Smart and Energy-Efficient Home Automation

DivyaJyoti Rajdev (085019)
Aman Chadha (085007)
Shruti Nirantar (085053)
Deeptha Narayan (D095069)
Smart and Energy-Efficient Home Automation

Project Group 3
Smart Home

• Smart homes make the residents' lives easier and more convenient.

• One can control the lighting, temperature, and entertainment from their couch.

• They provide energy efficient savings.

• Also, modules can be created for customised user environment.
Block Diagram

• The input is given in the form of gestures by the user.

• It is compared with the database of gestures to produce a match.

• Then, as per the recognised gesture, the appropriate action on the home appliance is performed.
Software Module

- End User
- Enrolment
- Training database
- Image and Motion Vector Matching
- Decision Device
- To Hardware Interface

Smart and Energy-Efficient Home Automation
Software Module

- The samples are enrolled in a training database for future reference.
- All test gestures are matched to the training samples.
- **Feature extraction** is used to detect and isolate the desired gesture.
- According to the gesture, the input is fed to the hardware module.
Hardware Module

From Software Interface

Level Shifter
MUX

Logic Unit

To different relays, relays are connected to actual components

Smart and Energy-Efficient Home Automation
Hardware Module

- The input is fed to a level shifter to make it compatible with the on-board hardware.

- The relay corresponding to the action is activated via a multiplexer.

- The end devices are the various appliances in a home.
2D GESTURE RECOGNITION
2-D Gesture Recognition

- A white opaque screen is used on which the gesture is drawn by the user.
- The gesture is captured by the camera placed on the other side of the screen.
- This gesture is further compared with the database to perform the required action.
Problem Formulation

- **SMART** ➔ High standards of living have encouraged automation to come to the forefront

- **ENERGY EFFICIENT** ➔ Environmental concerns have ensured that energy efficient housing models and appliances are used

Coupling the above two concepts, we obtain a **smart** and **energy-efficient** home model which can employ device control using **gestures**
Problem Formulation (Contd…)

- Everyday appliances such as AC, TV etc. can easily be controlled, say thanks to those remote controls!

- Jack is all tucked in his bed and suddenly he realizes he has forgotten to switch off the lights of the living room! **Now what?!**

And here lies the answer to our problem: **A centralized automation unit**
But Why Gestures?

- If a remote would have to be used to control the mainframe, then the entire purpose of the system is defeated.
- The answer to choosing gestures for this task lies beneath:
  - **Intuitiveness**
  - Interaction with the physical world
  - Moderate Efficiency

- **GESTURES**
But... Don’t We Already Have Techniques for this?

• Current techniques have numerous drawbacks:
  - Installation cost? GINORMOUS
  - Maintenance cost? FURTHER ADDS ON
  - Aimed at Common Folk? NOT AT ALL
  - Ported to all Appliances? NOT THAT EASY
  - Works good for Large Houses? POOR EFFICIENCY

V/S

• Proposed technique:
  - Implementation cost? MODERATE
  - Hardware? MINIMAL
  - Efficiency? ALGORITHM DEPENDENT
Pattern Recognition Algorithms

• Discrete Cosine Transform (DCT)
  - A well-known signal analysis tool used in compression due to its compact representation power
  - Similar to Discrete Fourier Transform (DFT), in the way that it transforms a signal from the spatial domain to the frequency domain
  - DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry
  - **Energy compaction**: ability to pack the energy of the spatial sequence into as few frequency coefficients as possible
  - **Specialized Application Domains:**
    - Image compression
    - Feature matching

• Discrete Sine Transform (DST)
  - DSTs are equivalent to DFTs of roughly twice the length, operating on real data with odd symmetry
  - **Specialized Application Domain:**
    - Solving partial differential equations by spectral methods
Pattern Recognition Algorithms

• Discrete Wavelet Transform (DWT)
  o DWT is a transform which provides the time-frequency representation
  o In DWT, an image can be analyzed by passing it through an analysis filter bank followed by decimation operation
  o The analysis filter consists of a low pass and high pass filter at each decomposition stage. Thus, filtering is performed
  o Upon being split into various sub-bands, the image is decomposed into low and high frequencies
  o **Specialized Application Domains:**
    • Image compression → JPEG2000

• Artificial Neural Network (ANN)
  o A computational model inspired by the structure and/or functional aspects of biological neural networks
  o A large diversity of training for real-world operation
  o **Specialized Application Domains:**
    • Classification → Pattern and sequence recognition
    • Data processing → Filtering and Compression

Smart and Energy-Efficient Home Automation

BE
EXTC
Pattern Recognition Algorithms

• **Hidden Markov Model (HMM)**
  - A statistical Markov model in which the system being modeled is assumed to be a Markov process with hidden states
  - Statisticians are comfortable with the theory behind Hidden Markov models
  - Freedom to manipulate the training and verification processes
  - Mathematical / theoretical analysis of the results and processes
  - HMMs are still very powerful modeling tools – far more powerful than most statistical methods
  - **Properties of HMMs:**
    - Modularity: HMM chains can be combined into larger HMMs
    - Transparency: People can read the model and make sense of it
  - Highly sought after and currently an ongoing topic for research
  - **Specialized Application Domains (Bioinformatics):**
    - Gene Finding
    - Protein Family Modeling
Image Processing

What is an image?

• An image is an array, or matrix of square pixels (picture elements) arranged in columns and rows.

• **Image processing** is any form of signal processing for which the input is an image; the output may be either an image or a set of characteristics or parameters related to the image.
Aspects Of Image Processing

• **Image enhancement**: This refers to processing an image so that the result is more suitable for a particular application.

• **Image restoration**: This may be considered as reversing the damage done to the image by known cause.

• **Image segmentation**: This involves subdividing an image into its constituents parts, or isolating certain aspects of an image.
Image Processing Using Matlab

Why MATLAB?

• **MATLAB** is a data analysis and visualization tool which has been designed with powerful support for matrices and matrix operations.

• It has excellent graphics capabilities, and its own powerful programming language.

• It has sets of programs designed to support a particular task; these sets of programs are called toolboxes.

• It supports a range of image formats including BMP, HDF, JPEG, PCX, TIFF, XWB etc.
Matlab Image Types

- Indexed images:

- Grayscale images:
• Binary images:

• RGB images:

Smart and Energy-Efficient Home Automation
## Data Types Supported by Matlab

Elements in MATLAB matrices may have a number of different numeric data types; the most common are listed as below.

<table>
<thead>
<tr>
<th>DATA TYPE</th>
<th>DESCRIPTION</th>
<th>RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>int8</td>
<td>8-bit integer</td>
<td>-128 to 127</td>
</tr>
<tr>
<td>uint8</td>
<td>8-bit unsigned integer</td>
<td>0 to 255</td>
</tr>
<tr>
<td>int16</td>
<td>16-bit integer</td>
<td>32768 to 32767</td>
</tr>
<tr>
<td>uint16</td>
<td>16-bit unsigned integer</td>
<td>0 to 65535</td>
</tr>
<tr>
<td>double</td>
<td>Double precision real number</td>
<td>Machine specific</td>
</tr>
</tbody>
</table>
Basic Commands In MATLAB

- **image** – create and display image object
- **imread(‘filename’)** - Reads the image into variable
- **imshow(g)** – display matrix g as image
- **size(a)** – returns the number of rows, columns and pages of a, which is a three dimensional array.
- **impixel(a,200,300)** – returns the red, green, and blue values of the pixel at column 200, row 300
- **iminfo(emu.tif)** – returns several information fields
Image Type Conversion

• **gray2ind** - intensity image to index image
• **im2bw** - image to binary
• **im2double** - image to double precision
• **im2uint8** - image to 8-bit unsigned integers
• **im2uint16** - image to 16-bit unsigned integers
• **ind2gray** - indexed image to intensity image
• **mat2gray** - matrix to intensity image
• **rgb2gray** - RGB image to grayscale(intensity)
• **rgb2ind** - RGB image to indexed image
Signal Flow

Software Module

Hardware Module

Start

Initialize camera

Input sample

Match consecutive samples

If match found

Transmit database code

If device A code

Switch on A

If device n code

Stop

If match found

YES

YES

NO
Implementation Algorithm

• **Stage I**
  o Take first sample image from user
  o After necessary normalization and resizing, enroll image in database
  o Calculate feature vectors from image
  o Save the matching parameters obtained above
  o Repeat process for all samples of all gestures under test
  o *Stage I creates the database that acts as a virtual lookup table*

• **Stage II**
  o Switch on and initialize appropriately both hardware and software modules
  o Obtain testing samples
  o Calculate feature vectors
  o Match with parameters stored during enrolment
  o Send result to decision device
    • If match exists transmit unique code word indicating its recipient device
    • If no match exists take next sample image and repeat above steps
  o Transfer control to hardware module
  o *Stage II is responsible for gesture recognition*
Implementation Algorithm (Contd...)

• Stage III
  o Decode the received device code using logic circuitry
  o Check device codes of interfaced devices for a match
    • If match exists command the device to perform designated function
    • If no match exists check next device code for a match
  o Repeat the above steps till the required device is parsed
  o Enter power saving or idle mode
  o Stage III accomplishes actual home automation using the code transmitted

For the algorithm to function as expected, there are a number of critical checkpoints that need to be taken into account
Critical Checkpoints

• **Gesture Selection**
  - Relatively distinct gestures to select various devices
  - Gestures used for the same class of objects i.e. light1, light2 etc. should have lesser variations
  - Meaningful gestures are formed by combining the following stationary gestures with movements

  • **Stationary Gestures**

Class I

Class II
Critical Checkpoints (Contd...)

- Gesture Selection (contd.)
  - Movements
    - Linear movement
    - Circular movement
    - U-like movement
    - L-like movement
    - J-like movement
    - Arm waving
    - Wrist waving
    - Wrist rotation

- Alternate Touchscreen approach

Motion

- Smart and Energy-Efficient Home Automation
Critical Checkpoints (Contd...)

- **Software Module**
  - The processing software must be compatible with the hardware chosen
    - **MATLAB** supports serial communication
    - This can be used to communicate with a **PIC** via serial port
    - Also, a **USB port** can be converted to virtual serial port for better portability
  - For ease of enrolment front hand gestures and backhand gestures must be considered the same
  - Sampling rate chosen should not lead to
    - Loss of information
    - Computational over load
  - Error in detecting the number of fingers can cause the program to fail thus erosion and dilation steps must yield accurate
  - **Motion trajectory** calculated must be accurate to recreate correct complex gesture for database matching
Critical Checkpoints (Contd...)

- **Hardware Module**

  After Recognition, the Automation is achieved as per the following flow diagram:

  Once the system is initialized as ON, the microcontroller waits for the codeword. Each codeword corresponds to a specific class and a specific device within that class.
Critical Checkpoints (Contd...)

- **Hardware Module (contd.)**
  - The circuit design must take into account the required current and voltage to drive each appliance.
  - All devices connected to the central unit must be isolated w.r.t. each other for damage control in case of any faults.
  - For critical applications like electric heaters etc., *time dependent tripping* mechanism must be functional.
  - The unit must be portable as *position dependent recognition* is employed.
  - Entire module must be fairly priced to accomplish the initial goal of achieving smart and energy efficient Home Automation for middle income families.
Thank You!

Questions are welcome.