Department of Computer Science & Engineering
The University of Texas at Arlington

Architectural Design Specification
CSE 4316: Senior Design I
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MosaicMovement
In/E Motion

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Revision History

Revision	Date	Author(s)	Description
0.1	07.22.2024	JC, DP, SC, AM	document creation

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1 INTRODUCTION

The In/E Motion project aims to integrate advanced motion tracking technology with real-time animation projection to enhance live performances. By capturing detailed movement data from performers and participants using high-resolution cameras and motion tracking software, the system processes this data to generate dynamic animations projected onto the performance space. This creates an immersive and interactive experience, enhancing the visual appeal of performances in theater, dance, and live art installations.

Key Requirements

- Real-Time Motion Capture: The system must capture and process motion data in real-time, with minimal latency, ensuring synchronization with live performances.
- Real-Time Animations: High-quality animations must be generated based on the captured motion data, accurately reflecting the performers' movements.
- Reliable System Performance: The system must operate reliably during live performances, equipped with dependable hardware and software components to minimize downtime.
- User-Friendly Interface: Technicians require an intuitive interface to set up, control, and monitor the system, including a control panel, live preview, settings menu, and access to system logs.

The scope of the In/E Motion system encompasses several critical components and functionalities. The system integrates high-resolution cameras with calibration tools to ensure precise and synchronized data capture, managed by sophisticated data capture software that includes camera control and synchronization modules. The captured data is processed by motion tracking software to reduce noise and accurately track body and object movements. Data analysis components employ pattern recognition and interaction detection to interpret movements and generate corresponding animations. These animations are rendered in real-time using a powerful graphics engine and projected onto the performance space through high-resolution projectors. The system also includes an interaction system that monitors participant reactions and movements, enabling a responsive and immersive experience. Additionally, the user interface is designed to be intuitive, providing: settings menus, and access to system logs to facilitate setup, control, and monitoring during live performances.

2 System Overview

The In/E Motion system is designed with a multi-layered architecture to ensure modularity, scalability, and ease of maintenance. Each layer represents a distinct set of functionalities, allowing for clear separation of concerns and defined interfaces for interaction between layers. This approach facilitates the integration of related elements with similar capabilities within each layer, promoting independence and reducing inter-layer dependencies.

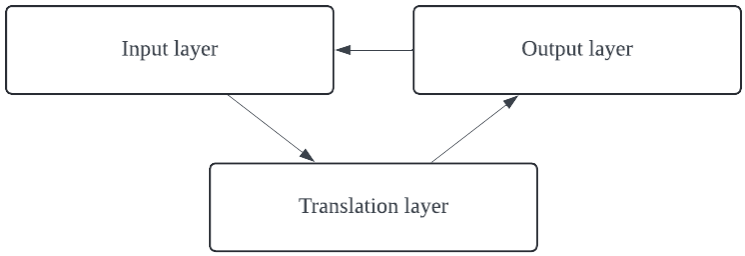

Figure 1: A simple architectural layer diagram of the In/E Motion System [1]

2.1 Input Layer Description

The Input Layer is the foundational component of the In/E Motion system, responsible for capturing raw motion data that will be processed and transformed into real-time animations. This layer includes high-resolution motion tracking cameras and sophisticated data capture software, both of which are crucial for ensuring accurate and synchronized data collection. Features of this layer include: motion tracking cameras and the data capture software. Interactions will occur between the input layer and the transmission layer by utilizing the motion tracking cameras to capture the movements of participants and performers for data analysis done in the transmission layer. The interaction between this layer and the output layer are based off the interactions between the projected animations and the participants that are being tracked.

2.2 Translation Layer Description

The Translation Layer serves as the intermediary between the raw data capture and the final output, processing the captured motion data to prepare it for animation rendering. This layer includes motion tracking software, data analysis components, and animation rendering engines, each of which plays a crucial role in transforming raw data into interactive visual effects. The features of this layer are the motion tracking software that will be used to capture that data using the cameras, the real-time data analysis, and animation rendering. The interaction between this layer and the output layer will be the data flow of animations to be rendered and projected onto the performance space.

2.3 Output Layer Description

The Output Layer is the final component of the In/E Motion system, responsible for presenting the processed animations and facilitating interactions with the participants. This layer includes the projector system and the interaction system, ensuring that animations are projected accurately and that participant movements are effectively integrated into the visual experience. The features of the output layer include a projector system and the interactions between the projected animations and participants. The interaction between this layer and the input layer are interactions from the participants that the animations invoke.

3 Subsystem Definitions & Data Flow

Here is a graphical representation of the logical subsystems that compose each layer and show the interactions/interfaces between those subsystems. A subsystem can be thought of as a programming unit that implements one of the major functions of the layer. It, therefore, has data elements that serve as source/sinks for other subsystems. The logical data elements that flow between subsystems need to be explicitly defined at this point, beginning with a data flow-like diagram based on the block diagram below.

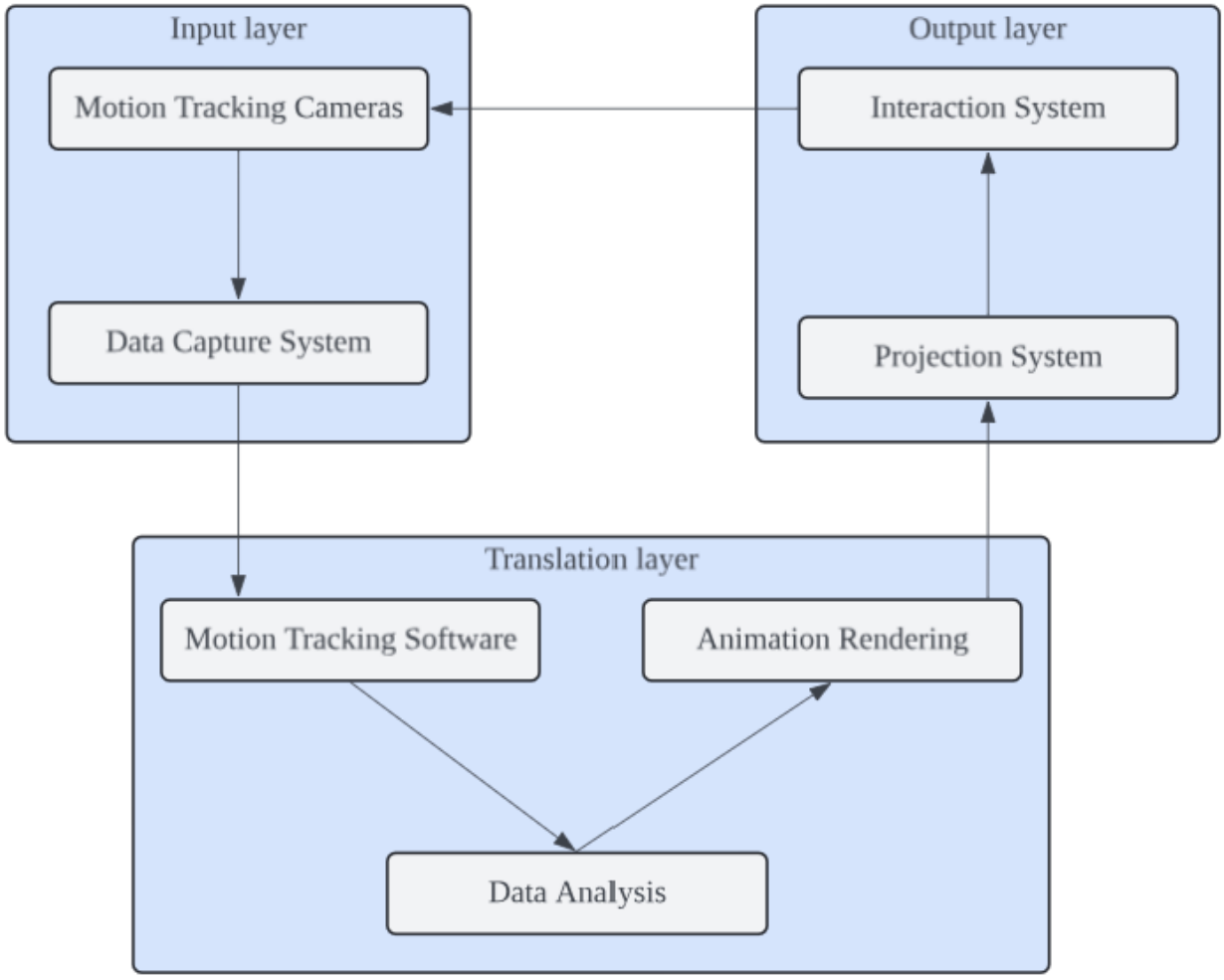

Figure 2: A simple data flow diagram of the In/E Motion System [1]

4 Input Layer Subsystems

The Input Layer is the foundational component of the In/E Motion system, responsible for capturing raw motion data that will be processed and transformed into real-time animations. This layer includes high-resolution motion tracking cameras and sophisticated data capture software, both of which are crucial for ensuring accurate and synchronized data collection.

4.1 Motion Tracking Cameras

The Motion Tracking Cameras subsystem is responsible for capturing detailed and precise movements of the performers. High-resolution cameras and calibration tools are used to ensure that the data captured is accurate and reliable. The subsystem communicates directly with the Data Capture Software to manage the operation of the cameras and synchronize the captured data.

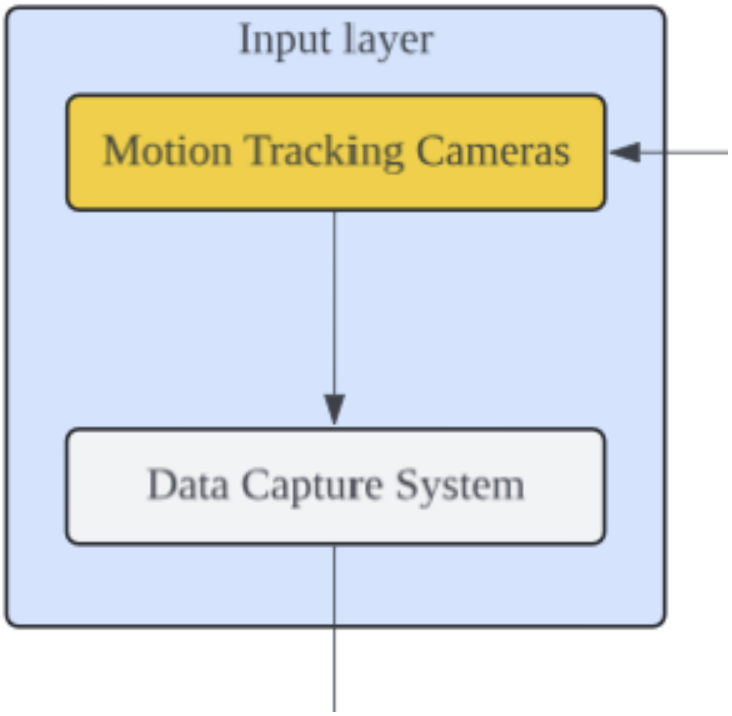

Figure 3: Motion Tracking Cameras diagram [1]

4.1.1 Assumptions

- The cameras are capable of capturing high-resolution video at the required frame rate.
- Calibration tools are available and effective in ensuring camera alignment.
- The environment where the cameras are used has sufficient lighting for optimal capture quality.
- The cameras are placed at strategic positions to cover the entire performance area without blind spots.

4.1.2 Responsibilities

- High-Resolution Capture: Capture detailed and accurate movement data.

- Calibration: Ensure cameras are properly aligned for synchronized data capture.
- Data Transmission: Send captured data to the Data Capture Software for processing.

4.1.3 Subsystem Interfaces

1. Camera Control Software Interface
2. Synchronization Module
3. Data Flow to Data Capture Software

ID #	Description	Inputs	Outputs
1	Manages camera operations including start/stop recording, setting adjustments, and status monitoring	Commands, Settings Adjustments	Status Updates
2	Ensures time-stamped data is synchronized across multiple cameras	Sync Commands	Time-Stamped Data
3	Transmits captured raw video data to the Data Capture Software	Raw Video Data	None

4.2 Data Capture System

The Data Capture Software subsystem is responsible for managing the operation of the motion tracking cameras, ensuring accurate synchronization of the captured data. It includes camera control software to handle the recording and settings of the cameras and a synchronization module to align the data from multiple cameras.

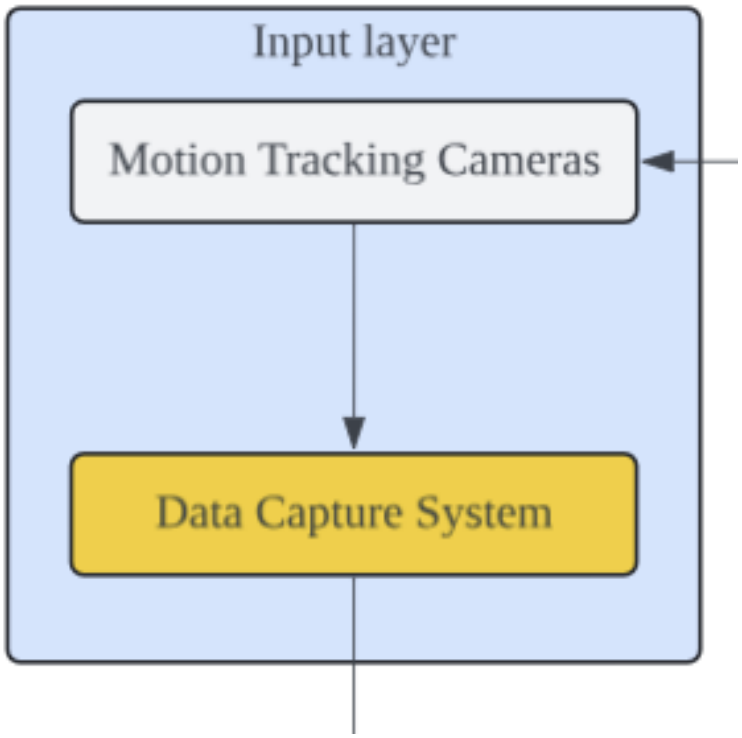

Figure 4: Data Capture System diagram [1]

4.2.1 Assumptions

- The software can handle multiple camera inputs simultaneously.
- The system environment provides enough computational power to manage high-resolution data in real-time.
- Network or direct connections between the cameras and the data capture system are stable and high-speed.

4.2.2 Responsibilities

- Camera Control: Start/stop recording, adjust settings, and monitor camera status.
- Data Synchronization: Ensure data captured from multiple cameras is accurately time-stamped and aligned.

4.2.3 Subsystem Interfaces

1. Motion Tracking Cameras Interface
2. Synchronization Module
3. Data Flow to Translation Layer

ID #	Description	Inputs	Outputs
1	Receives raw video data from the cameras	Raw Video Data	None
2	Processes synchronization commands and data alignment	Sync Commands	Aligned Data
3	Transmits synchronized and processed data to the Translation Layer for further processing	None	Synchronized Video Data

5 Translation Layer Subsystems

The Translation Layer processes the captured motion data, preparing it for animation rendering. This layer includes the Motion Tracking Software, Data Analysis, and Animation Rendering subsystems, each responsible for specific tasks in transforming raw data into interactive animations.

5.1 Motion Tracking Software

The Motion Tracking Software subsystem processes the captured data to reduce noise and accurately track the movements of bodies and objects. It ensures that only relevant movement data is passed on for further analysis. This subsystem communicates with the Data Capture System and the Data Analysis subsystem to ensure the accuracy and integrity of the motion data.

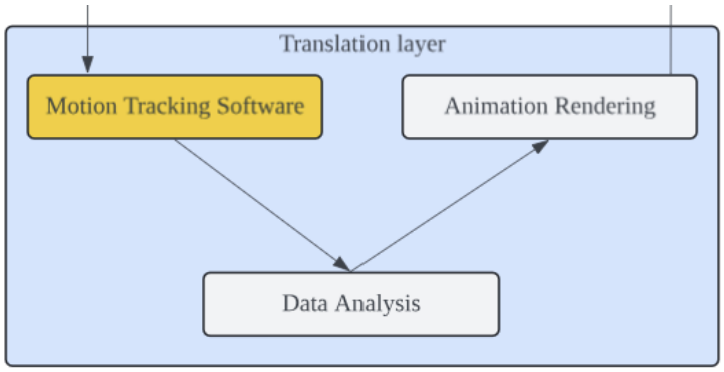

Figure 5: Motion Tracking Software diagram [1]

5.1.1 Assumptions

- The software is capable of handling high-resolution motion data in real-time.
- The computational environment provides sufficient processing power to perform noise reduction and tracking without significant latency.
- The data received from the cameras is accurately time-stamped and synchronized.

5.1.2 Responsibilities

- Noise Reduction: Filter out irrelevant data and noise from the captured footage to ensure accuracy.
- Body and Object Tracking: Identify and monitor the movements of bodies and objects within the captured footage.

5.1.3 Subsystem Interfaces

1. Data Capture System Interface
2. Noise Reduction and Tracking Interface
3. Data Analysis Interface

ID #	Description	Inputs	Outputs
1	Receives synchronized raw video data from the Data Capture System	Synchronized Raw Video Data	None
2	Processes data for noise reduction and tracking	Synchronized Raw Video Data	Processed Movement Data
3	Sends processed data to the Data Analysis subsystem	None	Processed Movement Data

5.2 Data Analysis

The Data Analysis subsystem interprets the tracked movements using pattern recognition and interaction detection algorithms. It identifies significant patterns and interactions, which are essential for generating meaningful animations. This subsystem communicates with both the Motion Tracking Software and the Animation Rendering subsystems to ensure seamless data flow and accurate analysis.

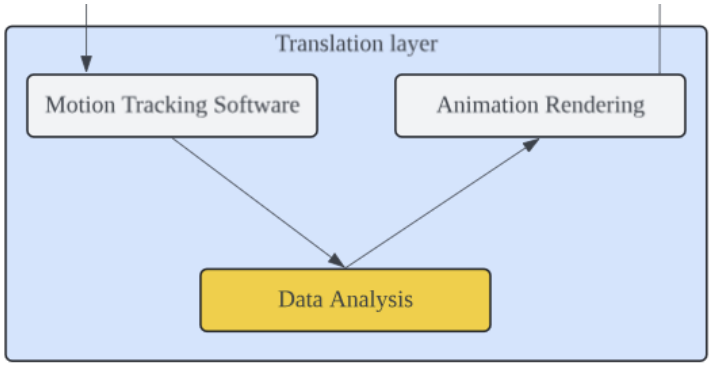

Figure 6: Data Analysis diagram [1]

5.2.1 Assumptions

- The environment provides sufficient processing power to perform real-time pattern recognition and interaction detection.
- The data received from the Motion Tracking Software is accurately processed and relevant for analysis.

5.2.2 Responsibilities

- Pattern Recognition: Analyze the tracked movements to identify common patterns.
- Interaction Detection: Detect interactions between different bodies or objects in the captured footage.

5.2.3 Subsystem Interfaces

1. Motion Tracking Software Interface
2. Pattern Recognition and Interaction Detection Interface
3. Animation Rendering Interface

ID #	Description	Inputs	Outputs
1	Receives processed movement data from the Motion Tracking Software	Processed Movement Data	None
2	Performs pattern recognition and interaction detection	Processed Movement Data	Analyzed Movement Patterns
3	Sends analyzed data to the Animation Rendering subsystem	None	Analyzed Movement Patterns

5.3 Animation Rendering

The Animation Rendering subsystem uses the analyzed data to create animations. This subsystem ensures that the animations are accurately aligned and projected in sync with the participants' movements. It communicates with the Data Analysis subsystem to receive the necessary data for rendering and with the Output Layer for projection.

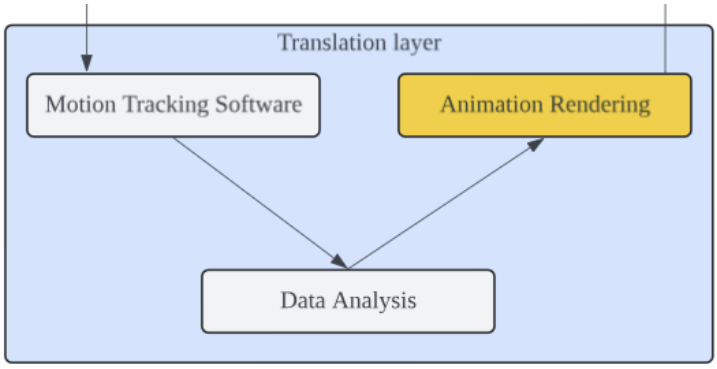

Figure 7: Animation Rendering diagram [1]

5.3.1 Assumptions

- The environment provides sufficient graphics processing power to render high-quality animations in real-time.
- The data received from the Data Analysis subsystem is accurate and timely.

5.3.2 Responsibilities

- Graphics Engine: Create animations based on the analyzed data.
- Projector Interaction: Ensure the animations are correctly aligned and projected in sync with the participants' movements.

5.3.3 Subsystem Interfaces

1. Data Analysis Interface
2. Graphics Engine Interface
3. Projection System Interface

ID #	Description	Inputs	Outputs
1	Receives analyzed movement patterns from the Data Analysis subsystem	Analyzed Movement Patterns	None
2	Creates animations based on analyzed data	Analyzed Movement Patterns	Rendered Animations
3	Sends rendered animations to the Output Layer for projection	None	Rendered Animations

6 Output Layer Subsystems

The Output Layer is the final component of the In/E Motion system, responsible for presenting the processed animations and facilitating interactions with the participants. This layer includes the Projection System and the Interaction System, ensuring that animations are projected accurately and that participant movements are effectively integrated into the visual experience.

6.1 Projection System

The Projection System subsystem is responsible for displaying the animations created by the graphics engine onto the performance space. High-resolution projectors and projection mapping techniques are employed to ensure that the visuals are clear, detailed, and aligned with the physical environment. This subsystem communicates with the Animation Rendering subsystem and the Interaction System to provide an immersive and interactive experience.

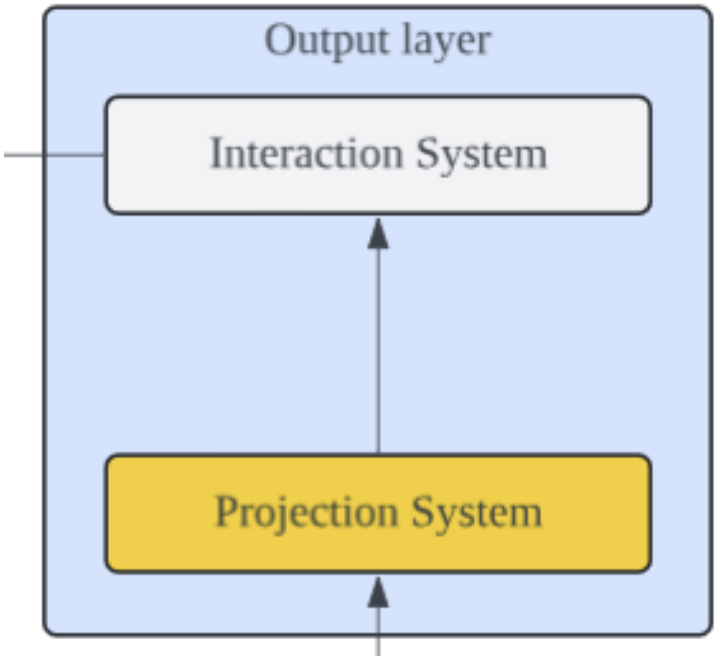

Figure 8: Projection System diagram [1]

6.1.1 Assumptions

- The projectors are capable of displaying high-resolution animations in real-time.
- The projection surface is adequately prepared and positioned to receive the visuals.
- The environment provides sufficient lighting conditions for optimal projection quality.

6.1.2 Responsibilities

- High-Resolution Projection: Display clear and detailed animations created by the graphics engine.
- Projection Mapping: Ensure animations are accurately mapped onto the physical performance space.

6.1.3 Subsystem Interfaces

1. Animation Rendering Interface
2. Projection Interface
3. Interaction System Interface

ID #	Description	Inputs	Outputs
1	Receives rendered animations from the Animation Rendering subsystem	Rendered Animations	None
2	Projects animations onto the performance space	Rendered Animations	Projected Animations
3	Interacts with the Interaction System to adjust projections based on participant movements	Participant Movement Data	Adjusted Projections

6.2 Interaction System

The Interaction System subsystem monitors participant reactions and movements, enabling the system to dynamically adjust animations in real-time. This subsystem ensures that the projections respond to participant behavior, creating a responsive and engaging experience. It communicates with the Projection System and the Animation Rendering subsystems to facilitate this interaction.

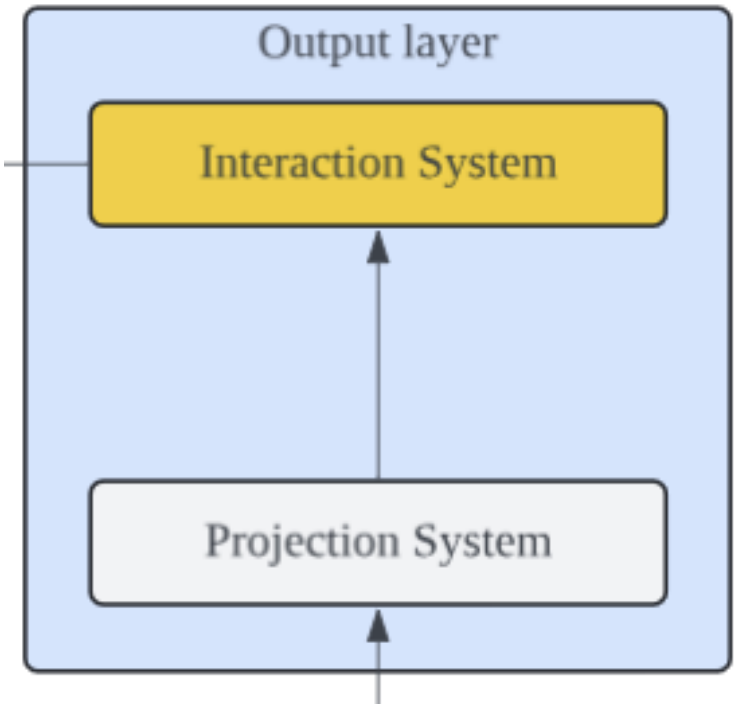

Figure 9: Interactive System diagram [1]

6.2.1 Assumptions

- The system is capable of accurately tracking participant movements and reactions in real-time.

- The environment allows for clear detection and monitoring of participant actions.
- Participants are willing to interact with the system.

6.2.2 Responsibilities

- Participant Reaction Monitoring: Track and analyze participant reactions to the projected animations.
- Participant Movement Tracking: Monitor and interpret participant movements to influence the animations.

6.2.3 Subsystem Interfaces

1. Participant Monitoring Interface

ID #	Description	Inputs	Outputs
1	Receives data on participant movements and reactions	Participant Movement Data	Update Data for Input Layer

REFERENCES

[1] Lucidchart. Diagrams for Architectural Design Specification, 2024.