination on the solar panel and efficiently convert the incoming power into usable energy.