

Neuron - Humanoid Robot

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ABSTRACT

This paper presents the development process of a humanoid robot that I named Neuron. The report describes the step-by-step creation of the mechanical, electronic, and software components, all designed and implemented by the author without external assistance. The robot is capable of bilingual communication (Bulgarian and English) and can reproduce human-like gestures such as blinking, nodding, and complex eye movements.

Neuron has been conceived as an interactive and intelligent system, capable of perceiving its environment, recognizing objects and faces in real time, and responding accordingly. The prototype demonstrates how artificial intelligence can be embodied in a humanoid form that is not only functional but also expressive. Beyond its current state, the system can be adapted and fine-tuned to specialize in various domains—for instance, as an educational assistant, a healthcare support tool, or a guide in public spaces.

The originality of the project lies in the fact that every stage of the prototype's development - from conceptual sketches, through CAD modelling and mechanical prototyping, to coding the AI modules—was carried out independently. This ensures that Neuron represents not just a technical demonstration, but also a proof of concept that complex humanoid robotics can be approached by individual researchers with limited resources.

Keywords: humanoid robot, step-by-step integration of mechanical, electronic, and software components.

INTRODUCTION

The topic of this report was chosen due to the growing global interest in robotics and artificial intelligence (AI) in today's rapidly evolving technological landscape. Humanoid robots are

attracting attention because they represent not only a convergence of engineering disciplines but also a vision of future interaction between humans and machines.

The Neuron project was conceived with the aim of demonstrating the practical potential of

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AI in humanoid robotics. At its current stage, the prototype exists primarily as a robotic head, yet it is already capable of executing complex movements and communicating with people in two languages - Bulgarian and English. These early results point to the broader ambition of the project: the creation of an interactive and multifunctional humanoid system that could eventually find applications in education, healthcare, entertainment, and public services.

Work on Neuron began in early 2024. The first functional version of the prototype was showcased on 22 June 2024 in Sofia during the XII National Competition “Young Researchers”, organized by the Minyu Balkanski Foundation in partnership with Bulgarian School and sponsored by Overgas. The event provided a valuable opportunity to present Neuron to a professional audience, where its innovative combination of mechanics, electronics, and AI attracted significant interest.

By choosing this topic, the project aligns itself with global trends that seek to make robotics more accessible, adaptable, and socially relevant. Neuron is not merely a technical experiment, but an example of how an independent initiative can contribute to the larger field of human-robot interaction research.

EXPERIMENTAL

To achieve the project’s objectives and to realize the initial prototype of the humanoid robot head *Neuron*, a structured workflow was followed. The development process combined both engineering practices and software design techniques, which together ensured a coherent integration of all subsystems. The main methods employed were as follows:

- Survey of existing solutions for mechanical design - An extensive review of available humanoid eye and head mechanisms was carried out, drawing from academic papers, open-source projects, and online resources. This

step provided an understanding of different design philosophies and allowed the identification of advantages and limitations in existing approaches.

- Computer - Aided Design (CAD) using Fusion 360 - The mechanical components of Neuron were modelled in Fusion 360. The CAD environment enabled precise adaptation of dimensions, testing of kinematic constraints, and evaluation of durability under simulated loads.

- Prototyping of polymer components through 3D printing - Key structural parts, including the eye sockets, eyelid mechanisms, and face elements, were manufactured using a 3D printer. Polymers such as PLA and PETG were selected for their balance of durability, weight, and ease of prototyping. This method allowed for rapid iterations and low-cost experimentation.

- Fabrication of metallic components - Load-bearing and joint elements were produced in metal to improve structural stability. These included parts of the neck mechanism and frame connections, where plastic alone was insufficient for long-term mechanical reliability.

- Software development and integration - The control software was implemented in Python, divided into specialized modules: (i) motor control, (ii) speech recognition and synthesis, (iii) vision-based recognition of faces and objects, and (iv) dialogue generation via GPT-based models. This modular approach ensured that different subsystems could be tested independently before integration.

RESULTS AND DISCUSSION

The head of the humanoid robot Neuron was developed through the step-by-step integration of mechanical, electronic, and software components. The process began with the design and construction of the eye mechanism (Fig. 1). Although inspired by existing solutions found online, the design was fully adapted, redrawn, and dimensioned independently to meet the specific requirements of the project. The eyeballs were

crafted from epoxy resin, providing a realistic and lifelike appearance (Fig. 2).

Once the eye mechanism was completed, attention turned to the construction of the rest of the head. The internal structure incorporated cooling elements for the Raspberry Pi 5 [1], which serves as the robot's "central brain," as well as dedicated space for additional microcontrollers. Following this, the neck mechanism was designed. The first version of Neuron relied on two servo motors, which proved insufficiently stable (Fig. 3). To address this limitation, a second version was introduced, consisting of three servo motors combined with a joint system (Fig. 4). While this improved stability and durability, it still highlighted the challenges of replicating the

flexibility of human neck movement (Fig. 5).

After completing the head and neck assemblies, a supporting frame was built to house the structure. A CAD model was first prepared, after which aluminium profiles were cut and assembled. The resulting frame demonstrated excellent rigidity, providing a solid foundation for the continued development of the robot.

With the mechanical construction finalized, electronic wiring was carried out. For the vision system, a recycled webcam was repurposed, emphasizing the project's sustainability by reusing existing components while maintaining sufficient image quality for real-time recognition tasks.

The software architecture (Fig. 6) of Neuron

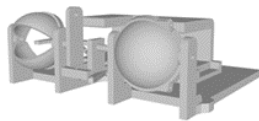


Fig. 1. Simple eye mechanism.



Fig. 2. Creation of the eyeballs.



Fig. 3. Display of Neuron's first version.



Fig. 4. Picture of Neuron after assembly.

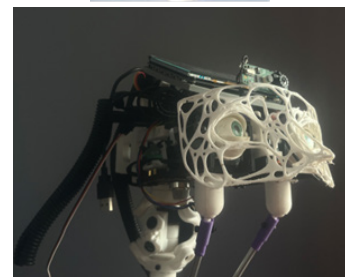


Fig. 5. Neck joint.

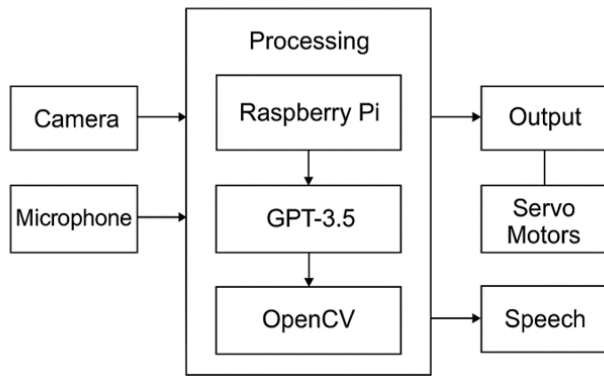


Fig. 6. Software architecture.

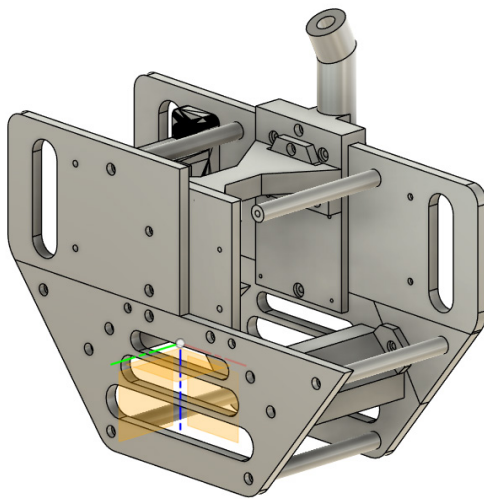


Fig. 7. Working model at the stage of building the robot's torso.

was implemented entirely in Python, structured into modular programs to ensure clarity and maintainability:

- Dialogue module - integration of GPT-3.5 Turbo for generating conversations [3]. This model was selected due to its strong performance and cost-effectiveness.
- Motor control module - responsible for servo actuation, controlling the movements of eyes, eyelids, and the neck.
- Speech processing module - enables speech recognition and synthesis for real-time

verbal interaction.

- Main controller - combines all other modules and governs the overall robot behaviour.

For computer vision, the OpenCV library was employed, allowing Neuron to detect and recognize both objects and faces in real time. This functionality grants the robot the ability to engage in interactive behaviour that is not purely verbal but also context-aware through its visual perception [2].

Looking forward, the system is designed to be extensible. Upgrading to higher-quality components and enhancing both the mechanical and software subsystems would be straightforward thanks to the modular structure. This foundation supports future expansions such as the integration of arms and advanced facial expressions.

Currently, Neuron's head can perform a variety of human-like gestures: blinking, nodding, eye rotation, and basic mimicry. By combining these motions with its speech and vision capabilities, the robot can interact with people both verbally and physically. In practice, this means that Neuron can answer questions, hold simple conversations in Bulgarian and English, and respond to visual stimuli such as recognizing the presence of a person or object.

CONCLUSIONS

The development of the humanoid robot head Neuron represents a successful prototype that demonstrates the integration of artificial intelligence into the field of humanoid robotics. Even in its current form, limited to a robotic head, the project highlights the potential of combining mechanical design, electronics, and software into an interactive system capable of speech, vision, and expressive movement.

Future work will focus on expanding the project beyond the head to include a complete humanoid body. This extension will allow Neuron to perform more complex actions, such as coordinated gestures, locomotion, and

task-oriented physical interaction with people. By introducing arms, legs, and a torso (Fig. 7), the robot will be able to serve as a more versatile platform for both research and practical applications. Beyond its current state, the system can be adapted and fine-tuned to specialize in various domains - for instance, as an educational assistant, a healthcare support tool, or a guide in public spaces [4].

In addition, improvements are envisioned in the areas of emotional recognition and multilingual communication. Enhancing the robot's ability to identify and respond to human emotions would allow for more natural and empathetic interaction, a crucial feature in applications such as education and healthcare. Expanding language support beyond Bulgarian and English would increase accessibility and enable Neuron to communicate effectively with a broader range of users.

Ultimately, the Neuron project illustrates how a modular and scalable approach can serve as a foundation for future humanoid systems. What began as an independent initiative has the potential to evolve into a robust research platform and educational tool, inspiring the next generation of engineers and AI specialists.

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