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FEUP FACULDADE DE ENGENHARIA
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Interactive Digital Systems

Masters in Multimedia 2024/2025

Tic-Tac-Toe
Gesture Your Way to Victory

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Content

Context of the Work

This work has been developed as part of the Interactive Digital Systems course and centers on the creation of a digital interactive system that incorporates computer vision components and generative visuals. The predominant goal of the system is to explore new forms of interaction through gesture recognition, encouraging users to engage with a computer device. Given the freedom to pick the theme of the project, taking a classic game like tic-tac-toe and adding a twist seemed like a good way to incorporate computer vision rather than relying on the traditional controllers.

The system uses computer vision techniques, such as hand-pose detection, to allow players to control the game intuitively by opening and closing their hands in front of a camera. The system interpretes this gestures as game moves by detecting key points on the hand, integrating physical movements with digital actions. This process follows the Bonger's interactive framework loop, which involves a repeated process of input, processing, output, and feedback.

Regarding real-world application, this type of gesture-based interaction has potential benefits in areas such as rehabilitation and physiotherapy. Similar systems could be used to help patients improve their hand mobility and coordination after an injury by turning physical therapy exercises into engaging and interactive experiences.

In terms of generative visuals, the system's interface dynamically generates visual feedback based on the user input. The board is updated in real time, displaying either the player's move or the AI's calculated response, creating a fluid and responsive interaction.

This is emphasized by the fact that the game's state is not predetermined but continuously evolving based on the player's gesture and the game's logic. This aligns with the concept of generative systems, where the visuals respond directly to user input.

Additionally, this gesture-based interface promotes sustainability by eliminating the need for paper-based tracking, which would be required in traditional forms of physical games. By doing this, the system demonstrates a move towards more sustainable interaction technologies.

The system is designed with inclusivity in mind, offering a way for users of all abilities to interact with a game environment that requires minimal physical contact, which can be especially beneficial for users with limited mobility. The intuitive nature of gesture controls opens up new possibilities for accessible gaming experiences. This allows a broader audience to engage in interactive digital systems without needing to manipulate physical devices.

In conclusion, this project aligns computer vision and AI technology while considering inclusivity, sustainability, and practical applications in fields like rehabilitation. The system demonstrates the potential of gesture-based interaction to offer more natural, accessible, and environmentally conscious forms of digital engagement.

Related work and artists

Gesture-based Interactive System

- **Tris with Computer Vision:** Hybrid approach that integrates physical interaction with a computer vision system to recognize symbols drawn on a paper. The languages used were Python and OpenCV to capture images of the physical board with a webcam.

- **Handy Tic Tac Toe AI:** Tic Tac Toe game that can be played using hand gestures. Uses OpenCV and MediaPipe for hand gesture recognition. The AI algorithm used was Alpha-Beta Pruning to determine the optimal moves for the computer.

Frameworks and Libraries

- **p5.js:** An open-source JavaScript library that makes creative coding accessible. Is widely used in interactive art, creative coding, and digital games. In this project, it was mainly used for rendering the visuals, like the tic-tac-toe board and the marks.

- **ml5.js:** An open-source library that makes machine learning approachable for artists, creative coders, and students. Has the ability to run predetermined models for interaction that can classify images, identify body poses, and, among others, hand positions. In this project, it was used for hand detection, specifically its HandPose model. This library enabled it to detect hand gestures without needing advanced machine learning expertise, thus playing a vital role in this project.

Physiotherapy through Gestural Interfaces

In recent years, computer vision has been increasingly explored for its potential applications in rehabilitation systems, especially for patients with motor impairments. Gesture-based interaction systems, like the one in this project, offer a promising way to engage users in activities that promote motor skills and hand mobility, similar to what is observed in rehabilitation exercises.

Several studies have explored the integration of computer vision in hand rehabilitation. For instance, a paper on computerized hand rehabilitation discusses the development of systems that use computer vision methods, like hand-tracking and finger-detection techniques, to assist patients in performing rehabilitation exercises.

These exercises are designed to improve mobility and reduce pain, aligning with the gesture recognition in this project, where hand movements are detected and translated into game actions.

Another study suggests a computer vision-based hand rehabilitation designed for post-stroke patients. This system employs MediaPipe Hands, hand and finger tracking technology to offer virtual assessments of motor skills that can be done at home.

While it is not specifically aimed at medical rehabilitation, the use of hand gesture detection shares similarities with this work, demonstrating how interactive systems can be adapted for both gaming and therapeutic goals.

By applying similar techniques to a game like Tic-Tac-Toe, this project exemplifies how gesture-based systems can have wider applications, potentially even contributing to the physioterapy of hand mobility through enganging activities.

Reduced Paper Used

The shift of traditional activities to digital platforms reduces papaer consumption. In areas such as education and gaming, digital tools like this project provide an eco-friendly alternative to physical paper, helping reduce waste and encouraging more sustainable practices.

Technical Architecture

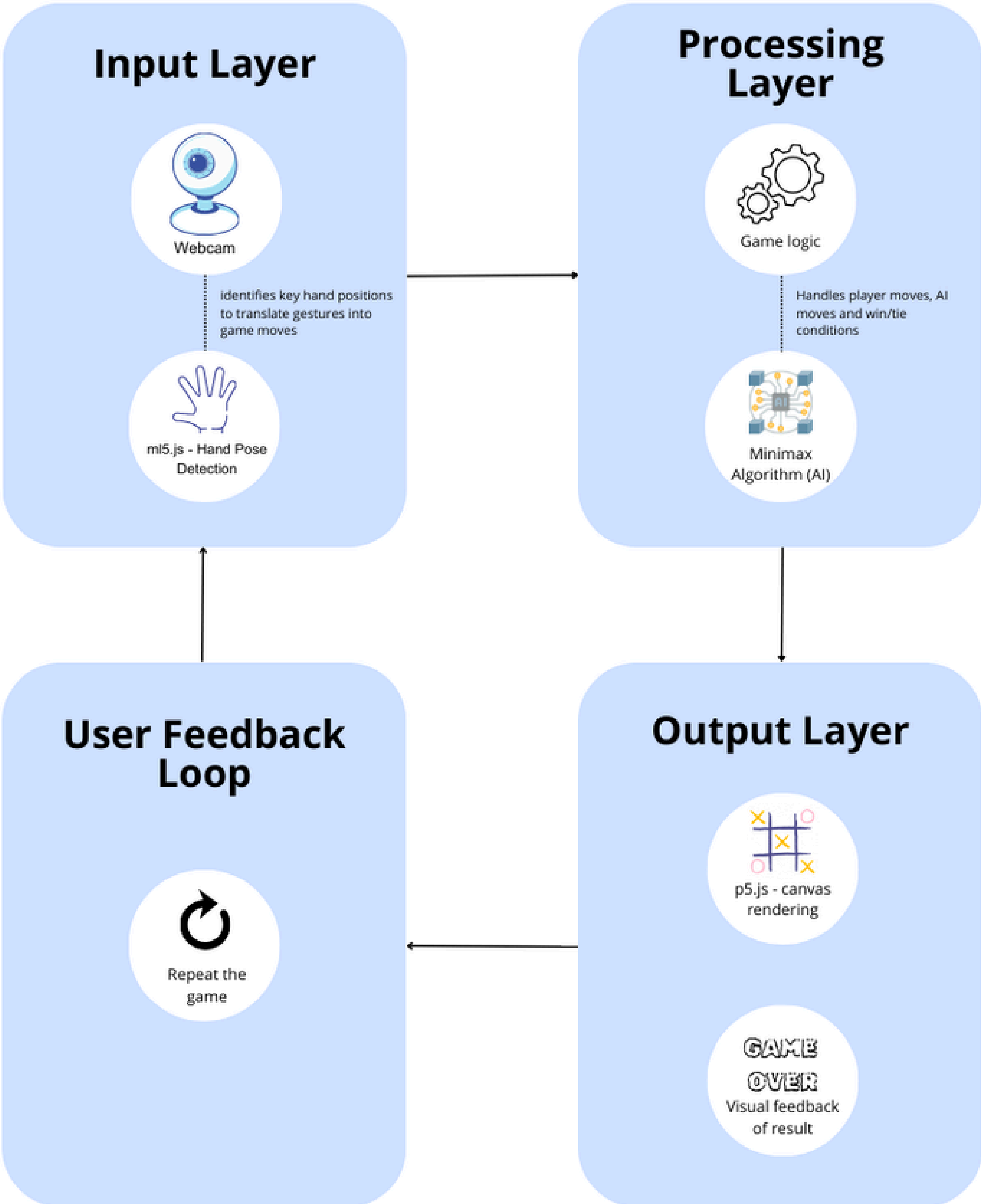

Fig. 1: Technical Architecture Diagram

As shown in figure 1, the diagram illustrates the technical architecture of this project, organized into 4 layers. These layers closely follow the principles of **Bongers interactive framework loop**, where the continuous exchange between user and system creates a dynamic interaction cycle.

The **Input Layer** captures real-time input through the Webcam, where library ml5.js processes the video feed to detect hand key points. This allows the system to track if the hand is open or closed, converting these gestures into game moves. The user's physical gestures becomes the primary input, initiating the interaction loop.

Once the gesture is recognized, the **Processing Layer** guarantees that the system processes the input to update the game state. The game logic maps the user's gesture onto the Tic-Tac-Toe board, updating the game status - whether it's the user's turn, the AI's turn, or if the game is over. Additionally, this layer deals with the AI algorithm, in this case the Minimax that evaluates the game board and calculates the optimal AI move based on the minimax decision-making process. This layer processes the user's input and prepares the system's output, following Bongers notion of computing a response based on user actions.

The third layer, **Output Layer**, displays the updated Tic-Tac-Toe board and game marks ('X' and 'O') after processing the user's gesture. If the game is over, it also displays the result (win, lose, or tie). This visual feedback is essential for keeping the user informed and engaged, prompting further interaction.

Completing the interactive loop, the **User Feedback Layer** encapsulates the ongoing cycle of user interaction. After displaying the updated board and game status, the system encourages the user to make the next move - restarting the game. This aligns with Bongers feedback concept where the system's output affects the user's next input, creating a continuous exchange between user and machine.