Development of a smart sensor for controlling artificial lights and venetian blinds

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Introduction

In a typical office building, the energy-saving of lighting is an important problem because the lighting accounts for 40% of the total electric power consumption in the entire building. However, the lighting affects the amenity of an office space, and inappropriate energy-saving of the lighting decreases the productivity of office workers. Therefore, a lighting control system for the office building must achieve the appropriate energy-saving based on careful and accurate control of light. In any case, energy efficiency must never compromise indoor comfort for building users. Lack or poor indoor comfort has a direct affect on users' productivity and an indirect effect to actual buildings' energy efficiency. Unreasonable users' reaction is proved to be disastrous for energy efficiency, i.e. heating greenhouse extensions to buildings, using internal blinds during the day to cut daylight and keeping electric lights on.

Existing techniques for artificial lights and blinds

- Newsham developed a model in which the blinds were lowered if the intensity of the sunlight, which fell on the occupants, exceeded 233W/m^2. (Newsham et al. 1994)

- Trobec Lah built a fuzzy logic system for managing a roller blind with respect to lighting levels inside the building. The inputs for the system are internal illuminance, global and reflected solar radiation, as well as the current position of the roller blind. The system was applied to a test chamber where it showed a solid performance in controlling the inside illuminance in correlation with the available solar radiation. (Trobec Lah et al. 2006)

- Guillemin and Molteni developed an integrated self-adaptive controller. The controller consists of two artificial neural networks (ANN) for the prediction of room temperature and weather, and two fuzzy logic controllers for controlling heat artificial lighting and blinds. (Guillemin and Morel 2001) and (Guillemin and Molteni 2002)

- Kolokotsa presents a fuzzy logic controller for indoor thermal and visual comfort and air quality based on the EIB (European Installation Bus) and Matlab. The system was tested and implemented in an experimental chamber (size: 1 m x 1 m x 2 m). The fuzzy controller is fed the following parameters: Predicted Mean Vote (PMV), outdoor temperature, heating or cooling requirements, window opening, indoor illuminance, level of electric lighting, and shading. This produces the following outputs: artificial lighting level and shading position. (Kolokotsa et al. 2006)

Development of the fuzzy controller

In order to control both blinds and lights in an office using Takagi-Sugeno fuzzy system two models were created with 2 inputs and 1 output, one for blinds and the other for lights.

		Artificial lights	Shades
Type of fuzzy controller		'Sugeno'	'Sugeno'
N. of inputs		2: error between current and desired light level, outside light level	
N. of outputs		1: change in the artificial lights state	1: change in the venetian blinds level
Fuzzification parameters error('trapmf')	'NE':	[-1000 -550 -400 -300]	[-1000 -550 -400 -300]
	'ZERO':	[-200 -100 100 250]	[-200 -100 100 250]
	'PE':	[400 550 2200 2500]	[400 550 2200 2500]
	'SNE':	[-400 -300 -200 -100]	[-400 -300 -200 -100]
	'SPE':	[100 250 400 550]	[100 250 400 550]
Fuzzification parameters outside('trapmf')	'low':	[-450 0 250 450]	[-450 0 250 450]
	'normal':	[250 450 550 950]	[250 450 550 950]
	'high':	[550 950 1050 1450]	[550 950 1050 1450]
De-fuzzification parameters (constant)	'down':	[-100]	[-100]
	'ldown':	[-50]	[-50]
	'stable':	[0]	[0]
	'lup':	[50]	[50]
	'up':	[100]	[100]

The fuzzy controller developed in matlab is then translated in C++ and it is loaded in the arduino Microcontroller, which is transforming the input volt signals to lux values of the indoor and outdoor illuminance as well as the presence sensor's indication.
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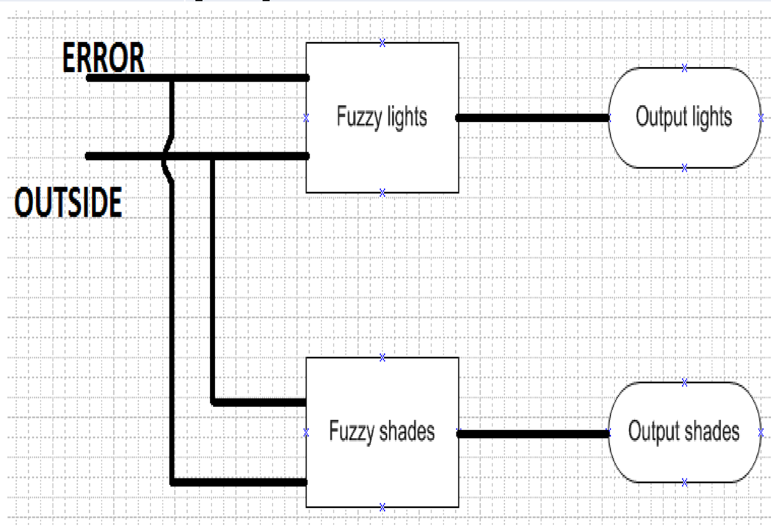


Application in the arduino micro-controller and utility of the zigbee protocol

The system uses xbee modules to communicate with computer through zigbee protocol. It sends the outputs, sensor values, current position of blinds and lights state to computer that monitors the system or to an arduino equipped with an LCD screen in the office room. Also the system can be programmed through zigbee from distance, send and receive files from and to memory card. The personnel of the office can bypass with zigbee the system for using their own parameters of the lighting and blinds state to match their needs.

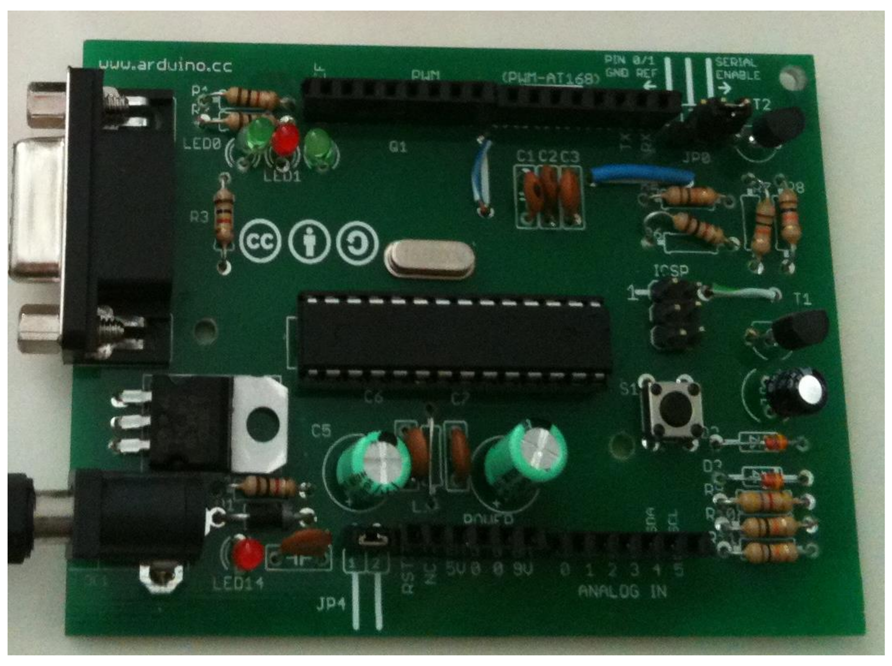


Fig. 1: Developed Arduino micro-controller

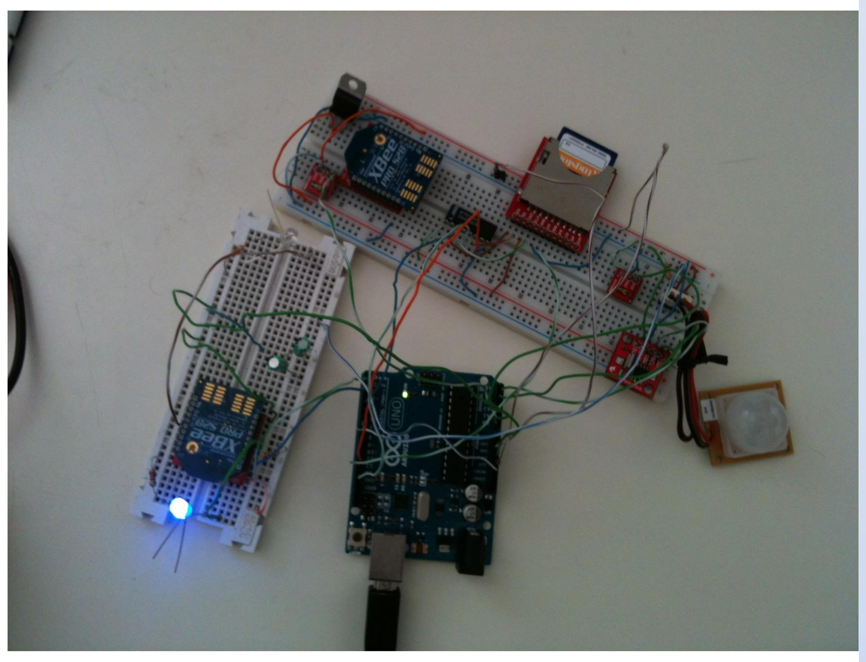


Fig. 2: Development of the smart sensor in the breadoard

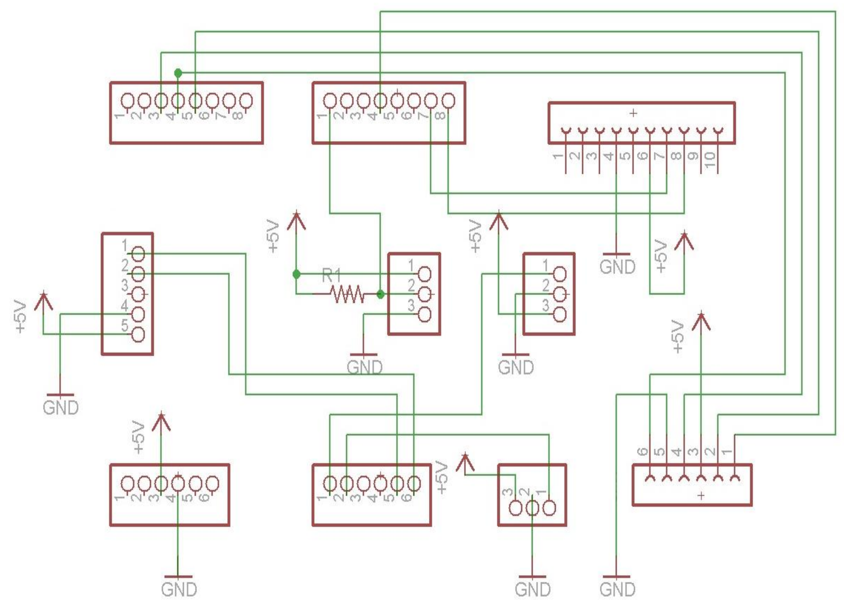


Fig. 3: Schematic diagram of the main shield

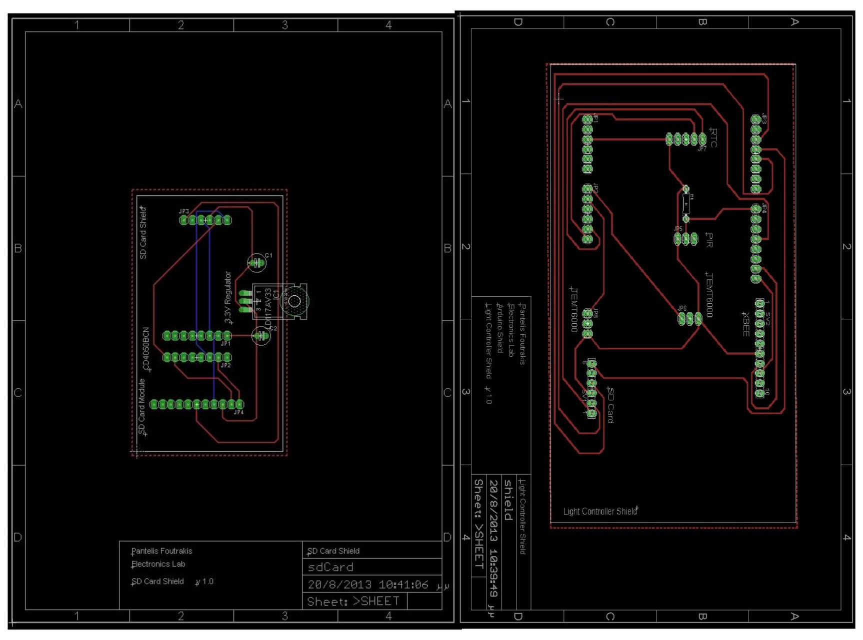


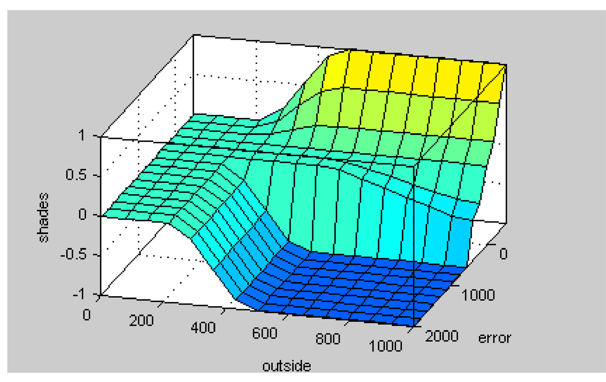
Fig. 4: Board layout for the main shield and the SD card shield

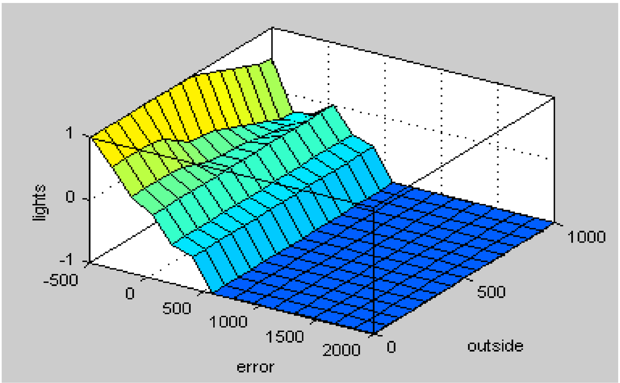
Results

The fuzzy controllers are developed in Matlab and have been transformed in C++ form. The fuzzification parameters as well as data collected by the sensors are stored in SD-card. Thus the controller can be characterized as a distributed one because it can control light level without requiring interaction with a central controller.

Furthermore, the fuzzification parameters stored in the SD-card can be updated by changing the files manually or they can be updated wirelessly using the Zig-Bee protocol. Thus the controller can be updated to a distributed one, but centrally optimized using optimization techniques such as genetic algorithms or particle swarm optimization in a central computer and then send the updated parameters.

In the figures bellow the reader can see the relation of the 2 inputs (outside illuminance and difference between internal and set-point with the change in the state of the lights.





Conclusions

- The fuzzy controller applied in the arduino micro-controller can maintain light level while saving energy.
- The zigbee protocol is transferring all the data to the central computer and updated fuzzification parameters can be transmitted wirelessly.
- SD-cards record data and can be used for the optimization of the controller using ANFIS architecture

Acknowledgements

This work is partly funded by the EU Commission, within the research contract GREEN@Hospital (Contract Nr. 297290) a three year European Project co-funded by the ICT Policy Support Programme as part of the Competitiveness and Innovation framework Programme (CIP).

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