

## Technical Note

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# LEGO Mindstorms NXT for elderly and visually impaired people in need: A platform

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**Abstract.** This paper presents the employment of LEGO Mindstorms NXT robotics as core component of low cost multidisciplinary platform for assisting elderly and visually impaired people.

LEGO Mindstorms system offers a plug-and-play programmable robotics toolkit, incorporating construction guides, microcontrollers and sensors, all connected via a comprehensive programming language. It facilitates, without special training and at low cost, the use of such device for interpersonal communication and for handling multiple tasks required for elderly and visually impaired people in-need.

The research project provides a model for larger-scale implementation, tackling the issues of creating additional functions in order to assist people in-need. The new functions were built and programmed using MATLAB through a user friendly Graphical User Interface (GUI). Power consumption problem, besides the integration of WiFi connection has been resolved, incorporating GPS application on smart phones enhanced the guiding and tracking functions.

We believe that developing and expanding the system to encompass a range of applications beyond the initial design schematics to ease conducting a limited number of pre-described protocols.

However, the beneficiaries for the proposed research would be limited to elderly people who require assistance within their household as assistive-robot to facilitate a low-cost solution for a highly demanding health circumstance.

Keywords: LEGO Mindstorms NXT, elderly, visually impaired, MATLAB, healthcare

## 1. Background

The past few years, Robots were successfully adapted in various events such as hospitals, industrial plants, buildings, and even houses, where they perform cleaning services, deliver, educate, or entertain [1–4].

The recent developments in the field robotics focus on guiding blind people robots, as well as elderly's aids-robots. Today, the number of elderly in need of care is increasing dramatically [5]. As the baby-boomer generation approaches retirement age, this number will increase significantly. Current living

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conditions for the majority of elderly people are already unsatisfactory, and the situation will worsen in the future [6].

Rapid progress of standard of living and health care resulted in the increase of aging population [7,8]. More and more elderly people do not receive good care from their family or caregivers. Maybe the intelligent service robots can assist people in their daily living activities. Robotics aids for the elderly have been developed, but many of these robotics aids are mechanical aids [3,5,9]. The intelligent service robot can assist elderly people with many tasks, such as remembering to take medicine or measure blood pressure on time [10,11].

Overall significant research has been made relating to assisted-living facilities in the field of elderly people and visually impaired patients [6,12–14]. According to Clover et al., the modified device uses localization software suite to give room-by-room directions in an indoor environment. In addition, it is based on a commercial walker frame that offers a stable non-robotic walker during normal ambulation in order to reduce fall risk [15].

Another researchers working on improving the assisted living facilities' performance based on robotic system design in order to tailor the functionalities of the robot such as behavior, navigation, exploration, localization, mapping and perception [16].

The state-of-the art of a large-scale project, aimed towards the development of assisted-living robots for the elderly people challenging, not only a highly facilities but also looking after the needs range of challenges that faced by society. For these reasons, using natural language, the need for a robot provides information related to activities of daily living obtained from different resources is crucial for development and foundation of such a robotics [6,17].

According to the current state of research, several groups of researchers have launched diverse types of intelligent internet service, in order to accelerate research through telecommunication revolution [18]. A modular, platform-based, approach is the way to obtain this result [19]. These services created new types of research called "smart house systems" [1,4,11,20].

The most common assistive-living system uses rapid prototyping, it is a key aspect for the development of innovative robotic applications. Bonarini et. al. anticipated new approach that should be invested in development of a new robot based on implementation of a physical, working prototype to test the application idea [21]. Nevertheless, they suggested new frameworks to implement real-time, high-quality architectures for robotic systems with off-the-shelf basic modules (e.g., sensors, actuators, and controllers), integrating hardware and software, used in assembled in a plug-and-play way that can substantially reduce costs to design new robotic products [21].

Other studies revealed noticeable problems described by the end-user. The target group of these assistive-living systems is elderly people whom do not have an extra time to learn new technologies. To overcome such a difficulties, children can be a key solution in this concern. Several researcher groups have implemented the use of LEGO NXT Mindstorms as a medium of teaching robotics in order to facilitate an active learning environment, interpersonal communication and programming skills [14,22–27].

## 2. Objective

The principal objective of assisting two groups of people, elderly and visually impaired people in their daily-life activities, especially tracking and monitoring elder people within their households, such as medication-dose reminder. In addition, guiding visually impaired by means of using LEGO Mindstorms NXT instead of guide-dog.

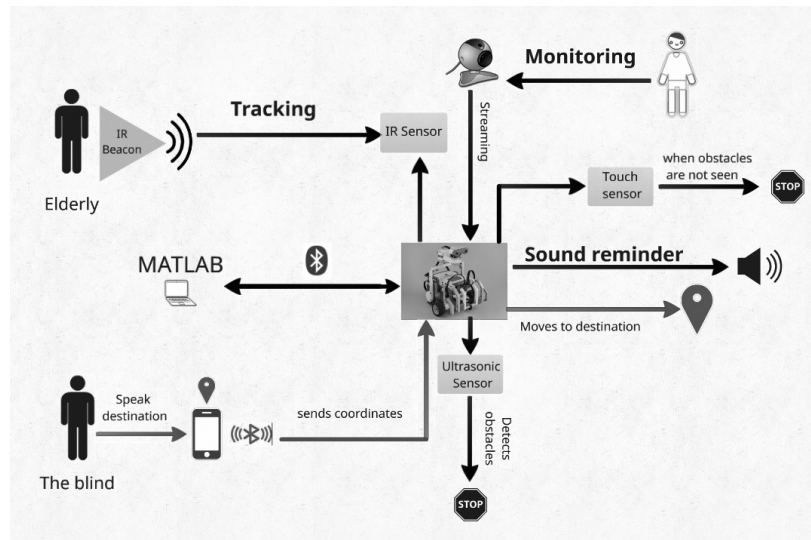


Fig. 1. Block diagram of desired LEGO Mindstorms functions.

One of our proposed applications is to facilitate the NXT for health monitoring of elderly and visually impaired people, to be remotely assistive robot in a convenient manner, providing a user-friendly software-programming interface and an easily configurable approach to instrument design.

Additionally developing and expanding the system to encompass a range of applications beyond the initial design schematics to enable people to conduct a limited number of pre-described protocols.

NXT is a programmable robotics kit developed by Lego. It was released in 2009 and is made up of various Lego bricks and Lego technical pieces [28]. NXT has an intelligent, computer-controlled LEGO brick, a 32-bit microprocessor furthermore, it is compatible with a variety of programming languages (e.g., MATLAB, NXT G, RobotC, LabVIEW and Java) and offers alternatives for building simple shapes and structures. The LEGO NXT has been selected for this study due to its robustness and easiness for engineering students use.

### 3. Methodology

Helping elderly and visually impaired people in their daily life, new functions (i.e., reminding, tracking, guiding and monitoring) have been built and programmed to be compatible with the custom used NXT robot. A block diagram that summarizes developed functions is depicted in Fig. 1.

MATLAB was implemented as a programming language of functions algorithms. Developed algorithms were designed in a flexible way to allow implementing of targeted functions together or independently through a user friendly Graphical User Interface (GUI).

Figure 2 illustrates a robot car design to ensure enough space on the NXT body for targeted functions, both ultrasonic and infrared sensors have been placed on a servomotor of the NXT in order to rotate centrally to get the widest range possible for reading values.

The other components such as RPi was placed in the middle of the NXT and above the brick to keep it protected as it is a fragile board. The RPi camera is mounted on top of the NXT in an inclined angle as the tracked subject would be best monitored in that angle.

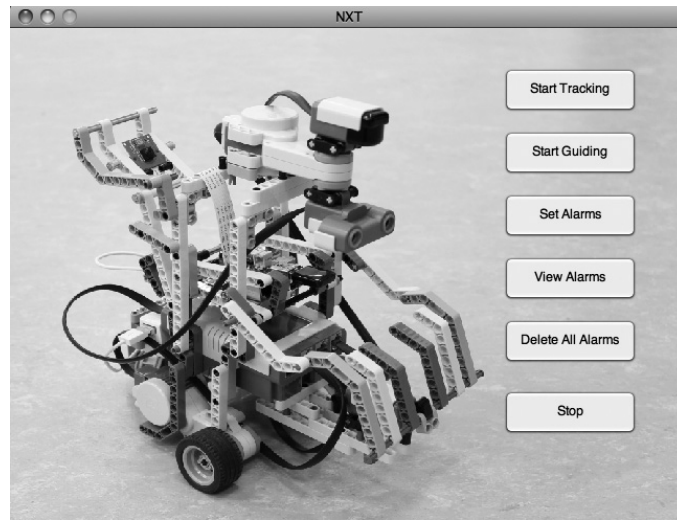


Fig. 2. LEGO Mindstorms car robot GUI.

Finally, a bumper with the touch sensor was added to the front end of the NXT aiming to take any hits in case the NXT ran into obstacles that ultrasonic sensor could not detect to avoid any possible damaging to any other part in the NXT.

In our work, few additional functions were developed on the way to match the objectives of this research. One of these functions is a reminder, it is based on a Matlab GUI alarm code that allows users to insert desired reminder options.

Another important function was employed such as tracking function in order to adjust the position of NXT robot to be within a short distance from targeted person. This has been achieved using Infrared (IR) light receiver and emitter circuits that consists of IR sensor and transmitter (IR beacons), the IR beacons can be used as navigational aids for the autonomous operation of a robot.

In our research, three different IR beacons, HiTechnic IR Beacon (FTCBCN), HiTechnic 360 (HBK2100) and self-made Arduino-based (ATtiny85 microcontroller) IR beacons were tested.

The circuit was built using an ATtiny85 microcontroller and four IR LEDs, the microcontroller was programmed to give 1200 Hz PWM (Pulse Width Modulation).

Furthermore, remote monitoring function is a live video streaming system added to the NXT body. It consists of a Raspberry Pi (RPI) board with a WiFi adapter and an RPi camera. The RPi operating system was chosen and installed on the Pi. An external laptop was used for the first installation steps and then for adjusting the RPi to get a static IP address in order to be able to securely access the RPi over an insecure network [29]. After that, the RPi was connected to the WiFi by installing the software package and examined [21].

The RPi camera was connected to the board and enabled by sending commands. The motion JPEG or MJPEG streaming protocol was used [30], in order to download the picture directly to the MJPG streamer on web browser.

Guiding function is very crucial in this research and has been used for visually impaired people. An android application was used that enables the longitudes and latitudes for the two points of this route, followed by MATLAB processing to enable the robot movement in the desired path.

Haversine formula was used to calculate the designated distance, it is an important equation in navigation to calculate the shortest great-circle distance over the earth's surface for given longitudes and

latitudes [31]. Moreover, the angles are essential to initiate movement, due to lack of GPS property in NXT, initially they need to be converted to radians using MATLAB, then accompanied with distance to move robot from one point to another [32].

Although, in our project we developed few more functions in the GUI using MATLAB to enable alarms setting and run the NXT and stop it whenever needed.

#### 4. Results and discussion

As the system was designed to help elderly people and visual impaired ones, four functions has been designed and tested, the desired goals efficiently achieved. By using NXT robot and its technology, the elderly people have an accurate reminder for their medicine time and other medical purpose. In addition, it tracks their movement for protection through monitoring their activities by sending videos to their family and/or medical supervisor and even more, it helps the visual impaired people during movement from one position to another.

In tracking function, the system that was used in previous researches and works was an external clock of 16 MHz for the chip ATtiny85 and resistor with value of 7.4 K $\Omega$ . In this project, a usage of internal clock of 8 MHz and a resistor with 36  $\Omega$  was much effective, at which makes less hardware on the board, also in this function.

The NXT Motor Class that has been used to send commands to the NXT's servomotors, responsible for moving the NXT, cannot handle more than one command at a time. During testing, problems of skipping commands were faced as well as wrong directions read. Those problems were solved by adding stop, wait and pause functions after each motor class function, to give each function enough time to fully execute before starting the next one.

In remote monitoring function, video streaming was not as smooth as desired, because of time delay during saving images in SD-card then MPGJ-streamer reads it from card, resulting low number of frames per second uploaded. It is much better to get pictures directly from camera to mjpg-streamer, without detour over SD card. In addition, the disadvantage of RPi camera is that in case internet connection was lost, a reboot of the RPi is needed due to RPi camera freezing.

Guiding function is still in progress. However, the tested function on MATLAB worked quite well. The enhancement of the guiding function has been achieved via using ultrasonic sensor that detects obstacles and avoids them. It was found that it is hard to avoid obstacles while moving in streets.

Different limitations rose up during testing, one of these limitations is the power consumption of both NXT as well as RPi board. Another limitation is due IR sensor range, therefore, IR beacon needs always to be in a precise position for IR sensor to detect it. Moreover, as the subject moves, IR LEDs would slightly change position making it even harder for IR sensor to detect IR signal.

Bluetooth coverage causes the computer-running MATLAB always to be within a short distance of the NXT, integrating the NXT with WiFi connection instead of Bluetooth enabled faster coverage for data transmission. In addition to the small size of flash memory of NXT, prevents function of being uploaded on the NXT brick to run independently of MATLAB.

#### 5. Conclusion

The research project holds a promising future as a model for larger-scale implementation. Tackling the issue of power consumption by means of using generator to the rechargeable batteries. Besides,



integration between the NXT with WiFi connection instead of Bluetooth to enable faster coverage for data transmission. In addition, using GPS application on smart phones can improve guiding function including voice recognition to visually impaired person to speak the desired destination, which in turns draw a route between two points and generate GPS coordinates of the waypoints of this route in order to provide them for MATLAB.

Finally, we anticipate that NXT robot can be effectively used as an assistive tool for elderly people in their households, since it can provide them a reliable, low-cost, and user-friendly instrument compare to the commercial available robots.

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