



A S7-1200 PLC-BASED MOTION SEAT SYSTEM FOR 3D CINEMA APPLICATIONS

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ABSTRACT: Immersive cinematic experiences are becoming increasingly important in enhancing audience satisfaction. By integrating various pneumatic and electrical actuators, a 3D cinema seat system is developed to simulate real-time motion effects such as vibration, lifting, wind blowing, and mist spraying. These effects are synchronized with movie content to improve viewer engagement. In this paper, we present a prototype that utilizes a Siemens S7-1200 PLC as the main controller and a Weinview HMI for interaction. The system's effects are triggered through a scenario-based timeline controlled via ladder logic. Through experimental trials, the model demonstrates high responsiveness and reliability, meeting real-time synchronization requirements. A supervision interface is also designed to allow users to manage effect sequences during playback.

KEY WORDS: *3D cinema seat, PLC S7-1200, pneumatic control, real-time effects, motion platform.*

1. INTRODUCTION

Immersive entertainment technologies have emerged as a significant trend in modern cinema, aiming to enhance the viewer's sensory experience [1]. By integrating audiovisual elements with physical motion, contemporary 3D cinema environments provide a more realistic and engaging experience. In particular, the incorporation of motion-enabled seating systems—featuring vibration, tilting, wind blowing, and mist spraying—plays an important role in achieving emotional synchronization between the audience and the film narrative [2]. An example of such an integrated system is illustrated in Figure 1, which demonstrates a commercial implementation of a 3D cinema system.

To realize these interactive effects, automation systems are commonly employed. Previous studies have utilized Arduino-based controllers to manage the system and design Human-Machine Interfaces (HMI) [3]. However, limitations in stability and robustness make Arduino less suitable for industrial-scale or continuous operation. As a result, programmable logic controllers (PLCs) have become the preferred platform for such applications due to their reliability and capability for real-time control [4].

Among various PLC options, the Siemens S7-1200 series is widely adopted because of its modular architecture, high reliability, and strong performance in automation systems [4]. When integrated with an HMI, such as Weinview, operators can flexibly configure and monitor effect sequences in accordance with different movie scenarios [6]. This enables synchronized control of multiple actuators, ensuring precise timing between cinematic content and physical responses.



Despite the technological advancements in commercial 4D and 5D cinema systems, their implementation is often associated with high costs and proprietary architectures. These limitations restrict their accessibility, particularly in educational and research contexts, where open, flexible, and cost-effective platforms are required.



Fig.1. 3D Cinema System by Dolby Cinema [1]

Therefore, this study aims to design and develop a low-cost, educational-oriented 3D cinema seat system by integrating pneumatic and electric actuators under PLC-based control. The proposed system is intended to function both as an interactive entertainment prototype and as a practical learning platform for automation engineering education.

2. EXPERIMENTAL MODEL

The designed system consists of several integrated functional blocks that collectively enable the operation of an immersive 3D cinema seat system, as illustrated in Figure 2. The system is structured to ensure seamless interaction between control, actuation, and power subsystems.

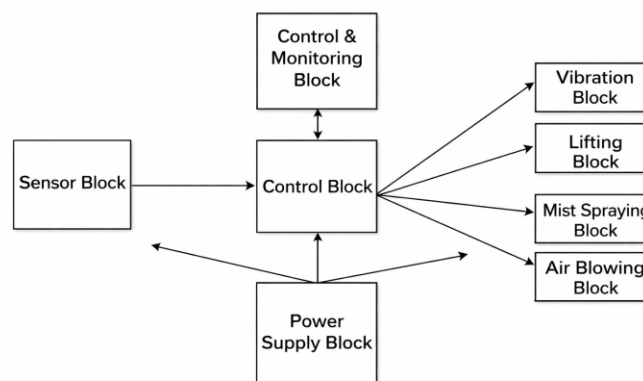


Fig.2. System overview

The control and monitoring function is performed through a combination of a Human–Machine Interface (HMI) and a personal computer, which serve as the primary user interface for selecting movie scenarios and activating or deactivating specific effects. This interface communicates with the central controller via Ethernet using the TIA Portal Runtime environment. The central control unit is based on a Siemens S7-1200 programmable logic controller (PLC), which processes input commands received from the HMI, executes logical control algorithms, and generates output signals to drive various actuators in real time.



The actuator subsystem is responsible for producing the physical effects that enhance the cinematic experience. This subsystem includes two 24VDC vibration motors (Figure 3) that generate seat vibration effects, a pneumatic cylinder type SC63×150 (Figure 4) combined with a 4V210-08 solenoid valve (Figure 5) to produce seat lifting and tilting motions, and two 3V110-06 pneumatic solenoid valves (Figure 6) that simulate directional wind effects. Additionally, a 24VDC water valve (Figure 7) is utilized to create a mist spraying effect, further enhancing sensory immersion. These actuators are controlled through specific PLC output channels to ensure synchronized operation with the selected scenario.



Fig.3. 24VDC vibration motor



Fig.4. SC63x150 pneumatic cylinder valves

In the current system configuration, the sensor block is not implemented, and all system operations are manually triggered via the HMI rather than relying on real-time sensor feedback. This approach simplifies the system design while maintaining flexibility for user-defined control. The entire system is powered by a 24VDC switching power supply, with electrical protection provided by an LCP32FM-5A circuit breaker to ensure operational safety and reliability.



Fig.5. 4V210-08 pneumatic solenoid valves



Fig.6. 3V110-06 pneumatic solenoid valve

The overall system design is modeled using SolidWorks, as presented in Figure 8, which illustrates the arrangement and integration of all components. Within this design, the mist effect is generated through the combination of a water solenoid valve and a pneumatic valve, while separate pneumatic valves are used to produce rear and under-seat airflow effects. The electrical cabinet houses the PLC, circuit breaker, and power supply, and the HMI is positioned to facilitate user interaction. The seat motion is achieved through the coordinated operation of



a pneumatic cylinder and its associated solenoid valve, while vibration motors are mounted to simulate dynamic shaking effects.



Fig.7. 24VDC water valve

Finally, the physical implementation of the system is shown in Figure 9, demonstrating the successful realization of the proposed design into a functional prototype.



Fig.8. Designed model in Solidworks



Fig. 9. Real system overview

3. CONTROL METHOD

The 3D cinema seat system is designed to generate various physical effects, including seat lifting and lowering, vibration, air blowing, and mist spraying, all of which are synchronized with movie content to enhance the viewer's immersive experience. The system operation is governed by a Siemens S7-1200 programmable logic controller (PLC) integrated with a Weinview Human-Machine Interface (HMI), enabling both automated control and user interaction.

The system control architecture is based on real-time execution of control logic within the PLC, which is programmed using Ladder Logic. In this framework, Timer and Compare functions are utilized to trigger specific effects at predefined time intervals. The HMI serves as the primary interface, allowing users to select movie scenarios, monitor system status, and control the initiation or termination of effect sequences. All external devices, including pneumatic solenoid valves, air cylinders, vibration motors, and mist valves, are directly interfaced with the digital output channels of the PLC, ensuring precise and reliable actuation.



To achieve accurate synchronization between physical effects and movie scenes, a scenario-based timeline method is implemented. The movie is divided into discrete time segments, each associated with specific effects that correspond to the cinematic context. For instance, at the 16th second, a pneumatic valve is activated for two seconds to simulate wind, while at the 30th second, vibration motors are triggered to mimic collision effects. Each movie is assigned a unique timeline configuration, allowing flexible adaptation for different content. An example of this synchronization strategy is presented in Table 1, which illustrates the effect timing sequence for a selected movie scenario.

Table 1: Effect Timing Table - Example: Avatar 2

| Time (s) | Movie Scene Description | System Effect (Q Output) | Duration |
|----------|-----------------------------------|-----------------------------------|----------|
| 0–5 | Opening scene, background music | Seat lifted (Q0.0 ON) | Full |
| 6–8 | Loud sounds, slight shaking | Vibration motor ON (Q0.4) | 2 s |
| 12–15 | Calm sound, slow movement | Stop vibration | — |
| 16–18 | Strong wind phenomenon | Under-seat wind ON (Q0.1) | 2 s |
| 20–22 | Waterfall or rain scene | Mist (Q0.3) + rear wind (Q0.2) ON | 2 s |
| 30–32 | Intense shaking/collision | Both motors ON (Q0.4 + Q0.5) | 2 s |
| 35–37 | Sudden seat drop | Seat lowered (Q0.0 OFF) | 2 s |
| 38–40 | Return to calm scene | Seat raised again (Q0.0 ON) | 2 s |
| 45–47 | Closing scene with soft wind/mist | Mist + wind combination | 2 s |

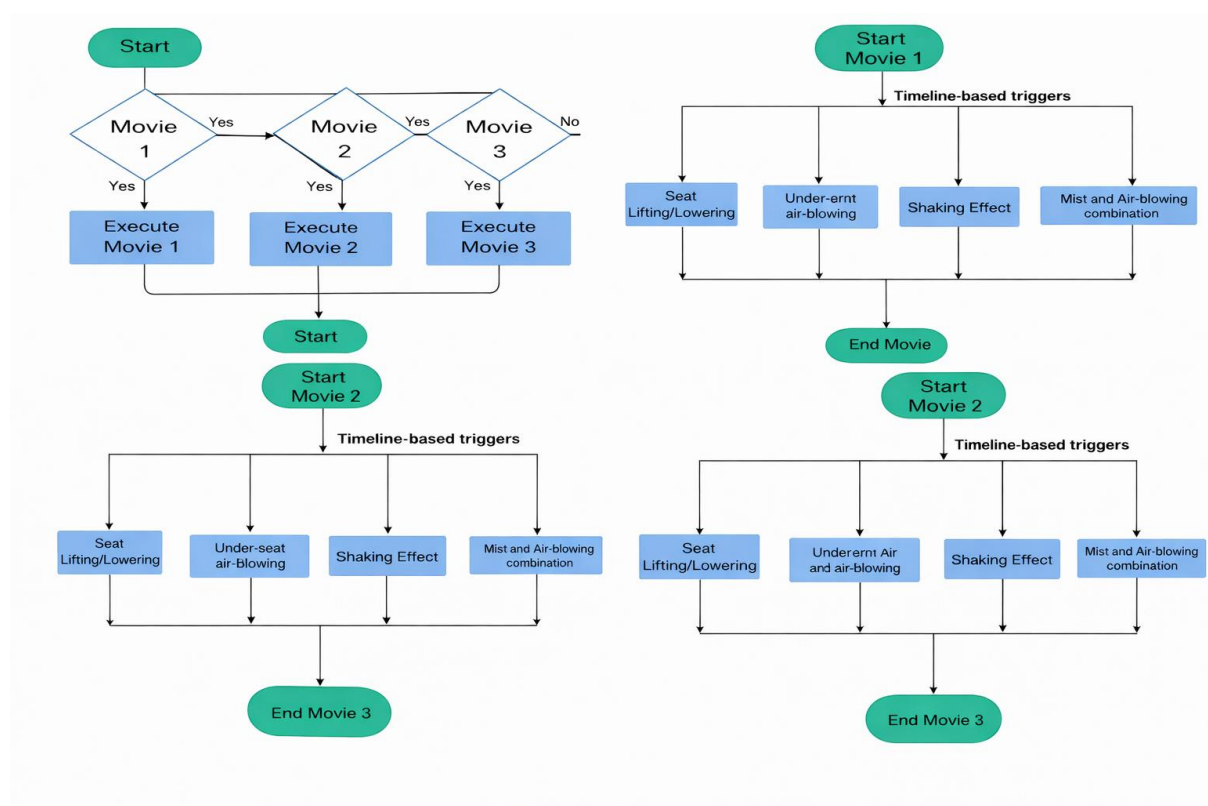


Fig. 10. Control Flowchart

The control process follows a structured flow in which the user initiates a movie via the HMI, after which the PLC continuously compares the system time with predefined trigger points. Based on this comparison, corresponding outputs are activated to generate the required effects. The system incorporates start and stop functions to control both movie playback and effect execution, while each actuator is mapped to a dedicated PLC output channel. The control sequence operates cyclically through time checking, effect activation, delay execution, and effect deactivation. This operational logic is illustrated in the control flowchart shown in Figure 10.

4. CONTROL METHOD

After completing the design, construction, and programming stages, the developed system was evaluated through testing using real movie scenarios. The results demonstrate the overall functionality, reliability, and user acceptance of the proposed 3D cinema seat system.

4.1. Electrical Implementation

The electrical implementation was carried out by integrating the PLC, HMI, and all supporting control components within a dedicated electrical cabinet, as illustrated in Figure 11. This configuration ensured proper wiring management, protection, and ease of maintenance. During testing, the system exhibited stable operation without any electrical faults or communication failures between components, indicating that the control architecture was implemented effectively and reliably.

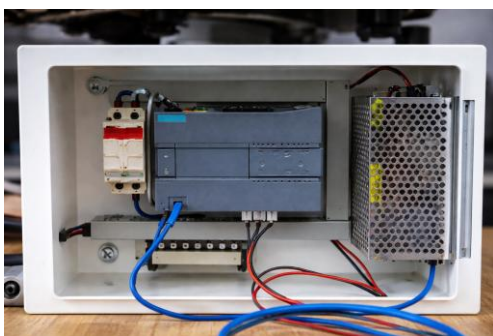


Fig. 11. Electrical cabinet interior



Fig. 12. Seat lifting mechanism

4.2. Mechanical Construction

The mechanical construction of the system focuses on a steel frame structure designed to support loads exceeding 80 kg, ensuring robustness and user safety. As shown in Figure 12, the seat mechanism integrates pneumatic cylinders, solenoid valves, and vibration motors to generate dynamic motion effects. All mechanical components were assembled according to the design specifications and operated smoothly during testing, demonstrating proper alignment, stability, and functional integration.

4.3. Control Interface and Operation Results

The control interface, implemented the HMI, provides an intuitive and user-friendly platform for system operation. As depicted in Figure 13 and Figure 14, the interface allows users to easily select movie scenarios and control system operation *באמצעות* START and STOP commands. During experimental testing, all physical effects—including vibration, seat movement, wind, and mist—were executed accurately and synchronized in real time with the movie content. The synchronization strategy proved effective in delivering consistent and context-aware responses across different movie scenarios. The performance of effect execution for various movies is summarized in Table 2, which highlights how each effect is mapped to specific cinematic situations.

Table 2: Evaluation Table – Effect Usage per Movie

| Effect | Island Coaster | Avatar 2 | Jurassic Park |
|------------------------|------------------------|----------------------------------|-----------------------------|
| <i>Seat lifting</i> | Frequent on slopes | Often during character drops | When dinosaurs appear |
| <i>Vibration</i> | During acceleration | Scene transitions | Violent attacks |
| <i>Under-seat wind</i> | While ship glides fast | Underwater scenes | Dinosaur roar effect |
| <i>Rear wind</i> | Short bursts | Water spray from above | Tree shaking effect |
| <i>Mist spraying</i> | Water splash scenes | Smooth mist in underwater scenes | Dinosaur roar + rain effect |
| <i>Synchronization</i> | Fixed segment-based | Timeline-effect mapped | Aligned with scene markers |

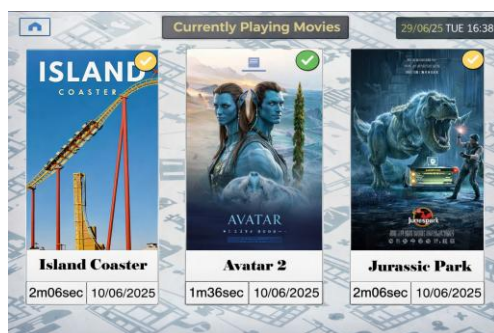


Fig. 13. Movie selection interface

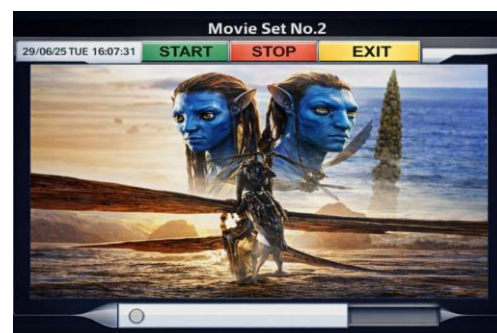


Fig. 14. Movie Playback Interface

4.4. User Experience Evaluation

To assess system performance from the user perspective, a live evaluation was conducted involving five student participants. Each participant experienced a short demonstration film that incorporated all available effects, including vibration, lifting, mist spraying, and air blowing. After the session, participants completed a structured questionnaire consisting of five



closed-ended questions using a Likert scale (1–5) and two open-ended feedback questions. The survey results, presented in Table 3, indicate high levels of user satisfaction across multiple aspects, including realism, synchronization, actuator smoothness, and ease of use.

The average scores reveal that the system performs particularly well in delivering realistic motion effects and encouraging user engagement, with strong willingness among participants to reuse or recommend the system. Although some feedback suggested minor improvements in response time and actuator smoothness—particularly in pneumatic cylinder motion—the overall evaluation confirms that the system achieves a high level of performance. Therefore, the developed motion seat system is considered suitable for implementation in educational environments and small-scale immersive entertainment applications.

Table 3: Survey on User Experience with the Motion Seat System

| Survey Question | Average Score (1–5) |
|--|---------------------|
| Realistic feeling when experiencing motion effects | 4.5 |
| Synchronization between effects and movie content | 4.4 |
| Smoothness in seat movement and other actuators | 4.6 |
| Ease of use and clarity of HMI interface | 4.0 |
| Willingness to experience again or recommend to others | 4.6 |

5. CONCLUSION

This study successfully designed, developed, and validated a low-cost 3D cinema seat system based on a Siemens S7-1200 PLC integrated with a Weinview HMI. The proposed system is capable of generating multiple synchronized physical effects, including seat lifting/lowering, vibration, air blowing, and mist spraying, which are effectively aligned with movie content using a timeline-based control approach.

Experimental results demonstrate that the electrical and mechanical systems operate reliably, with stable performance and smooth actuator integration. The implemented control method enables precise real-time synchronization between cinematic scenes and physical responses, ensuring consistent and repeatable operation across different movie scenarios.

User evaluation results indicate a high level of satisfaction in terms of realism, synchronization, and usability, confirming the effectiveness of the system as an immersive platform. Although minor improvements are required in actuator response and smoothness, the overall performance meets the requirements for both educational and small-scale entertainment applications.

Therefore, the developed system provides a practical, flexible, and cost-effective alternative to commercial 4D/5D cinema technologies, with strong potential for further development, including the integration of sensor-based feedback and advanced adaptive control strategies.

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APPENDIX

To further validate the performance and functionality of the developed 3D cinema seat system, experimental demonstrations were conducted and documented through video recordings. These demonstrations provide visual evidence of the system's capability to generate synchronized motion effects under different operating conditions.

The first demonstration (Link 1) presents the system operating without a user seated on the platform, allowing clear observation of actuator movements, including seat lifting/lowering, vibration, air blowing, and mist spraying. This condition highlights the mechanical response and baseline system behavior without external load.

The second demonstration (Link 2) shows the system under actual operating conditions with a user seated on the chair. This scenario evaluates the system's performance under load, demonstrating its structural stability, actuator effectiveness, and overall responsiveness during real-time operation.

The videos can be accessed through the following links:

- Link 1 (Unoccupied seat):
https://youtu.be/_rabrqi-0Nw
- Link 2 (Occupied seat):
<https://youtu.be/YDQZTkFu1M0?si=mANEt4K6W9BBmp4K>

These experimental recordings complement the quantitative and qualitative results presented in the main manuscript and provide additional insight into the practical implementation of the proposed system.

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