Texas A&M University at Qatar

Electrical and Computer Engineering Program

ECEN 403

FSR Assignment

Project Title: AI-Social Robot for University assistant

Semester: Summer 2025

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Submit date: 21/06/2025

Table of Contents

1. Introduction

1.1 Purpose and Scope

The purpose of this report is to define the functional system requirements of the Educational Assistance Robot, a socially interactive platform designed to help students and visitors navigate the university campus environment. The system aims to facilitate student onboarding, accessibility, and campus engagement by providing personalized assistance through face recognition and voice-guided interactions.

The scope of this system includes facial detection and recognition, user data collection (name, grade, college type), personalized voice responses, and LED-based visual cues. The system must be cost-effective, safe for indoor use, respect user privacy, and be easy to operate by non-technical university staff. The system should also be modular to support upgrades and expansions, such as multilingual support or emotion recognition in future iterations.

1.2 Responsibility and Change Authority

The student design team holds primary responsibility for the definition, implementation, testing, and documentation of the system. All functional changes must be reviewed and approved by the supervising faculty member. Any changes during the development process are to be version-controlled, with updates tracked using an internal change log system. Stakeholders including academic supervisors and lab technicians are authorized to suggest and review change requests.

2. Applicable and Reference Documents

2.1 Design Standards

A. **IEEE 7001-2021**: Standard for transparency of autonomous systems, which guides ethical AI design.

B. **ISO 13482:2014**: Safety requirements for service robots used in personal care applications.

C. **IEEE 1028-2008**: Procedures for software reviews and audits.

D. **IEEE 1621**: Defines user interface standards for system status and user feedback indicators.

E. **IEEE 1872**: Ontologies for Robotics and Automation, relevant for defining behavior semantics.

2.2 Reference Documents

A. Arduino Mega 2560 technical datasheet

B. Dlib & OpenCV library documentation for facial detection

C. SQLite database system reference

D. OpenAI GPT API (for future-proof optional integration)

E. DFPlayer Mini MP3 module datasheet

F. University campus map for defining location-based responses

G. Python Speech Libraries (pyttsx3, speech_recognition)

3. Requirements

3.1 System Definition and Characteristics

The system is a stationary, microcontroller-based robot embedded with a camera, speakers, LED array, and control software written in Python. It connects to a laptop for real-time data processing and interacts with students by recognizing faces, storing session information, and providing direction-based voice feedback. The Arduino Mega controls LED outputs and serves as a bridge between software and hardware interactions.

Key characteristics:

A. Stationary mount (tabletop or kiosk)
B. Operates entirely offline to ensure privacy
C. Built-in SQLite database for session tracking
D. Real-time audio prompts and LED status feedback
E. Plug-and-play capability with clear startup diagnostics

3.2 Functional Requirements

A. Detect and recognize faces using a webcam with OpenCV within 2 seconds

Rationale**:** A 2-second detection time ensures users are not left waiting, improving responsiveness and user satisfaction

B. Use Dlib-based facial embeddings for robust recognition
C. Prompt user for name, grade, and college type if unrecognized
D. Deliver audio responses from pre-recorded or synthesized voice libraries
E. Log session data locally for time-stamped feedback analysis

F. Trigger LED animations based on interaction state (e.g., thinking, speaking)

Rationale**:** Visual cues improve accessibility and help users understand system states (e.g., thinking, processing, responding)

G. Modular code to allow external APIs or mobile apps in future upgrades

3.3 Physical Characteristics

A. Dimensions: 30 cm (L) × 20 cm (W) × 20 cm (H)
B. Housing: Clear acrylic box with ventilation holes and cutouts for camera, LED matrix, and speaker
C. Camera: USB HD Webcam with tilt support
D. Speaker: 5W 8 Ohm mounted inside casing, directed forward
E. Eye display: RGB LEDs or Matrix capable of showing expression states
F. Accessibility: Removable rear panel for maintenance

3.4 Electrical Characteristics

A. Input Voltage: 12V/2A via wall adapter
B. DC-DC converters regulate power to 5V and 9V outputs
C. Arduino Mega (5V), Camera (USB-powered), LEDs (5V), and DFPlayer (5V)
D. Power Protection: Diode-based polarity protection and resettable fuse

Rationale**:** Diode-based polarity protection and resettable fuses help prevent electrical damage and improve system reliability during unexpected power issues

E. Max Operating Power: <10W total system draw

Rationale**:** A <10W power draw ensures the system remains energy efficient and safe for continuous use indoors

F. Cable Management: Routed internally using modular connectors

3.5 Environmental Requirements

A. Deployment: Indoor only

B. Operating Temp: 10–40°C

C. Humidity: 20–80% RH, non-condensing

D. Avoid direct sunlight or water exposure

E. Acoustics: Speaker must remain functional up to 60 dB background noise

F. EM Interference: Shielded cables to avoid USB interference

3.6 Failure Propagation

A. If the webcam fails to initialize, an error message will be logged and LED lights will flash red
B. If face recognition fails, the system will prompt the user to try again
C. If audio output fails, LED patterns will substitute to indicate system status

Rationale**:** Early error detection allows the user to take immediate corrective actions, improving system reliability

4. Support Requirements

4.1 Software Support:

A. Python modules maintained in GitHub with version tagging

B. Commented scripts and configuration files

C. Integrated logging system for user interactions

D. Capability to switch between offline TTS and recorded prompts

4.2 Hardware Support:

A. Components sourced from verified suppliers (Amazon, local electronics)
B. Schematic diagrams, pinout tables, and assembly photos documented
C. Spare parts list included for field maintenance

4.3 Training & Documentation:

A. Illustrated setup guide and startup script
B. System Reset procedures and safety warnings
C. Video tutorials for common troubleshooting scenarios

4.4 Testing & Diagnostics:

A. Built-in self-test: LEDs cycle, voice check, camera frame check
B. Error log for detecting device failures (e.g., camera offline)
C. Calibration mode for voice volume and LED timing adjustments
D. Debug USB port for serial monitoring during development

5. References

1. F. Schroff et al., "FaceNet: A Unified Embedding for Face Recognition," CVPR, 2015.
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7. SQLite Project Documentation, https://sqlite.org/docs.html
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9. DFPlayer Mini MP3 Module Datasheet
10. Python Speech Libraries
11. University Campus Layout Reference Maps