ME SDP 305 Robotic Arm for NES Power Glove

Integration and Test Plan Procedures

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Submitted by:

Maxine Krueger, ME

Nicholas Marzan, ME

John Milham, ME

Ragul Ganesh Anitha Palanivel, COE

Faculty Advisor: Prof. Jaeho Lee

Submitted in partial fulfillment of ME SDP

Requirements

Thomas J. Watson School of Engineering and Applied

Science Department of Mechanical Engineering

State University of New York at Binghamton

Binghamton, NY

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1. Scope

1.1 System Overview

The central goal of this project is to create a fully functional robotic arm that is able to successfully display the capabilities of the NES Power Glove System in a museum setting. This arm will coincide with a corresponding transmitter glove that visitors will be able to wear to control the movement of the robotic arm. As such, the broader project incorporates mechanical engineering, electrical engineering, and computer engineering. A partnering group is responsible for the transmitter glove and the electrical aspect of the project while we are mostly responsible for the mechanical functionality of the robotic arm. Both teams will work together to incorporate effective coding to ensure the transmitter glove and the robotic arm are entirely compatible and operational. Last year's robotic arm struggled in a multitude of areas, but the most significant ones were: shakiness/lack of stability while moving, inability to fit the NES Power Glove, and an extremely messy aesthetic due to convoluted and exposed wiring. These are all issues we have worked to remedy in our design and verification process and we firmly believe this will be reflected in our implementation of the project.

1.2 Document Overview

This document will serve to clearly state our previously created requirements along with how we plan to verify each of them successfully. Every test will be concisely explained and planned with extensive detail to be carried out this semester. This will be neatly formatted to ensure simplicity in understanding which test fulfills which requirement.

2. Referenced Documents

The following documents serve as the basis for our plans for testing and validation of this project:
ME SDP 305 Final Presentation
ME SDP 305 Project Specifications
NES Power Glove Guidelines:
https://www.digitpress.com/library/manuals/nes/power%20glove.pdf

3. Integration and Test Environment

The tests will be conducted in the time leading up to the Senior Design Expo. All tests and verifications will be complete by April 23rd, one week before the Expo.

3.1 Test Site

Our test site will be the Fabrication Lab in Binghamton University's Engineering Building.

3.1.1 Hardware and Firmware Items

The required hardware for testing includes: tape, a protractor, and a camera. No firmware is required for the testing process.

3.1.2 Software

The Software utilized for testing includes: Creo

3.1.3 Participants

All 4 members of the Senior Design Project team will participate in testing. Testing the connectivity with the controller glove will also involve the members of the ECE 526 Senior Design Project team.

3.1.4 Tests to be Performed

MESDP305-T-001: Finger Extension Angle Measurement Test

MESDP305-T-002: Finger Curl Angle Measurement Test

MESDP305-T-003: Wrist Rotate Angle Measurement Test

MESDP305-T-004: Arm Pitch Angle Measurement Test

MESDP305-T-005: Arm Yaw Angle Measurement Test

MESDP305-T-006: Glove Fitting Test

MESDP305-T-007: Shoulder Stabilization Test

MESDP305-T-008: Free Movement Test

MESDP305-T-009: Concealed Wires Test

MESDP305-T-010: Power Source Test

MESDP305-T-011: Game Response Test

MESDP305-T-012: Integration Test

MESDP305-T-013: Disassemble Test

MESDP305-T-014: Budget Test

4. System Integration

All requirements will be thoroughly validated through our planned tests. Each test correlates to a desired requirement that must be effectively passed to ensure our project's success.

5. System Verification

5.1 Requirements

Requirements Table		
ID	**Brief Description**	**Qualification Method**
{MESDP-305-001}	Full finger extension.	[I]
{MESDP-305-002}	90° finger curl.	[I]
{MESDP-305-003}	90° wrist rotation.	[I]
{MESDP-305-004}	90° arm pitch.	[I]
{MESDP-305-005}	90° arm yaw.	[I]
{MESDP-305-006}	NES glove must fit on arm.	[D]
{MESDP-305-007}	Shoulder base must be fixed during use.	[D]
{MESDP-305-008}	Uninterrupted movement of arm.	[D]
{MESDP-305-009}	Concealed wires.	[D]
{MESDP-305-010}	Arm is plugged into a power source.	[D]

{MESDP-305-011}	Arm will respond to Super Glove Ball inputs.	[T]
{MESDP-305-012}	Integration with ECDP-526.	[A,T]
{MESDP-305-013}	Disassembly without power tools.	[T]
{MESDP-305-014}	Project is within a $1,000 budget.	[D]

Table 1: Requirements

5.2 Test Coverage

System Verification Table			
ID	**Brief Description**	**Requirement Fulfilled**	**Qualification Method**
{MESDP305-T-001}	Finger Extension Angle Measurement Test	[MESDP-305-001]	[I]
{MESDP305-T-002}	Finger Curl Angle Measurement Test	[MESDP-305-002]	[I]
{MESDP305-T-003}	Wrist Rotate Angle Measurement Test	[MESDP-305-003]	[I]
{MESDP305-T-004}	Arm Pitch Angle Measurement Test	[MESDP-305-004]	[I]
{MESDP305-T-005}	Arm Yaw Angle Measurement Test	[MESDP-305-005]	[I]
{MESDP305-T-006}	Glove Fitting Test	[MESDP-305-006]	[D]
{MESDP305-T-007}	Shoulder Stabilization Test	[MESDP-305-007]	[D]
{MESDP305-T-008}	Free Movement Test	[MESDP-305-008]	[D]
{MESDP305-T-009}	Concealed Wires Test	[MESDP-305-009]	[I, D]

{MESDP305-T-010}	Power Source Test	[MESDP-305-010]	[D]
{MESDP305-T-011}	Game Response Test	[MESDP-305-011]	[T]
{MESDP305-T-012}	Integration Test	[MESDP-305-012]	[A,T]
{MESDP305-T-013}	Disassemble Test	[MESDP-305-013]	[T]
{MESDP305-T-014}	Budget Test	[MESDP-305-014]	[D]

Table 2: System Verification

5.3 Test Schedule

Testing that involves simulations and does not require the final product to be assembled will be performed in early to mid March of 2025. Testing that involves the assembly of the final product will be performed in early April of 2025.

6. Bibliography

NES Power Glove Guidelines:
https://www.digitpress.com/library/manuals/nes/power%20glove.pdf

Appendices

Appendix A: System Verification Procedure

MESDP305-T-001: Finger Extension Angle Measurement Test

Objective: All fingers (excluding the pinky) must fully extend in a straight, 180° line when uncurled in order to input the correct controls to the NES Power Glove.

Qualification Method: (I)

Requirement Addressed: [MESDP-305-01] The robotic arm fingers shall extend outwards to 180 degrees.

Equipment Needed: Protractor

Procedure: The controller will input the command to the fingers to fully uncurl and while extended, a protractor will be used to measure the angles of lines marked along the central axis of each joint of each finger to ensure that the angle between each joint is 180°.

MESDP305-T-002: Finger Curl Angle Measurement Test

Objective: All joints of all fingers (excluding the pinky) must curl inwards 90° to allow for a fully closed fist and thus accurate inputs from the robotic arm to the NES Power Glove to allow for Super Glove Ball to be played.

Qualification Method: (I)

Requirement Addressed: [MESDP-305-02] The robotic arm fingers shall curl 90 degrees to each joint on the finger.

Equipment Needed: Protractor

Procedure: The controller will input the command for the fingers to fully curl and while in this fully curled state, a protractor will be used to measure the angles of the same lines used for MESDP305-T-001, although now they must be 90° at each joint. These angles must also be oriented so that the fingers are curled inwards towards the palm.

MESDP305-T-003: Wrist Rotate Angle Measurement Test

Objective: The hand must be able to rotate 180° in total with respect to the non-rotating forearm in order to accurately input control to the NES Power Glove to allow for Super Glove Ball to be played.

Qualification Method: (I)

Requirement Addressed: [MESDP-305-03] Wrist mechanism of the arm shall rotate +/- 90 degrees.

Equipment Needed: Protractor

Procedure: The command to fully rotate the hand in both directions from a neutral position will be input. A mark will be made on the stationary forearm that lines up with a reference point on the rotating piece at both extreme ends of rotation. The protractor will measure the angle between these marks to determine if the wrist has rotated 180°.

MESDP305-T-004: Arm Pitch Angle Measurement Test

Objective: The forearm/hand must pitch 90°, from horizontal to vertical in order to input the correct position controls to the NES Power Glove to allow for Super Glove Ball to be played.

Qualification Method: (I)

Requirement Addressed: [MESDP-305-04] The arm pitch shall be +/- 90 degrees.

Equipment Needed: Protractor

Procedure: A mark will be made on the stationary part of the part of the shoulder responsible for pitch, which will align with a reference point on the forearm. The command to pitch the arm from horizontal to vertical will be inputted to the arm. The new mark indicating the fully raised position will be made on the same stationary part of the shoulder. The protractor will be used to measure the angle between the 2 points to verify that it is 90°.

MESDP305-T-005: Arm Yaw Angle Measurement Test

Objective: The forearm/hand must yaw 90° in order to input the correct position controls to the NES Power Glove to allow for Super Glove Ball to be played.

Qualification Method: (I)

Requirement Addressed: [MESDP-305-05] The arm yaw shall be +/- 90 degrees.

Equipment Needed: Protractor

Procedure: The input will be given for the shoulder to yaw as much as possible in both directions and marks will be made on the stationary part of the shoulder base responsible for yaw at the extreme of each rotation. These marks will align with a reference mark on the rotating piece. A protractor will be used to measure the angle between these points from the rotational axis to ensure it is 90°.

MESDP305-T-006: Glove Fitting Test

Objective: The arm/hand must fit within the NES Power Glove so that the hand can control the glove and Super Glove Ball can be played.

Qualification Method: (D)

Requirement Addressed: [MESDP-305-06] The arm shall fit the NES power glove.

Equipment Needed: Camera

Procedure: The inputs to slightly close the fingers will be inputted to the hand, so that they converge and allow for the NES Power Glove to slip on. The glove will then be manually adjusted until it is determined that the robotic fingers are correctly positioned within the fingers of the glove and the glove is correctly oriented to allow for it to output controls to the game. The proper fit will then be photographed to include in verification documents.

MESDP305-T-007: Shoulder Stabilization Test

Objective: The shoulder base must be stationary during usage to prevent rocking and sliding due to the swinging of the arm. This test will verify if the 4.5 kg weight is sufficient in preventing movement.

Qualification Method: (D)

Requirement Addressed: [MESDP-305-07] The base of the arm shall be fixed to a surface during operation.

Equipment Needed: Video camera

Procedure: Various game-like movements will be inputted to the arm so it will swing (in pitch and yaw) at maximum speed. The base will be observed and video recorded to ensure there is no movement and that it is stable.

MESDP305-T-008: Free Movement Test

Objective: The robotic arm must move (in pitch, yaw, rotation, and finger movement) in a smooth, uninterrupted motion, similar to how the user's arm moves, in order to be used to play Super Glove Ball as if the glove were being worn by a person and not a robot.

Qualification Method: (D)

Requirement Addressed: [MESDP-305-08] Movement of the arm shall be uninterrupted.

Equipment Needed: Video camera

Procedure: The robotic arm will be inputted with controls that would be seen in game in all 4 types of movement (pitch, yaw, rotation, and finger movement) at various speeds. The subsequent movement of the arm and hand will then be monitored and recorded to ensure there is no detectable lag or jerkiness.

MESDP305-T-009: Concealed Wires Test

Objective: The wires should be concealed in both the arm and shoulder to have more visual appeal and to keep wires from being tangled during use.

Qualification Method: (I, D)

Requirement Addressed: [MESDP-305-09] The arm shall have concealed all wires and other exposed components.

Equipment Needed: Camera, video camera

Procedure: The arm, once fully assembled with the NES Power Glove on, will be visually inspected to verify no wires are protruding where they should not be, which is only the rear end of the shoulder. The arm will then receive various movement inputs to ensure that no wires come

out or tangle during operation. Photos and videos will be taken to document the state of the wires before, during, and after usage.

MESDP305-T-010: Power Source Test

Objective: The robotic arm will be operating and powered by an external power source. The test will show if the provided power is enough for the robotic arm to operate

Qualification Method: (D)

Requirement Addressed: [MESDP-305-010] The arm shall be plugged into a power source to operate as opposed to using batteries to charge.

Equipment Needed: Camera

Procedure: The arm will be turned on, respond to controller inputs, and turned off while being recorded.

MESDP305-T-011: Game Response Test

Objective: Verify that the robotic arm accurately responds to user inputs from the control glove and interacts correctly with the NES Power Glove in the game. Ensure minimal input lag and proper movement synchronization between the user and the robotic arm.

Qualification Method: (T)

Requirement Addressed: [MESDP-305-11] The system shall be responsive to inputs, for the game “Super Glove Ball”.

Equipment Needed: Camera, Video Camera, Stopwatch, NES console

Procedure: Power on the system, establish Bluetooth connection, perform predefined hand gestures, observe robotic arm and game response, measure input lag, and verify accuracy.

MESDP305-T-012: Integration Test

Objective: Verify that all system components (control glove, ESP32 communication, robotic arm, and NES Power Glove) work together seamlessly as an integrated system.

Qualification Method: (A, T)

Requirement Addressed:[MESDP-305-12] The system shall interface with the control device of the corresponding project ECDP-526. [A, T]

Equipment Needed: Camera for Recording Video

Procedure: Power on all components, establish Bluetooth communication, perform synchronized movement tests between the control glove, robotic arm, and NES Power Glove, and verify accurate data transmission and system functionality.

MESDP305-T-013: Disassemble Test

Objective: The robotic arm will be successfully disassembled without the usage of Power Tools

Qualification Method: [T]

Requirement Addressed: [MESDP-305-13] The arm shall be able to be disassembled using non-power tools. [T]

Equipment Needed: Screwdriver (or other non-power tool), Camera

Procedure: After completing the Expo, transport the arm into a private space with adequate space to disassemble (an average table should work fine), use screwdrivers to take apart the arm at all parts where screws are present, making sure to utilize a logical order to minimize potential damage, record process (perhaps in timelapse), take before and after photos of parts to confirm no damage.

MESDP305-T-014: Budget Test

Objective: The total cost of manufacturing for the project will remain within the $1000 budget provided by our client

Qualification Method: [D]

Requirement Addressed: The arm system shall remain within the budget given by the sponsor TechWorks ($1,000)

Equipment Needed: Excel Spreadsheet or Calculator

Procedure: Strategically select cost friendly products when ordering for our parts list, use calculator or Excel spreadsheet to ensure the sum of the products is below $1000, create a budget table to keep track of all parts and their respective costs.

Appendix B: Project Specifications

1. Project Specifications

1.1. System Capability Requirements

[MESDP-305-01] The robotic arm fingers shall extend outwards to 180 degrees. [D]
[MESDP-305-02] The robotic arm fingers shall curl 90 degrees to each joint on the finger. [D]
[MESDP-305-03] Wrist mechanism of the arm shall rotate +/- 90 degrees. [I]
[MESDP-305-04] The arm pitch shall be +/- 90 degrees. [I]
[MESDP-305-05] The arm yaw shall be +/- 90 degrees. [I]
[MESDP-305-06] The arm shall fit the NES power glove. [D]
[MESDP-305-07] The base of the arm shall be fixed to a surface during operation. [D]
[MESDP-305-08] Movement of the arm shall be uninterrupted. [D]

Stretch Goals

[MESDP-305-09] The arm shall have concealed all wires and other exposed components. [D]
[MESDP-305-010] The arm shall be plugged into a power source to operate as opposed to using batteries to charge. [D]

1.2. System External Interface Requirements

[MESDP-305-11] The system shall be responsive to inputs, for the game “Super Glove Ball”. [T]
[MESDP-305-12] The system shall interface with the control device of the corresponding project ECDP-526. [A, T]

1.3. Maintenance Requirements

[MESDP-305-13] The arm shall be able to be disassembled using non-power tools. [T]

1.4. Project Business Requirements

[MESDP-305-14] The arm system shall remain within the budget given by the sponsor TechWorks ($1,000). [D]

https://docs.google.com/document/d/1p48C0bLGMuA0nqLUBpZJSK7sJcPtLbewScaXXl6gNOA/edit?tab=t.0