Industry Oriented Problem

Fuzzy Logic based light intensity controller

Abstract

This report aims to describe a light intensity controller using Fuzzy Logic and Arduino UNO microcontroller. Many Home Automation devices are available but all of them are generally based on classical binary-valued logic.

We are targeting home incandescent lamps for their intensity control using Fuzzy Logic. We are using Fuzzy Logic so that we can detect the user behavior and initial environmental brightness. The Fuzzy logic technique gives control strategy a linguistic mode to work on so that controller can act accordingly through its designed Rule Base and not just crisp decisions thereby adapting for different environments easily.

We are planning to use Arduino UNO microcontroller along with Matlab based Fuzzy Logic model for our control strategy. Along with that, we can use optocoupler and Triac based dimmer circuit for modelling light intensity. For incorporating user input in the device, will use a mobile-based application. By using Blynk Slider and related widgets, we can take user input at a virtual pin of Arduino and then giving that value to the decision making circuit to compute output control signal for the dimmer circuit. That output can come as a voltage at an analog pin on arduino and then we can that to our dimmer circuit.

The control technique is distinct and incomparable with the original technique because in classical control, movement is rigid but in this, initial scaling is set by the environment initial brightness level and movement is fluid. The initial brightness data work as an input to fuzzy block in matlab and sets the initial membership function. So, initial membership function will vary according to the initial brightness level so that every environment has its own control and scaling thereby increasing power efficiency and saving cost.

Motivation and future prospects

Motivation for this idea was the environment adaptive and cost-efficient strategy of power utilisation. Along with that, its future applications attracted us to continue on this path. We can extend this strategy to make a full home automation device for any climate and region since it will automatically adapt to the environment by setting its initial scaling accordingly.
Along with that, we can incorporate linguistic user input control also in its further design update.

Solution of this problem also involved understanding of Fuzzy Logic that is a wide area and a remedy to classical logic that cannot handle linguistic variables and it is also fluidic control. Along with that Home Automation is a point of interest to everyone nowadays and our idea aims to a bigger Home Automation product at its next design update.

Along with that, future application are much more fascinating. We can use the project as an independent device in a commercial market. We can incorporate this technique for not only environment adaptive but also for user controlled settings and make a full product.

Technologies Targeted

We are aiming to develop a fully-equipped home automation device with additional Fuzzy Logic facility. To cope up with other Home Automation projects, we need to use some technologies. Prominent technology areas to be covered are User Input area, Computational area and Fuzzy Logic modelling area. We related softwares and hardwares for the purpose.

Matlab →

So, we can choose matlab as a software to model Fuzzy Logic in it. It is a multi-paradigm numerical computing environment designed by Mathworks. It is very easy to work with arduino IDE also. We connected arduino IDE with Matlab so that computations both in IDE and matlab can be useful and the Fuzzy Logics output can be directly given to the arduino without using the arduino IDE just by connecting Serial of arduino with Matlab.

Along with that we are also using Matlab Simulink to model our circuits that we have designed for intensity controller. By using that, we are simulating our circuits so that we can select ratings and components.

Blynk →

Our next concern is of user input. To compete with other products in the market, we need to give the device a glimpse of IoT. To do that, we can use a mobile-based application on Blynk.

Arduino →

Our final major concern is to do controlling action. For that we are using microcontroller Arduino UNO. It is an open source, computer hardware and software project for building digital devices and interactive objects that can sense and control objects in the physical world. The products are distributed as open-source hardware and software. Arduino boards are available commercially.

We can use Arduino to interface dimmer circuit of our lamp to the matlab based model of Fuzzy Logic controller. Arduino in our project is like a linker, acting as a bridge between all the technologies that we have incorporated. We can also configure Blynk application for our user input part by using arduino connected via USB in a computer and then connecting it to the Blynk server and also connecting the user input device to the same server.

Modelling Fuzzy Logic

Fuzzy Logic simplifies decision making by taking quick and efficient decisions in problems having imprecision and non-linearity issues.

Exploring Options →

There are various ways for modelling our fuzzy logic controller. We can buy a fuzzy logic chip which takes considerable amount of money for our implementation. Second possibility is by converting our Fuzzy Inference System Code written in matlab into ASCII format which can be later burned onto arduino. This would reduce the speed of decision making. So we have chosen MATLAB as our decision making system which would be interfaced to the outside world with the help of arduino.

Selecting Inputs and designing rules →

We need to select some inputs for the Fuzzy Controller. We aimed to have two way control in our project. One will be the control of initial scaling of intensity of the lamp and other for change in intensity of environment and one more for the user input of the desired intensity.

Fuzzy Logic Controller is the main decision taking module. It takes the current light intensity with respect to the user reference, i.e. the brightness of the surrounding as felt by the user and rate of change of intensity as inputs. Output is obtained following the membership functions for the two, using which the light intensity of the bulb is decided. A rule base has been defined for taking decisions and producing outputs.Controller has been implemented in Matlab. We are using Matlab's Arduino module to control inputs and outputs.

The Fuzzy logic controller was chosen as the most appropriate controller for the lighting system because of its generalisation of light level settings, simplicity and auto control.This controller comprises of four basic components :

1. Fuzzification Interface : It converts input into suitable linguistic values using a membership function.
2. Knowledge Base Consists of a database with the necessary linguistic definitions and the control rule set.
3. Inference Engine: It simulates a human decision making process in order to infer the fuzzy control action from the knowledge of the control rules.
4. Defuzzification Interface: Converts an inferred fuzzy controller output, using a membership function, into non-fuzzy (definite or crisp) control action signal.

Final Model →

We can finally test the model over various inputs and then selecting the appropriate rules and number of rules required for the purpose. Finally the output is a crisp number based on the centroid defuzzification technique. Final defuzzification output can be given directly from Matlab to the arduino to trigger the dimmer circuit for further processing of the lamp intensity. The designed model should work properly independently. This model can be used as a fuzzy computation unit in our project.

Designing circuit for light intensity

Objective

Circuit design ideology is to control light intensity output from the bulb via dimmer circuit which included a single phase AC voltage regulator whose gating signal can be controlled by Arduino's digital output. The firing angle was programmed by Arduino using output from the fuzzy controller.

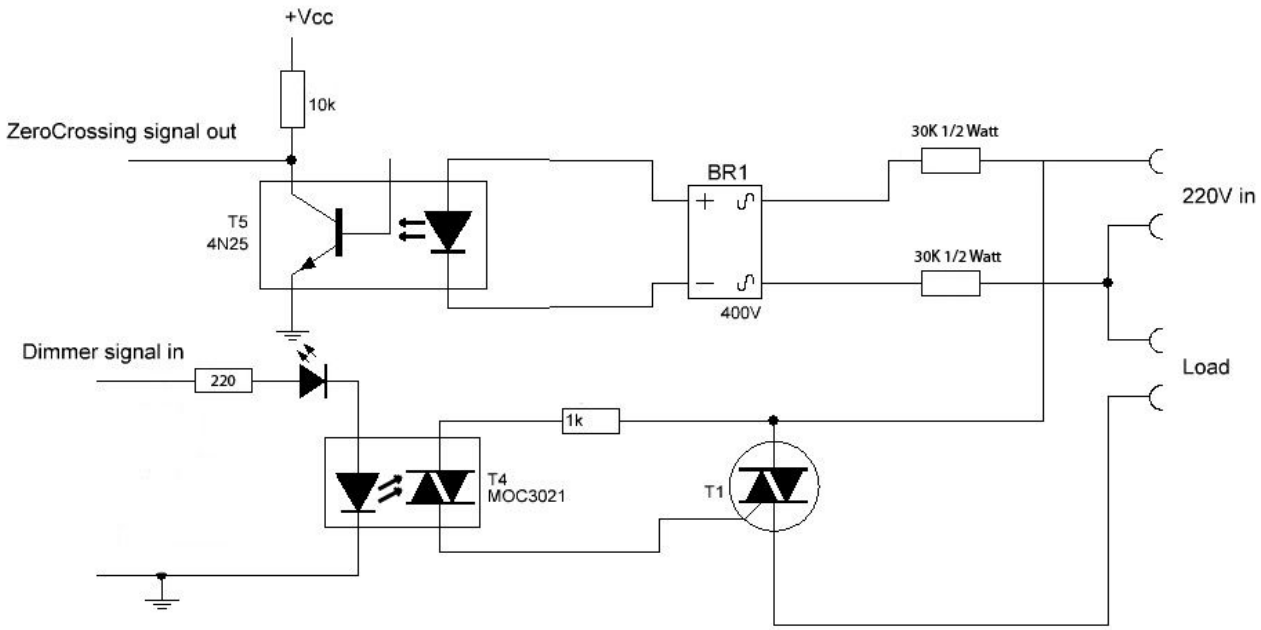
Dimmer Circuit Design

Dimmer Circuit design has two components → first, single phase A.C. regulator, whose output has been given to the bulb and second, the gating circuitry controlled by arduino getting interrupted by zero crossing signal.

The single phase A.C. regulator can be implemented using a triac in series with the supply. The output waveform of such a regulator is zero for the adjusted firing angle and then equal to the A.C. supply for rest of the half cycle. This is periodic for each half cycle. As the firing angle increases, the output rms voltage decreases. Thus, for more dimming, the firing angle is made further from 0° and more towards 180°.

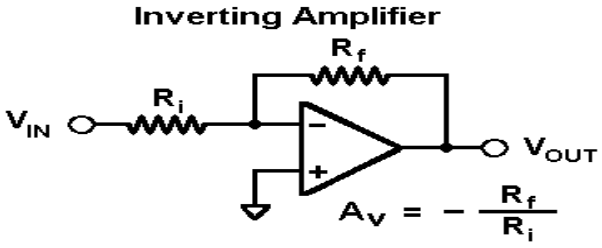
Zero crossing signal can be implemented by giving the output of a full wave bridge rectifier to an optocoupler with emitter grounded and the signal pulled from the collector. The output of full wave rectifier reaches zero to ground the base of optocoupler transistor thus open circuiting the pull up resistor attached to collector. This generates a short duration pulse at the collector which is used as the zero crossing signal. The time width of this pulse is dependent upon the minimum voltage level at which the optocoupler transistor reaches cutoff region.

This signal has been given as an rising edge interrupt to the arduino processor. The interrupt subroutine provides a delay (equivalent to the firing angle) set according to the fuzzy controller output. After the delay, an active high pulse of 10us from the digital output of arduino is used as the gating signal to the triac. This repeats for every half cycle of the A.C. supply.



Ambient Light Intensity Detection

We can use an opamp based intensity detection circuit for setting up the initial setting according to the current light intensity of the environment.We can use an OpAmp to design an inverting amplifier so as to give an output proportional to Rf/Ri, where Rf is a variable resistance that can give output according to the brightness of the environment.We can use an LDR for this purpose and Ri is a comparable fixed resistance.



User Input

Why User Input?

Imagine a particular use case scenario where a party is going on and the reference intensity of light in the hall is to be held low. The next day there might be an exam going on in that hall and we want the intensity of light to be moderately high for clear visibility of text on paper. In order for our fuzzy logic controller to adapt to these changing environment conditions, we need to take a user input about the current environment condition, so it can adjust its decisions accordingly.

Normal(Classical) home automation techniques only take either the user input or the sensor reading, to give the output. Here, in fuzzy based home automation, we use both, and using optimum membership functions, we produce the desired output.

How User Input?

User input can be achieved through the Blynk Mobile Application. Blynk provides a user friendly working interface wherein the user is entitled to give his desired inputs through the mobile app.

The Blynk application can act as an interface between the Arduino Uno, which contains the various sensor inputs, and the user. Any input given through the app can thereby generate the desired output on the hardware which in this case is a 100 W light bulb. We can thereby vary the intensity of the light bulb using Fuzzy logic control as well as by the user by giving mere inputs through the application.

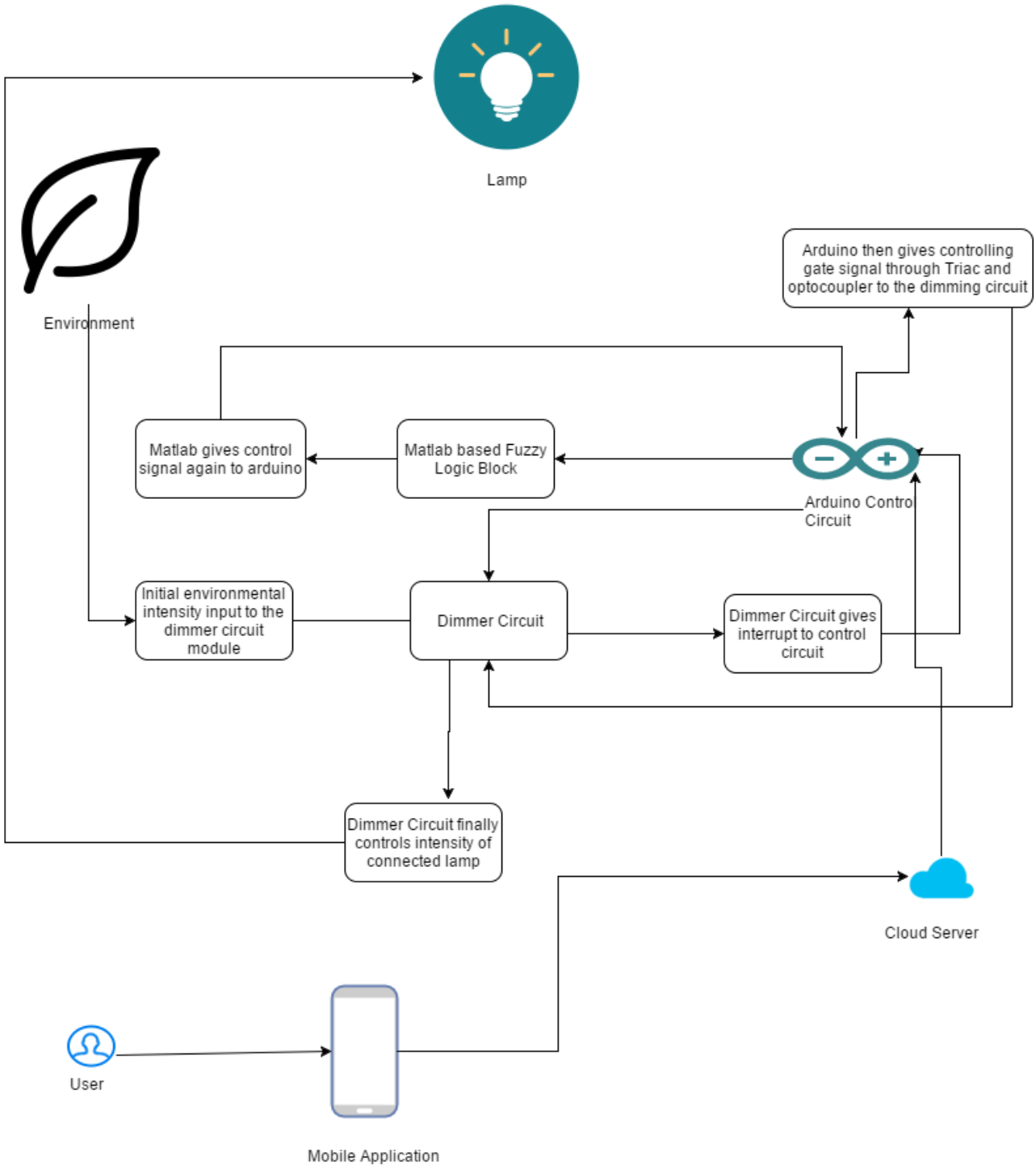
A more detailed explanation can be given as follows. The Fuzzy control is implemented through the use of matlab. The Matlab files are sent to the Arduino IDE and are decrypted in order to give inputs to the hardware for varying the intensity of the light bulb.This whole procedure can be thereby be interfaced to the user through the Blynk Application.

Arduino - MATLAB Interfacing

Fuzzy logic control can be implemented in Matlab. Matlab uses an extension package of arduino to control inputs and outputs from Arduino. Arduino sends sensor reading to the fuzzy controller(implemented in Matlab), which after the required processing, outputs the values. It also receives input from user and takes decisions accordingly.
Arduino opens a Serial port with the specified Baudrate(most commonly used is 9600). Matlab uses this serial to communicate with the Arduino board. Matlab creates an Arduino object for the connected Arduino board. Arduino puts the input data on the Serial stream, and Matlab reads the data from Serial, processes it, and generates output via the Arduino object.

Final Circuit and Interfacing

After we have completed all the individual modules, we connect them together as shown in this block diagram →



Complete Block Diagram

Applications

The very basic application of this project is that, here it is shown only on a light bulb but we can further incorporate it in other home appliances like fans,heaters,etc i.e. it can be extended as a complete home automation module involving fuzzy controller along with user input to be given from Blynk application.
Another application is that the present fuzzy controller is environment adaptive i.e. the fuzzy controller operates according to the environment,we can also improve it to make it user adaptive i.e the fuzzy controller will be operating differently with different users.
Another effective application can be incorporated in disco lights which can be controlled in intensity and colours respectively by input frequency.

Conclusion

We will control the intensity of an incandescent lamp of 100w using matlab based fuzzy logic model containing inference rules in the rule base. The inputs that we will use are current light intensity of the environment, change in intensity with respect to time, and the user desired intensity signal.We have successfully designed the Dimmer circuit using optocoupler and Triac. We are incorporating user input using Blynk application to give user required intensity control via slider widget of the Blynk.
We can combine Matlab with arduino IDE using Serial communication so that Fuzzy Logic based model can communicate with the remaining circuit.

The initial problem that we targeted was that current Home Automation devices available in the market are based on classical crisp logic i.e they give output as whether the light is to be switched on or not as seen in our department. With this type of control the efficiency of these lights will be improved by changing the power input to them smoothly and accordingly getting corresponding change in intensity. These devices which we will use in such control could only take user input as one of the parameters or would take decisions autonomously once started not allowing any further user interception. We will incorporate both the inputs and will design our fuzzy controller to adapt to these changing conditions.

Our device will target all the above issues that we have discussed till now in the report. It will adjust the initial setting of the slider according to the current environment brightness thereby maximizing power efficiency. Along with that, it uses fuzzy logic in our system so that it can also handle complex decision making processes. This technique can be extended to handle vague and ambiguous user inputs also. The dimmer technique that we will use implements opto couplers that are isolating the power circuit and the control circuit and along with that it is acting as a zero crossing circuit for giving interrupt to the arduino. We can conclude that our final output as a project will be a huge design update to classical light intensity controller.

References →

- http://www.iject.org/vol62/1/1-Paul-W-Mutua.pdf
- https://diyhacking.com/arduino-ldr-sensor/
- http://www.instructables.com/id/Arduino-controlled-light-dimmer-The-circuit/
- http://www.mecs-press.org/ijem/ijem-v5-n3/IJEM-V5-N3-2.pdf
- http://www.blynk.cc/
- https://in.mathworks.com/help/fuzzy/build-your-own-fuzzy-simulink-models.html
- https://in.mathworks.com/matlabcentral/fileexchange/55225-triac-block
- https://in.mathworks.com/help/physmod/elec/ref/optocoupler.html