Design and Development of Multi-functional Robotic Walker

GROUP 40

LITERATURE REVIEW PRESENTATION

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Outline

- ✓ Introduction
- ✓ Autonomous Mobility System
- ✓ Walking Assistance System
- ✓ Standing Support System
- ✓ Progress & Future Work

Introduction

Traditional Walkers
vs
Robotic Walkers

What are the
Functionalities
of the Walker?

Aim

Objectives

Robotic Walkers are equipped advanced features such as obstacle avoidance, fall detection, gait analysis, smart assistance, etc.

What are the Functionalities of the Walker?

Aim

Objectives

Traditional Walkers
vs
Robotic Walkers

What are the Functionalities of the Walker?

Aim

Objectives

Traditional Walkers
vs
Robotic Walkers

1. Autonomously navigate to user's location
2. User Operating Height Adaptation
3. Real-time Active Walking Guidance
4. User Assistance from sitting to standing position

Aim

Objectives

Traditional Walkers vs Robotic Walkers

What are the Functionalities of the Walker?

Aim

Objectives

Traditional Walkers
vs
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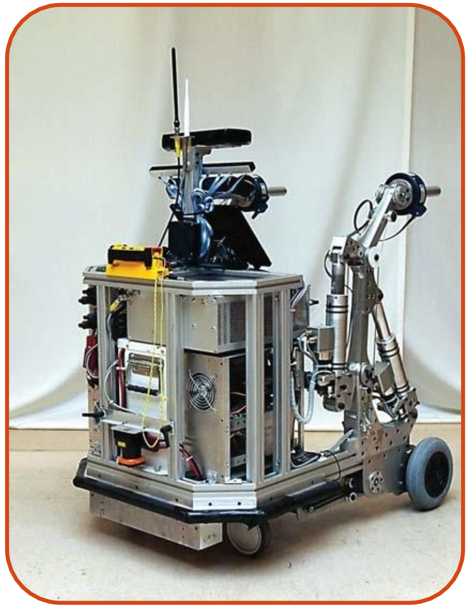
What are the Functionalities of the Walker?



To improve the daily lives of individuals with mobility challenges, using assistive robotic technology.

Objectives

Traditional Walkers
vs
Robotic Walkers

What are the Functionalities of the Walker?

Aim

Objectives

Traditional Walkers
vs
Robotic Walkers

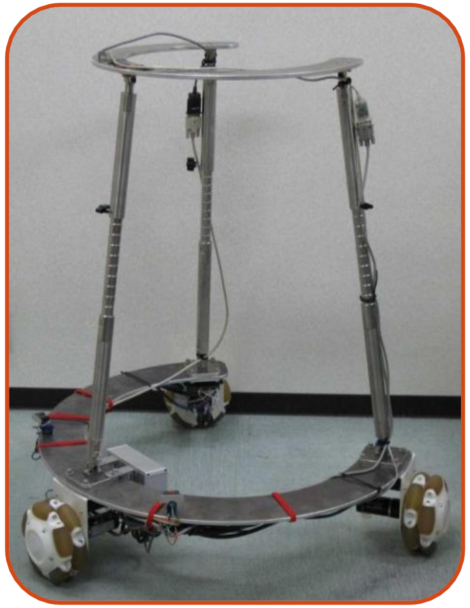
What are the
Functionalities
of the Walker?

Aim

1. Study the existing problems associated with mobility and identify key focus areas, research gaps.
2. Design and development of an appropriate mechanical structure for the platform of walker.
3. Development of the autonomous navigation system, walking guidance system, and standing assistance system of the walker.
4. Testing and validation of the developed robotic walker.

Traditional Walkers
vs
Robotic Walkers

What are the
Functionalities
of the Walker?



Aim

Objectives

Autonomous Navigation System

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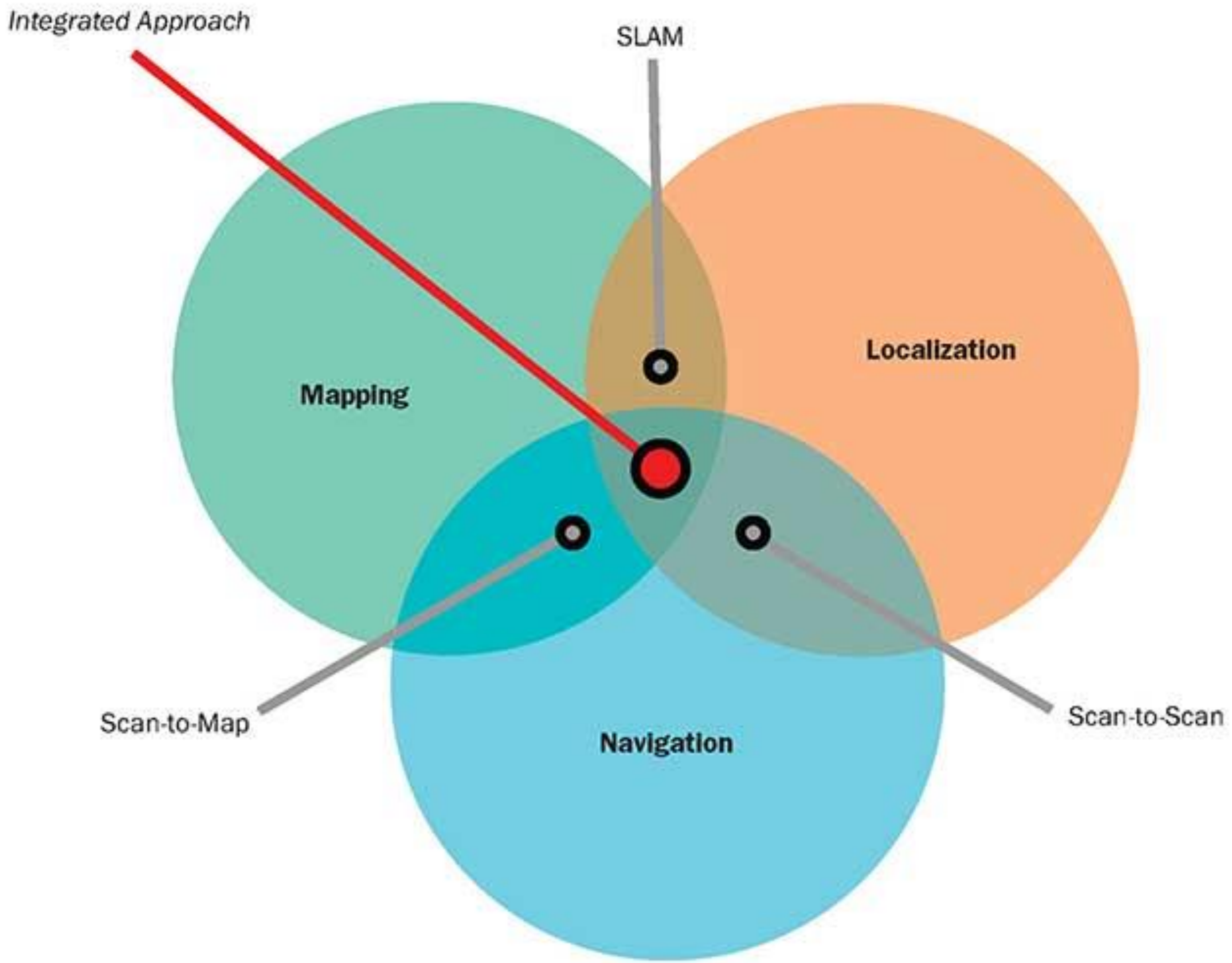
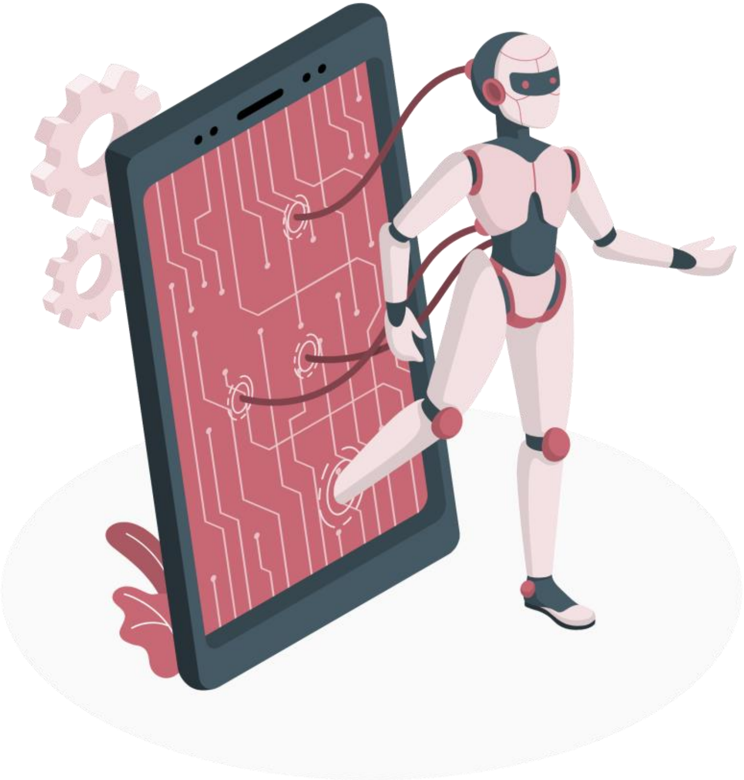
Central Focus Areas

1. Map building
2. Path planning
3. Localising
4. Obstacle detection
5. Software platform



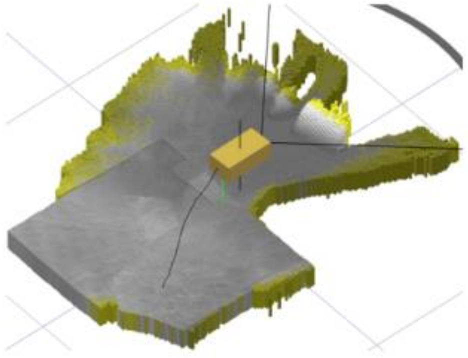


Analyzed Robots

1. Boston Dynamics' BigDog
2. DALi's C-Walker
3. I-Walk Assistive Robot

BigDog

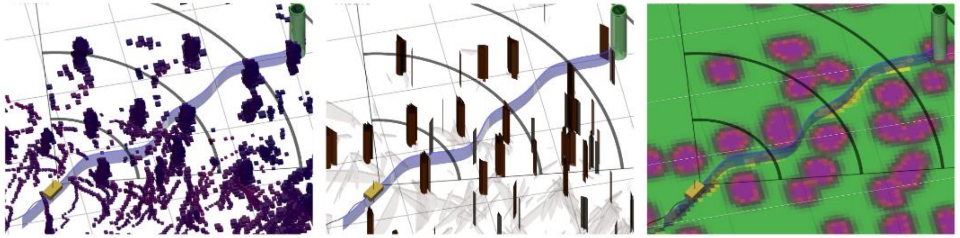
BOSTON DYNAMICS

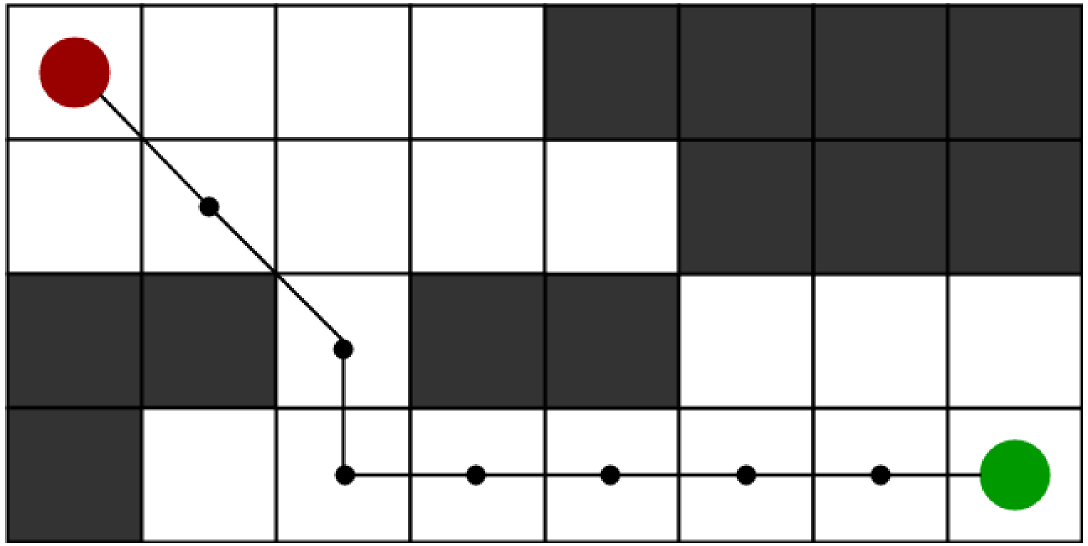


Map Building

2 sensors used

Uses point cloud segregation algorithm to combine data.





Path Planning

Adapted A* Algorithm

Spline Smoothing Algorithm

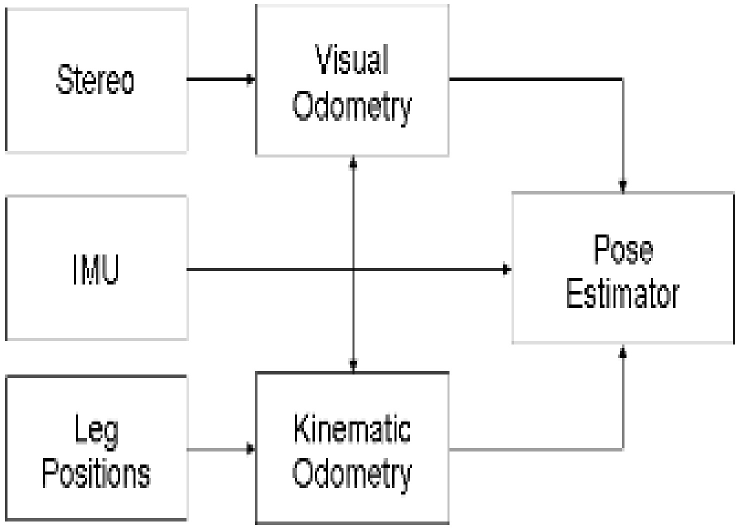
Robust and effective

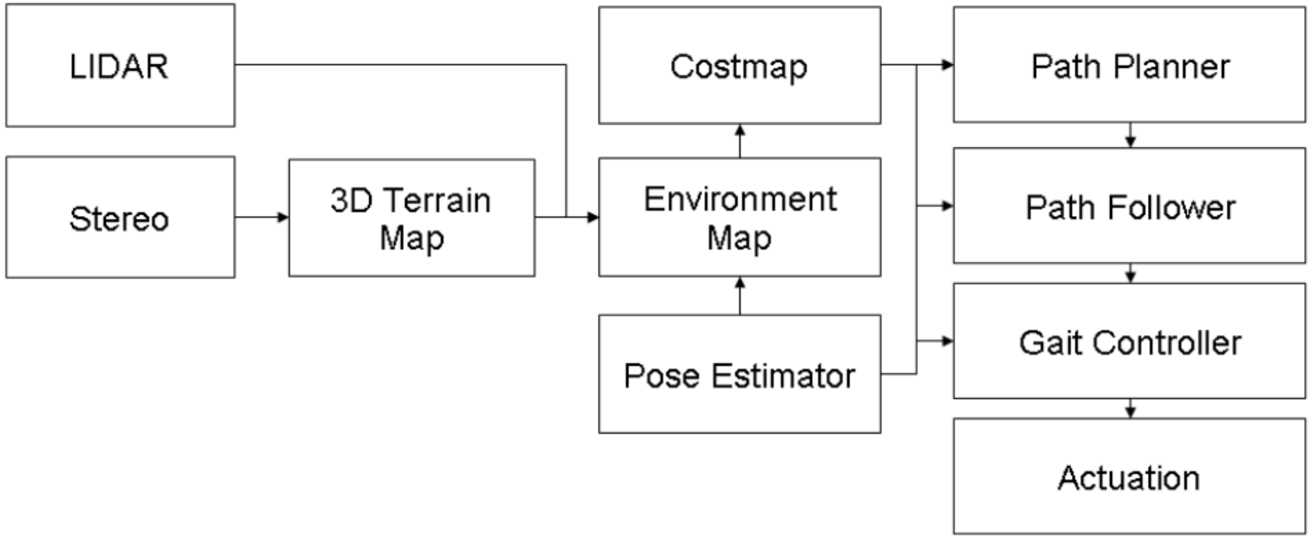
Localization

State-of-the-art Force and Joint Sensors

Stereo camera

Joining algorithm for the 2 data

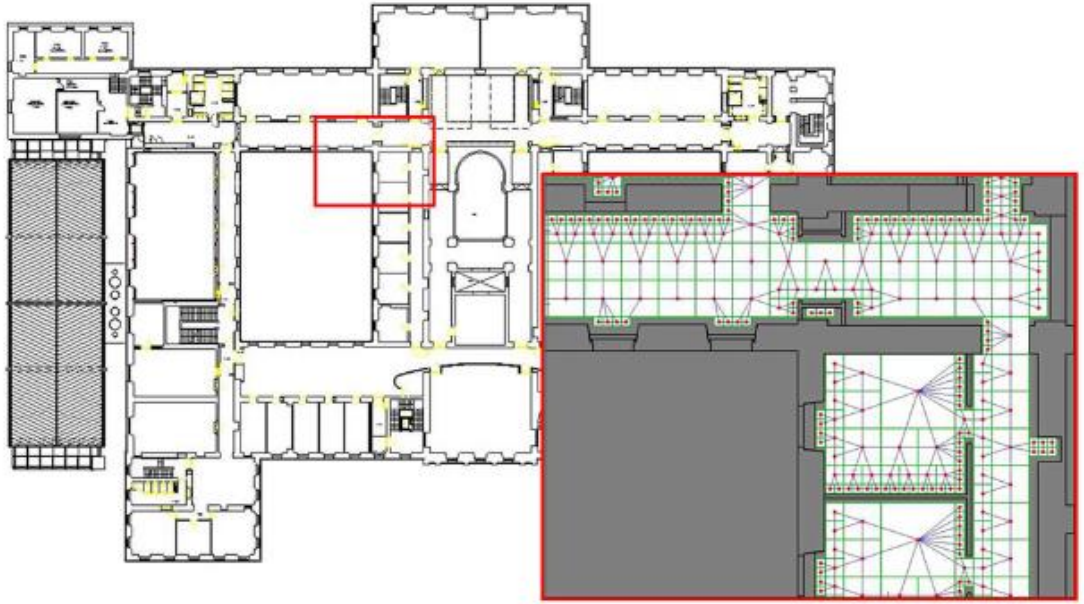




Software Architecture

C-Walker

DEVICES FOR ASSISTED LIVING



Map Building

Assumption

A plan view of the area exists.

Algorithm

Cell Decomposition Method

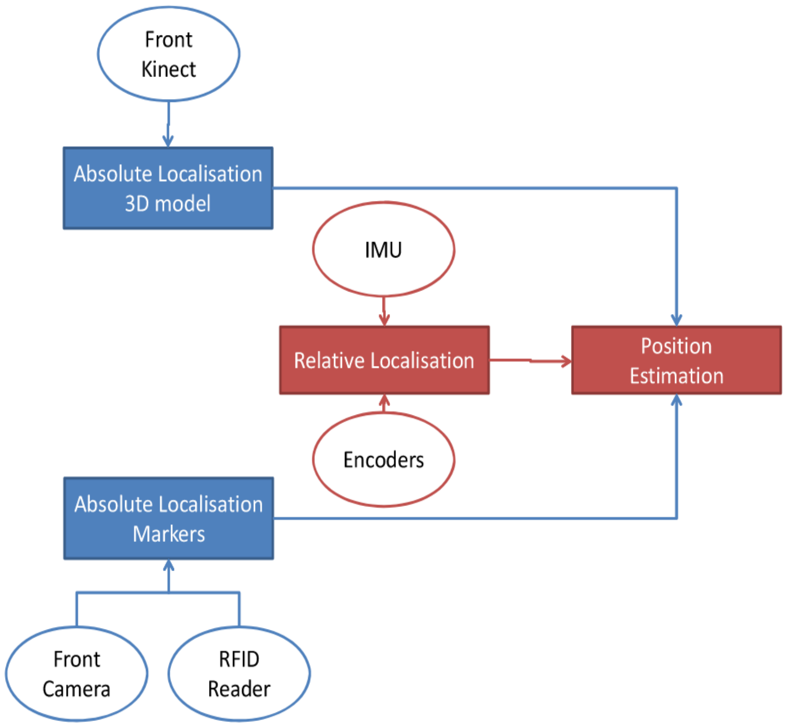
Localization

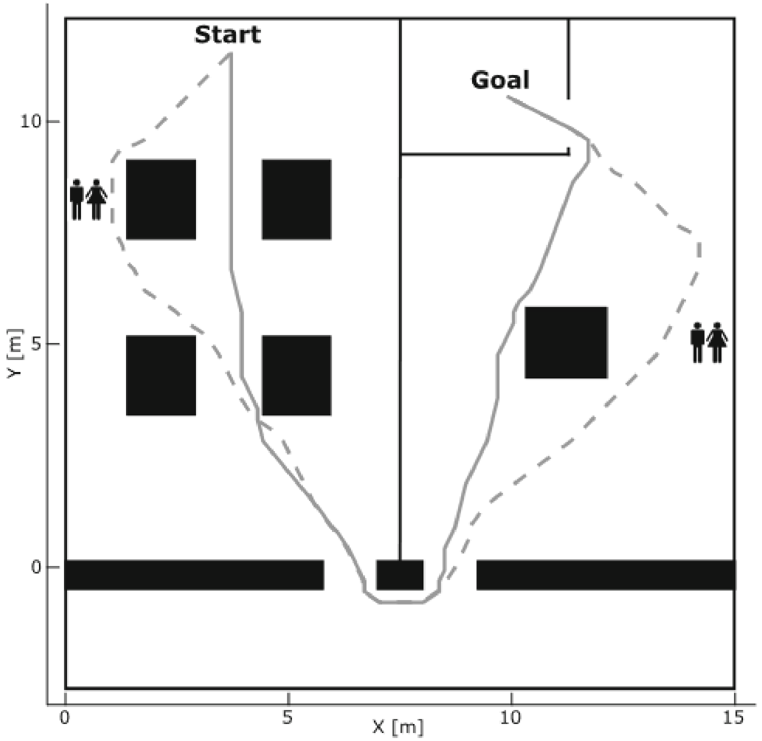
Uses both **relative localization** and **absolute localization.**

Relative → (IMUs + Encoders)→High rate pose estimates

Absolute → RFID Tags + Visual Markers

→ Kinect Sensor





Path Planning

Long Term Planner

Previously built map + User preferences → Dijkstra Shortest Path Algorithm → Path

Short Term Planner

Dynamic obstacles → Social Force Model + Statistical Model Checking → Short-term Path

I-Walk Assistive Robot

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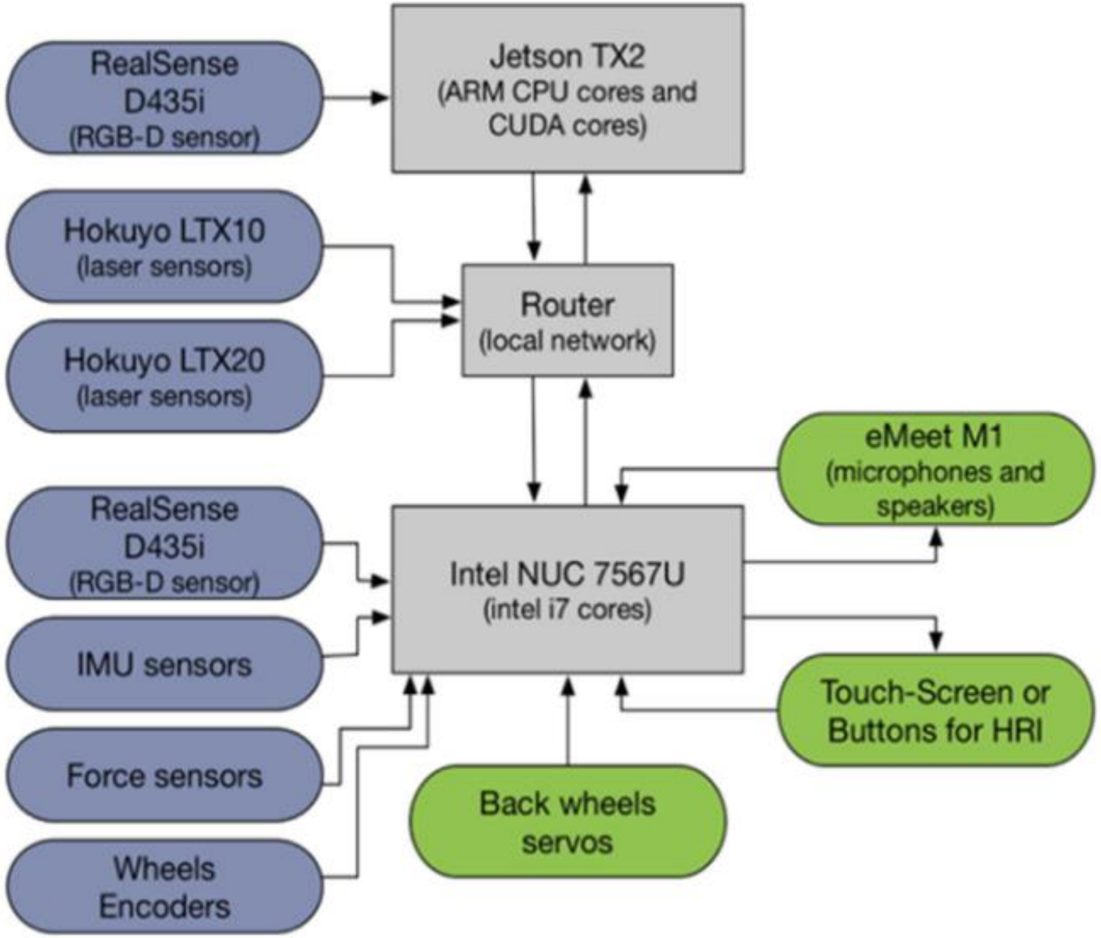


System Architecture

Map Building

Robot does not have map building function.

Existing map → Global Obstacle Cost Map

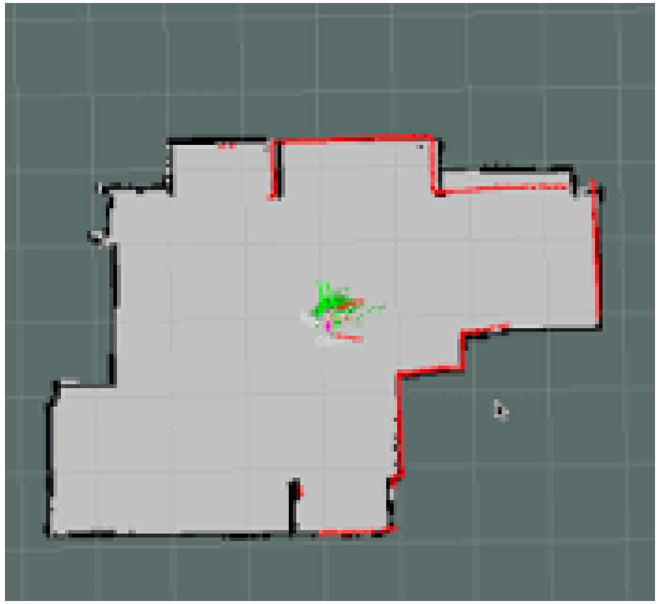
Path Planning

2 layers: Local Planner and Global Planner

Dijkstra's Algorithm

Trajectory Rollout and Dynamic Window Approach

Localization



Adaptive Monte Carlo Localisation (AMCL)

Particle filter → Pose of Robot

Gaps Identified

Lack of complete ROS Navigation Stack use in rollators

Lack of Sound Source Localisation (SSL) and goal setting in rollators

Lack of multi-model user interface

Lack of systems with manageable computational requirements.

Future Work

Future Work

Test navigation stack on prototype

Refine and tune its parameters

Integrate SSL for goal setting

Research Path

- Test navigation stack on prototype
- Performance Evaluation
- Algorithm Optimization and fine-tuning
- Sensor Fusion and Perception Enhancement on Main Robot
- Advanced Feature Integration
- Real-World Testing
- Deployment Planning
- Documentation and Reporting

Walking Guidance System

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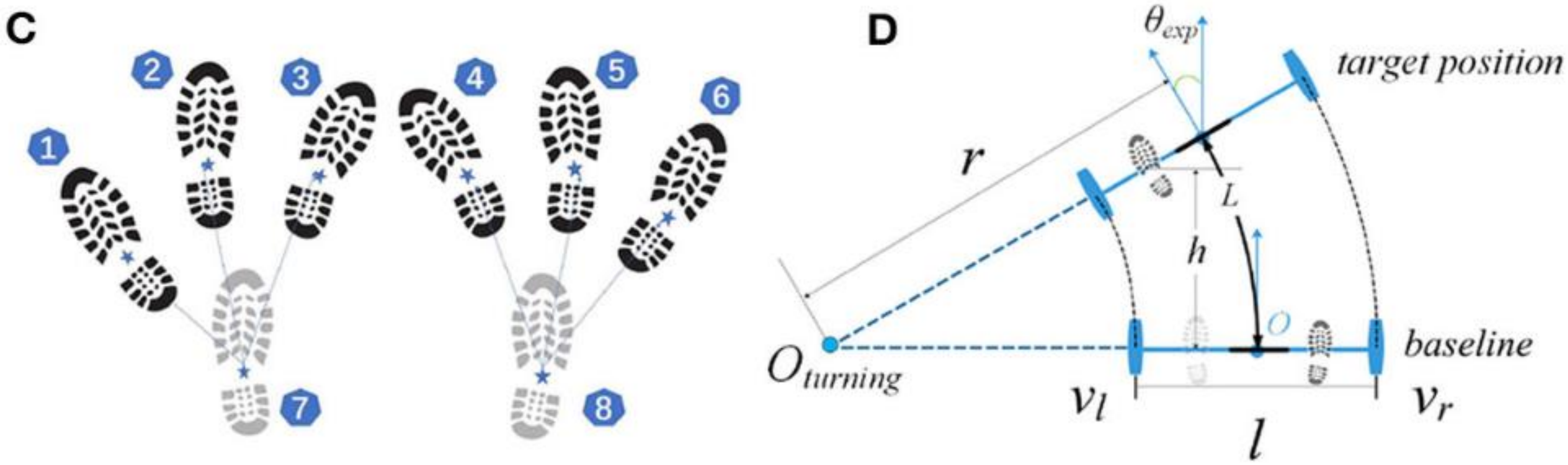


Figure 01 Detection of the position of feet [1]

- Tracks users by detecting lower limb motion
- Measures force pressure on a soft-robotic handle
- Predicts emergency scenarios like falling
- Uses infrared temperature and lidar sensors for gait data
- Trains a neural network (NN) model to understand user intention
- Computes target position to align with user's foot orientation and motion.

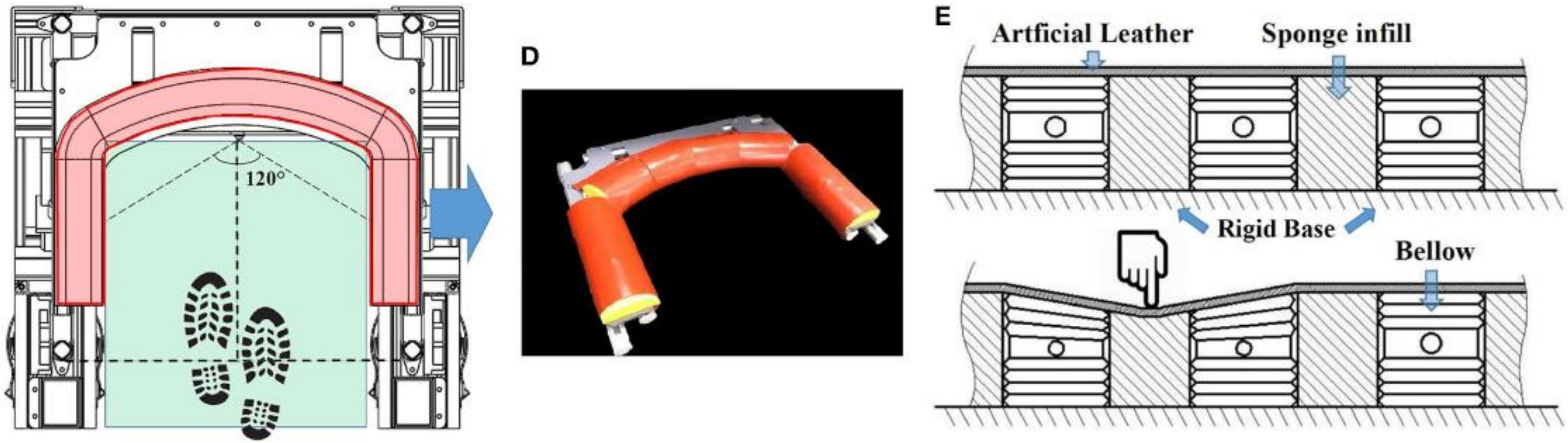


Figure 02 Soft Robotic Handle [1]

- Soft robotic layer as user interface
- Rigid acrylic board in handle's core for load transfer
- Multiple air pressure measuring bellows with sensors inside handle
- Two sensors on the handle for speed settings
- Left sensor for acceleration, right sensor for deceleration
- Only one button response at a time for safety

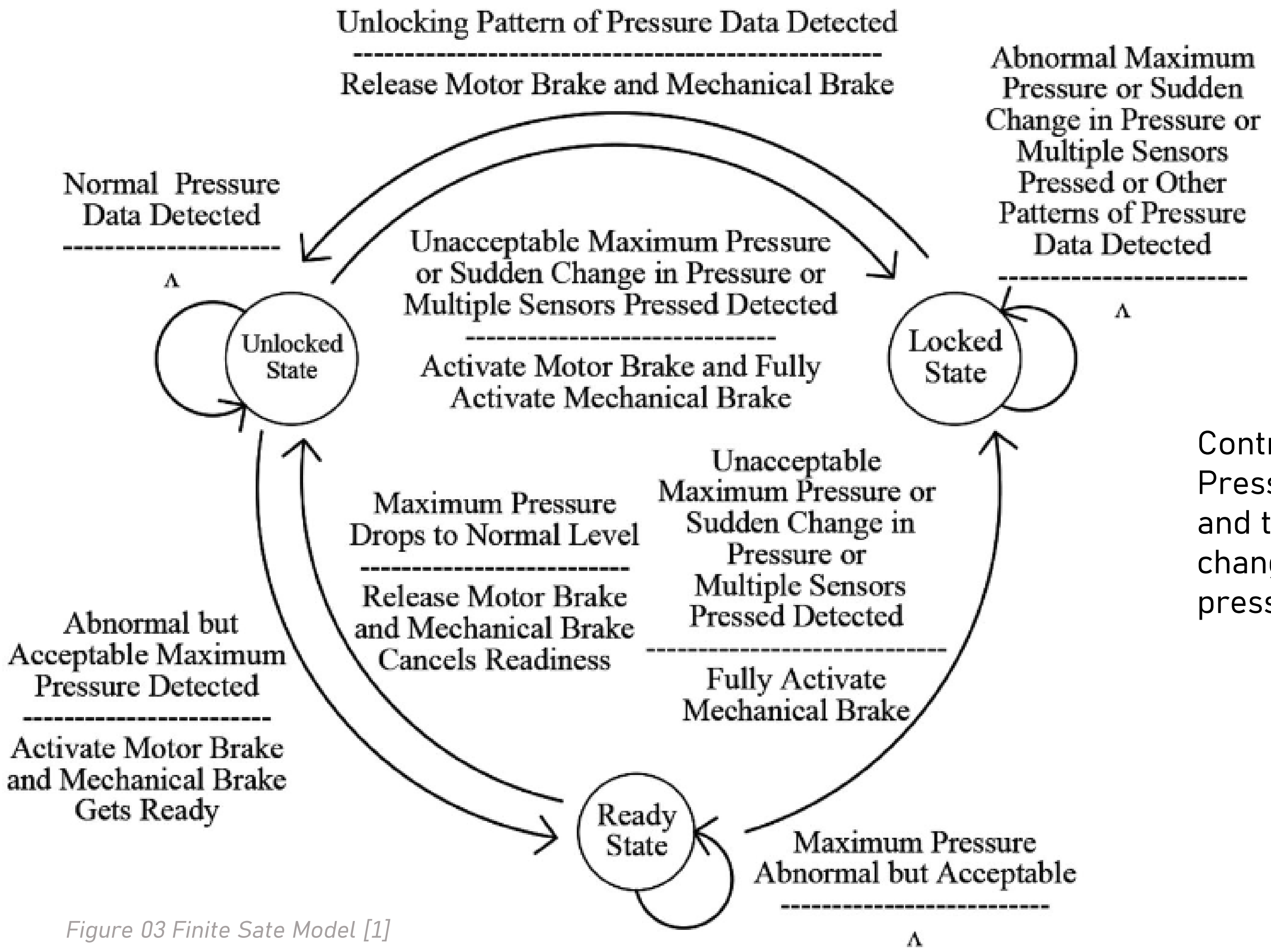
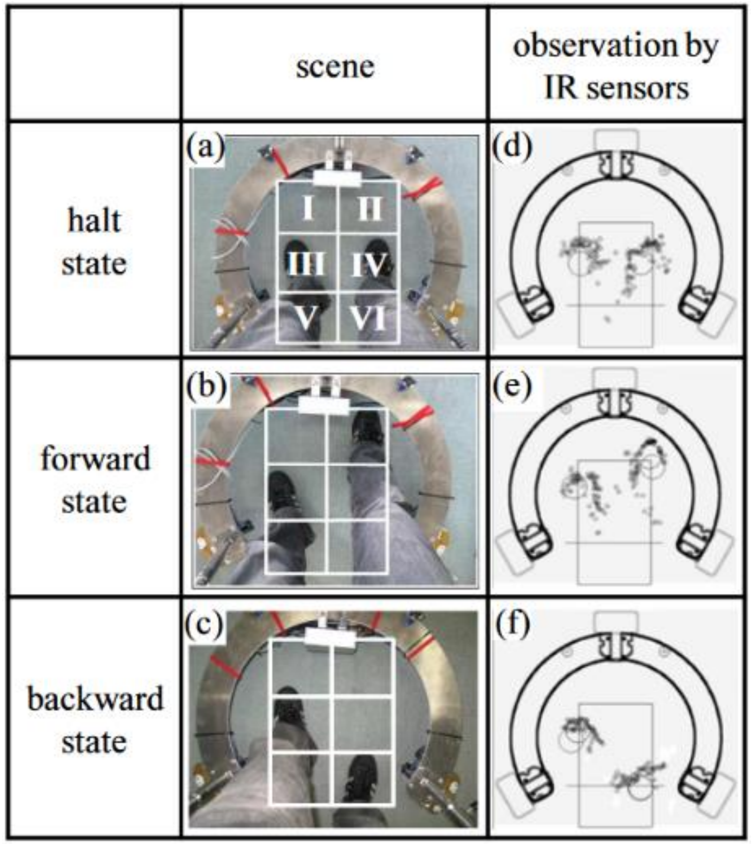


Figure 03 Finite Sate Model [1]

Control based on Pressure changes and the rate of changes of pressure type

LEE ET AL. [5]

- Infrared sensors determine user's lower limb states
- Automatic control of velocity without physical controls
- Lower leg modeled as a cylinder with radius 'd'
- Infrared sensors spin horizontally to measure shin location



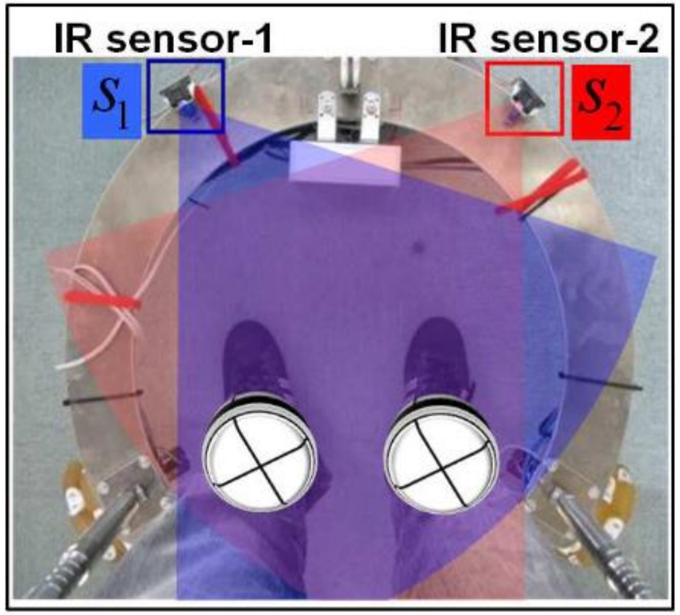


Figure 04
Mobility state identification by IR sensors [5]

- Base frame area is modelled as a rectangle with six grids
- Five empirical patterns of shin location observed
- Standstill state at positions III and IV, left and right legs in odd and even grids
- Forward state if one shin at III or IV and the other at I or II
- Backward state if lower leg at V or VI
- Main controller outputs velocity matrix with specific values based on forward or reverse state.

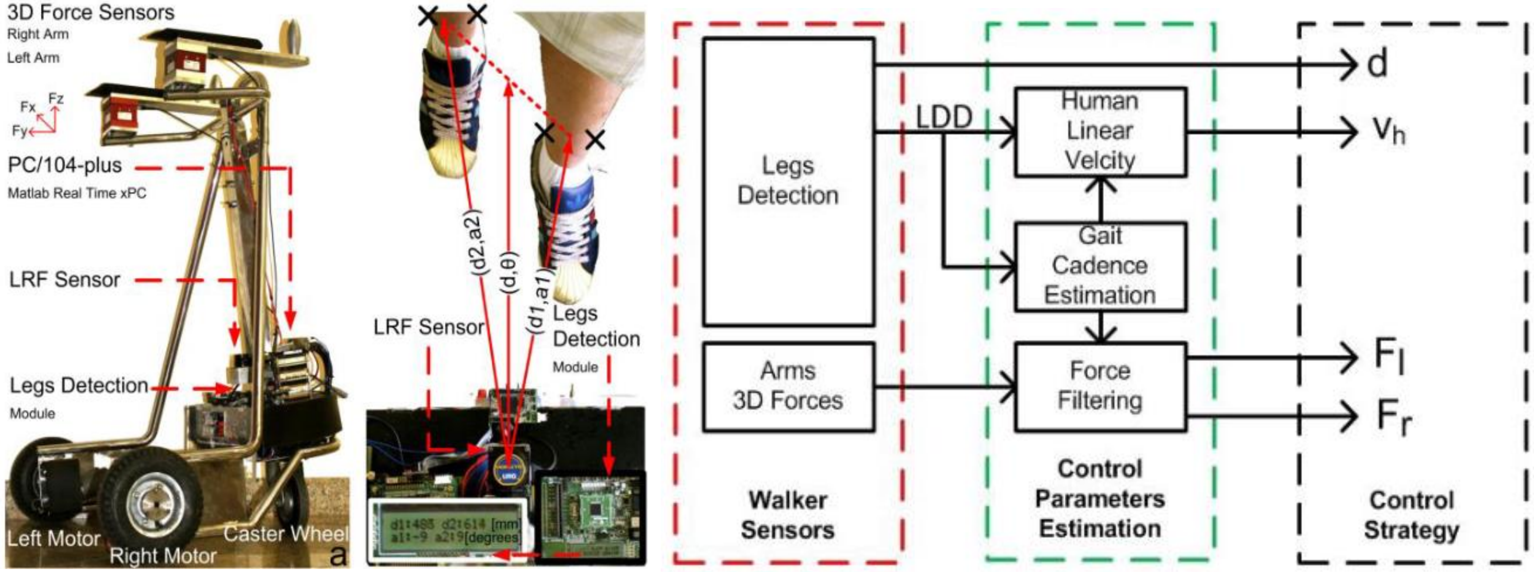


Figure 05 Sensor fusion architecture [12]

- A sensor fusion architecture is proposed.
- Integrates upper limb reaction forces with leg localization for walker control
- Distance between left and right legs (d) measured with LRF sensor
- LDD (Legs Difference Distance) measures separation between legs (d1 - d2)
- LDD used for adaptive filters and human linear velocity calculation
- Gait cadence and step amplitude is also used to calculate human linear velocity.

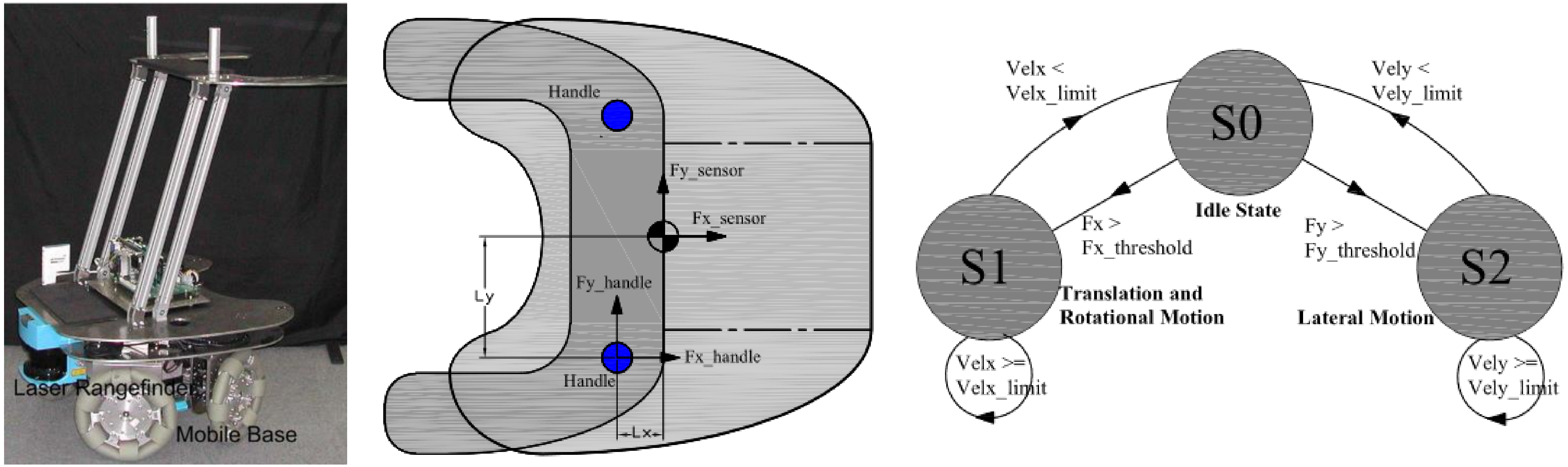


Figure 06 Omnidirectional mobile base, Sensor arrangement and state transition diagram [9]

- Uses applied force for velocity regulation with an omnidirectional mobile base which enables lateral motion
- Lateral motion is useful in crowded environments or in situations where user wants to reach something at its sides
- System includes active states and idle state
- Active state for translational or lateral motion
- Active states not directly connected to avoid oscillations when changing state.

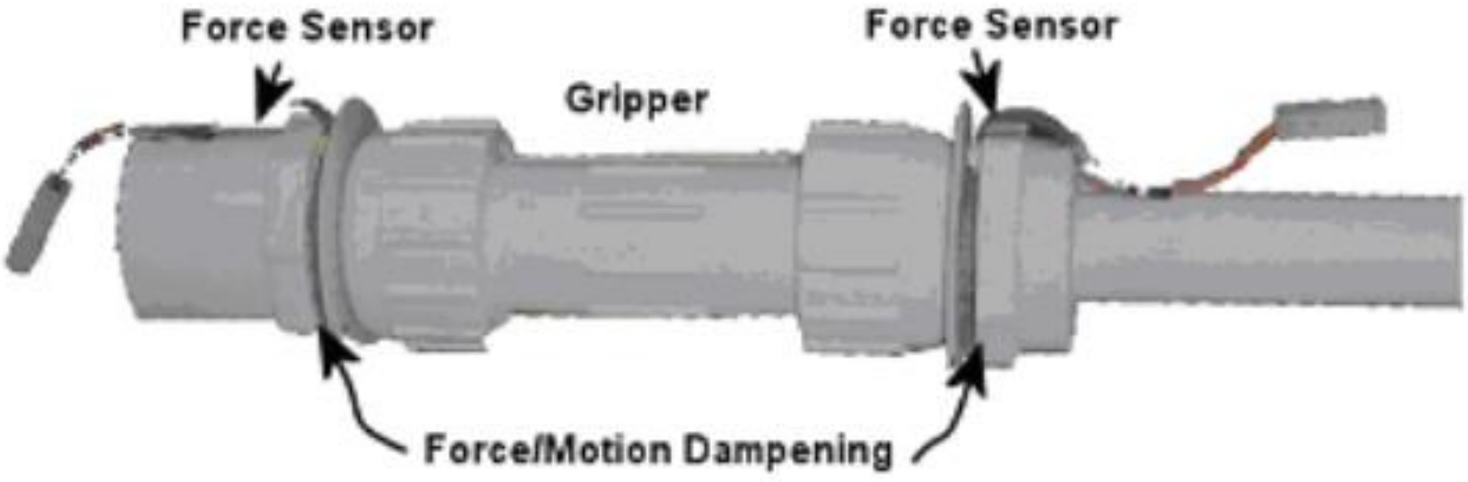


Figure 07 Haptic Interface implemented by Morris et al. [7]

- Haptic interface in walker's handlebar frame using force sensors
- Two force-sensing resistors in the foam detect pressure when force is applied
- Pressure values converted into planar rotational and translational velocities
- Forward push on handlebars makes the robot move forward
- A differential push-pull combination causes rotation
- A tug on handlebars stops the walker for simplicity in control.

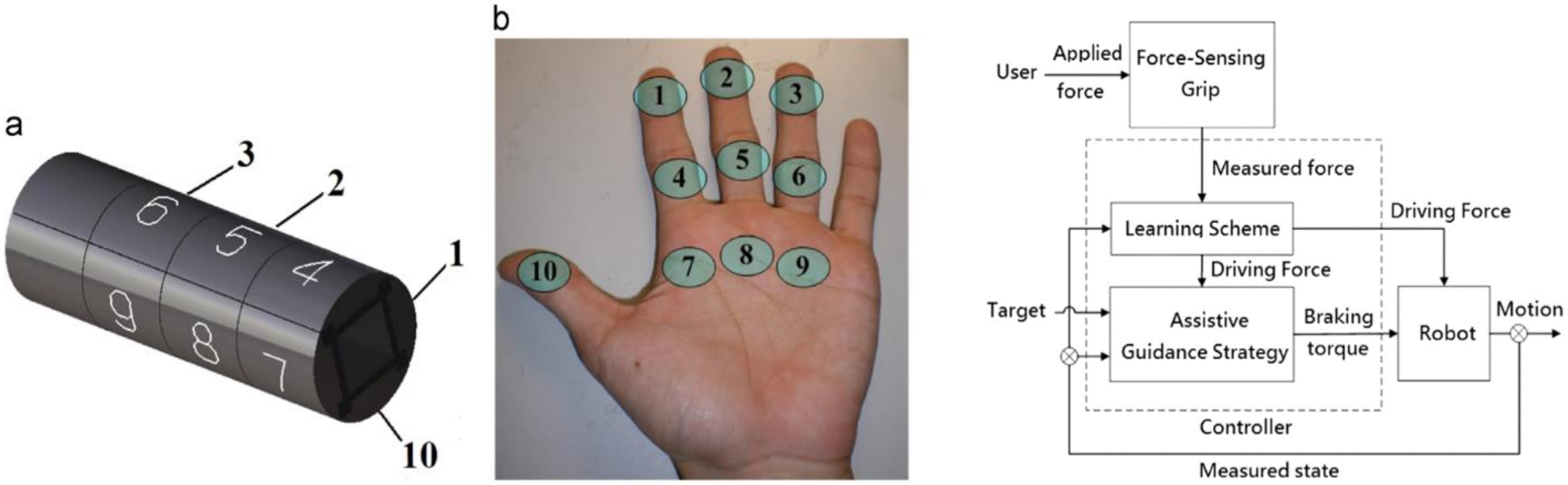


Figure 08 Force-sensing handles and system block diagram [7]

- Similar approach using two force-sensing handles which measure user-applied force
- An intelligent learning scheme calculates driving force from grip force
- Relationship between user's force and walker's motion established
- Learning scheme uses grip force and velocity as inputs, driving force as output
- Fuzzy technique employed to handle the fuzziness in the formulation and mapping between user's force and observed grip force.

Figure 09 Haptic bracelet for guidance assistance [11]

- Wearable haptic bracelets with two cylindrical vibro-motors
- Vibro-motors produce vibratory signals to alert the user
- One bracelet on each arm for optimal stimulus separation
- Right bracelet activation signals a right turn
- Left bracelet activation signals a left turn
- No feedback from either bracelet advises going straight.

Figure 10 Binaural guidance assistance [11]

- Acoustic interface described uses synthetic signals.
- Guides the user in the direction they should go in through a headphone.
- Binaural theory enables directional sound perception
- Sound direction guides user's movement (e.g., turn left)
- Left/Right Guidance sets virtual sources at 90° or 180° for left or right turns
- Audio Slave software module uses spatial coordinates for sound source
- Cartesian coordinates transformed into relative polar coordinates (r, θ)
- Binaural Guidance offers more specific directional information than just suggesting a turn.

Control Strategy	Neural network (NN) model, Finite State Model (FSM)	Optimal control, selective braking	Fuzzy logic, grip force learning scheme	State-based operation, lateral motion	Path-following control, virtual corridor
User Interface	Soft robotic handle	Plush armrests	Haptic handle	Haptic bracelets	Force-sensing handles
User Feedback	Lower limb motion	Force Feedback	Haptic feedback	Grip force, grip force learning scheme	Acoustic signals
Sensors	Infrared sensors	Cameras	Force-sensing resistors	Laser Range Finder (LRF)	Pressure Sensors
Additional Features	Emergency scenario detection	Stumble detection	Walker locking mechanism	State-based operation	User-controlled and robot-controlled modes

Research Gap

1. Improved control transitions (User, Robot, Controller)
2. Mobility support for a wide range of users with different needs and preferences
3. Integrating sensory modalities
4. Safe and reliable operation in complex environments
5. User learned algorithms to provide customized walking support

Research Constraints

1. Accuracy and reliability of control
2. User preference on wearing sensors (Headphones, Haptic bracelets, etc.)
3. Cost of sensors
4. Processing Power Requirement: On-board processing power and battery life restrictions.
5. Limited data availability: Lack of real-world user data for algorithm development.
6. Computational limitations: On-board processing power and battery life restrictions.
7. Privacy and security concerns: Ensuring user data privacy and security.
8. Need for better integration with other assistive technologies
9. Need for more user-friendly interfaces

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Walking Guidance System

Research Path

1. Design and Development of Testing Platform
2. Selecting suitable Force-Sensitive Resistors
3. Designing armrest to optimally place arms for control input
4. Fabrications of armrests & Installation of FSRs on armrests
5. Mapping Output to usable range for active motor control
6. Designing tests and obtaining results to fine tune parameters
7. Integrating Guidance system with the rest of the system
8. Running system tests after integration

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Standing Support System

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Standing, Walking, and Sitting Support Robot Based on User State Estimation Using a Small Number of Sensors

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Design and Structure

- Walker type robot with an armrest with grippers.
- Consist of two wheels with brakes, and four castors.
- Equipped with three distance and four touch sensors.
- A linear actuator is used to adjust the height of the armrest during standing-to-sitting and vice versa.

Design Specifications

Specification	Value	Unit
Height	77-103	cm
Armrest Height	71-97	cm
Length	50	cm
Width of the Armrest	46	cm
Width of the Robot Body	54	cm
Armrest Moving Time	4	S
Armrest Weight Capacity	40	Kg

Functions of the Robot

1. State Estimation using CoG Candidate Calculation

Sensor Data → CoG Candidate Calculation → State estimation using SVM → State

Functions of the Robot ctd.

2. Anomaly Detection

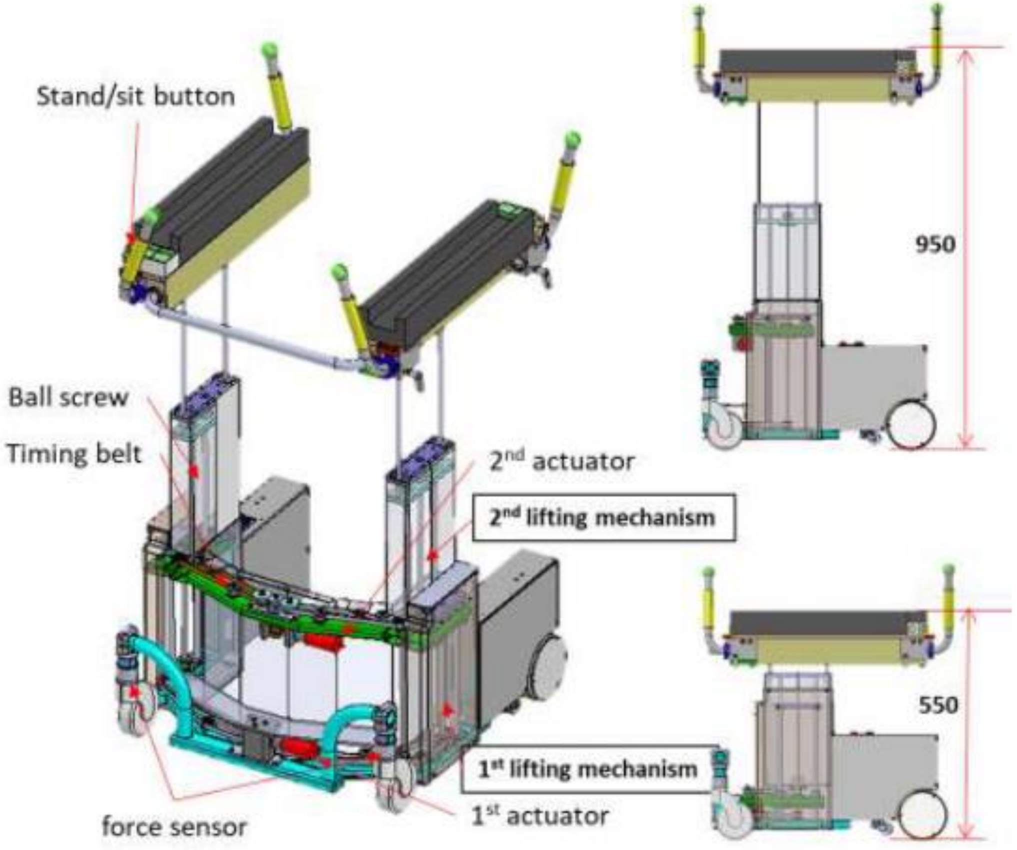
- If the user is unable to sit, stand or walk properly using the help of the walker, it is considered as an anomaly.
- Can be identified by the positions of joint candidate points given by the sensors.

Design of an Indoor Robotic Walking Care Device for Daily-Activity Activation of the Elderly

Seonghee Jeong∗, Hiroki Aoyama∗,∗∗, Satoshi Takahara∗, and Yoshiyuki Takaoka∗∗

Design and Structure

- 4-wheeled robotic walker
- Armrest height adjustment of 500mm
- Floor occupation – 600mm x 600mm
- Two switch boxes at the front and back ends o the armrest for walker controlling.
- DC brushless motored drive wheels with braki capability.

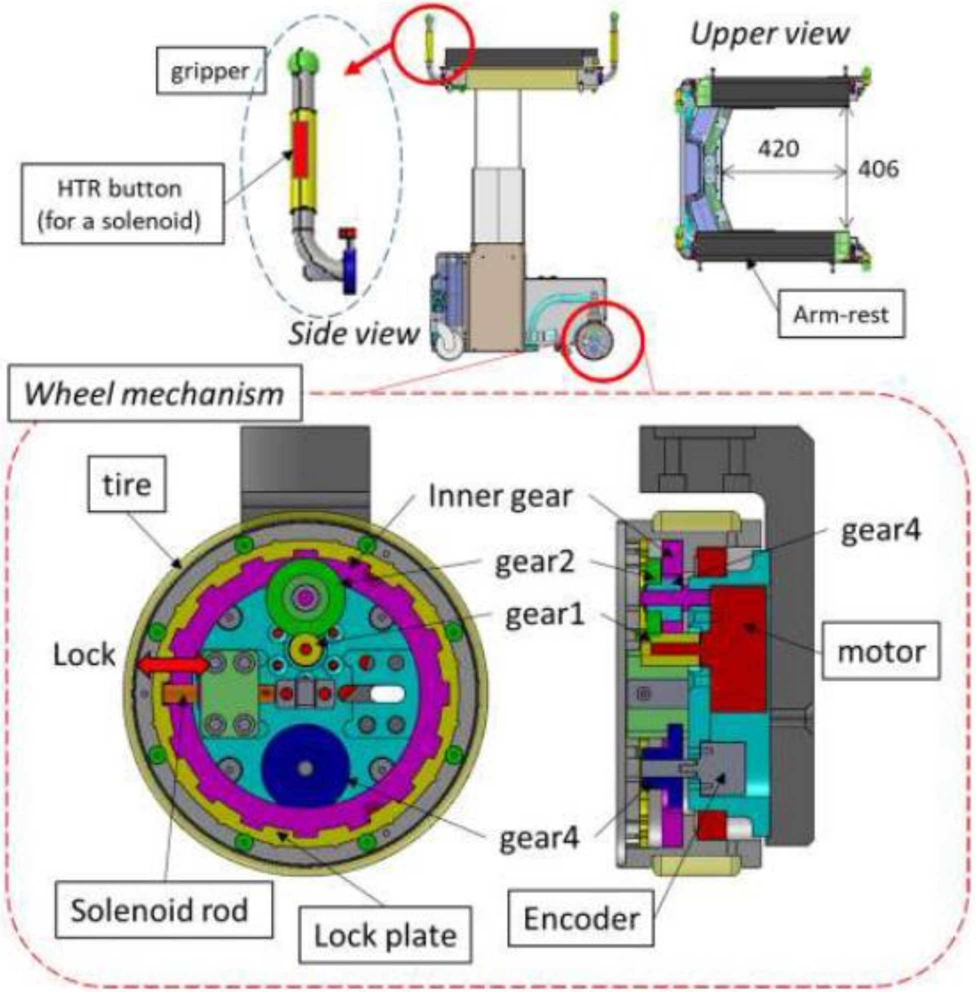


Design Criteria

- Speed of armrest movement – 250 mm/s
- Can support a weight of 400N on the armrest

Functions of the Robot

- Help to maintain upright posture while doing daily activities.
- Walking assistance with powered wheels.
- Power-assist function for standing and sitting.

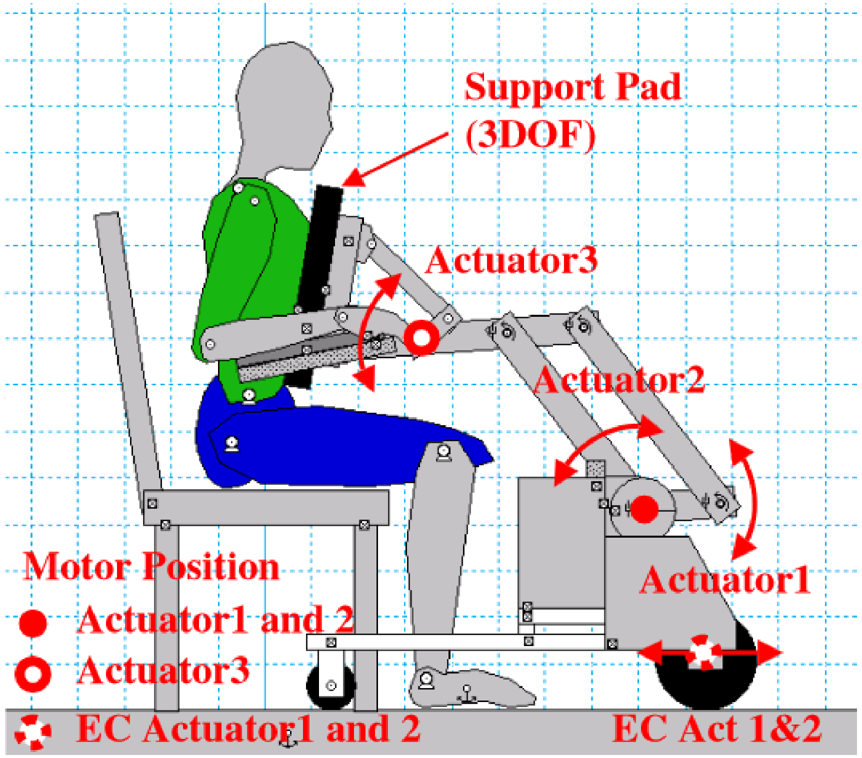


A Motion Control of a Robotic Walker for Continuous Assistance during Standing, Walking and Seating Operation

Daisuke Chugo1 and Kunikatsu Takase2

Design and Structure

- 4-wheeled robotic walker
- DC brushless motored drive wheels with electromagnetic brakes.
- Support pad with 3 DOF linkage controlled by three DC motors.
- Force sensors built into armrests and support pad.

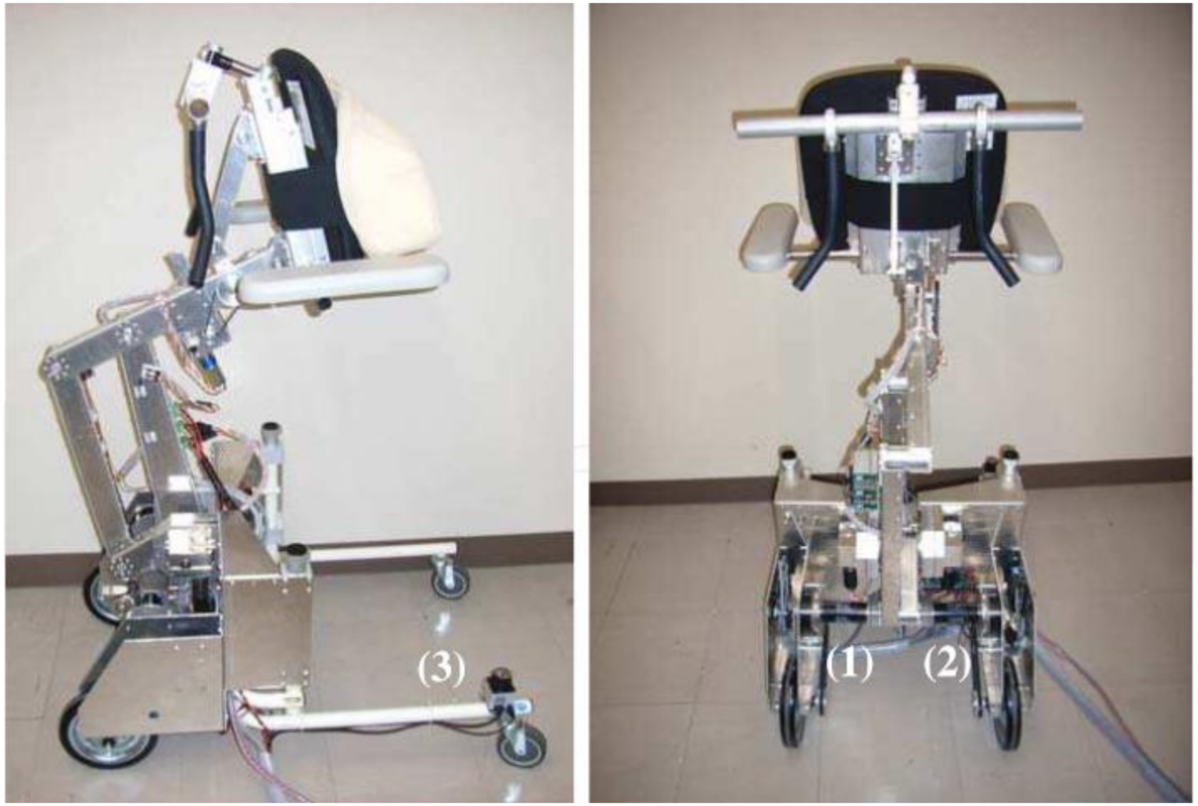


Design Criteria

- Should be able to assist a person weighing a maximum of 150Kg.
- Lift the person to a maximum height of 1.8m.

Functions of the Robot

- Walking assistance with powered wheels.
- Power-assist function for standing and sitting.
- Measure the body balance by the force sensors on the support pad.



Research Gap

- Reducing bulkiness of the base platform allowing more room for the leg movements of the user.
- Using simple and reliable actuators which requires minimum maintenance.
- Developing a robotic walker affordable for a larger community of people.

Research Path

Build Simple Robotic Platform and Conduct Motor Controlling and Testing

→ Design Base Structure in Solid Modeling Software

→ Conduct Structural Analysis

→ Fabricate Base Structure and Integrate Sit-to-Stand Mechanism

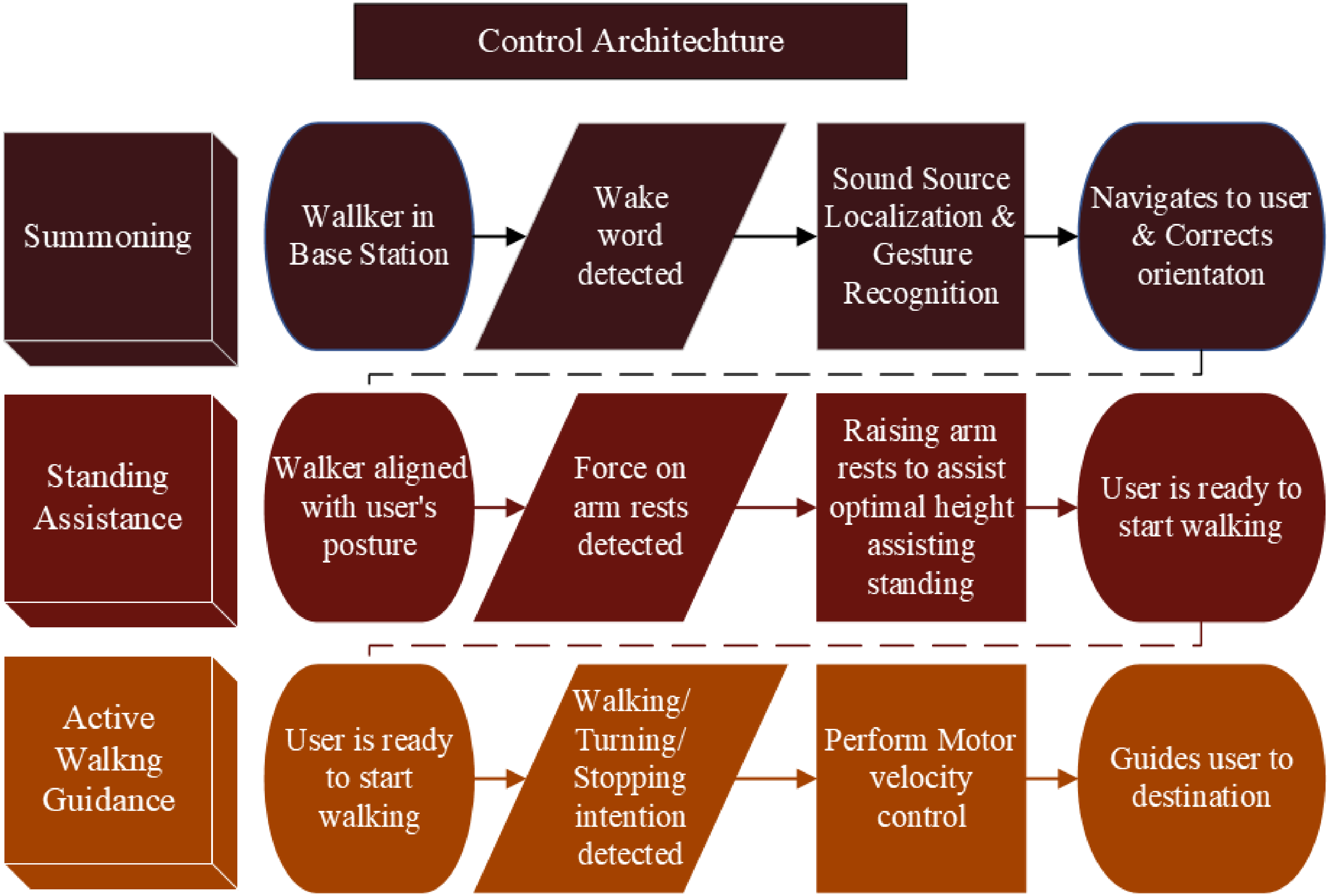
→ Design and Fabricate Armrest Platform

→ Final Testing/Evaluation and Documentation

Current Progress

Current Progress

Development of System Control Architecture



System Control Architecture

Current Progress

Development of User Summoning Algorithm

Algorithm 1 User Summoning Algorithm

```
map = generate_map_with_SLAM()
while sound_source_detected = True:
    take_360_degree_scan()
    user_gesture = recognize_gesture()
    if user_gesture is None:
        navigate = (map, sound_sound_direction,
        defined_threshold)
    else:
        exit loop
if user_gesture is not None:
    navigate_to_user(map, user_gesture)
    correct_orientation()
    recognize_user()
    if user_in_database = True:
        raise_armrest()
    else:
        calculate(user_height)
        store_in_database()
        raise_armrest()
```

User Summoning Algorithm

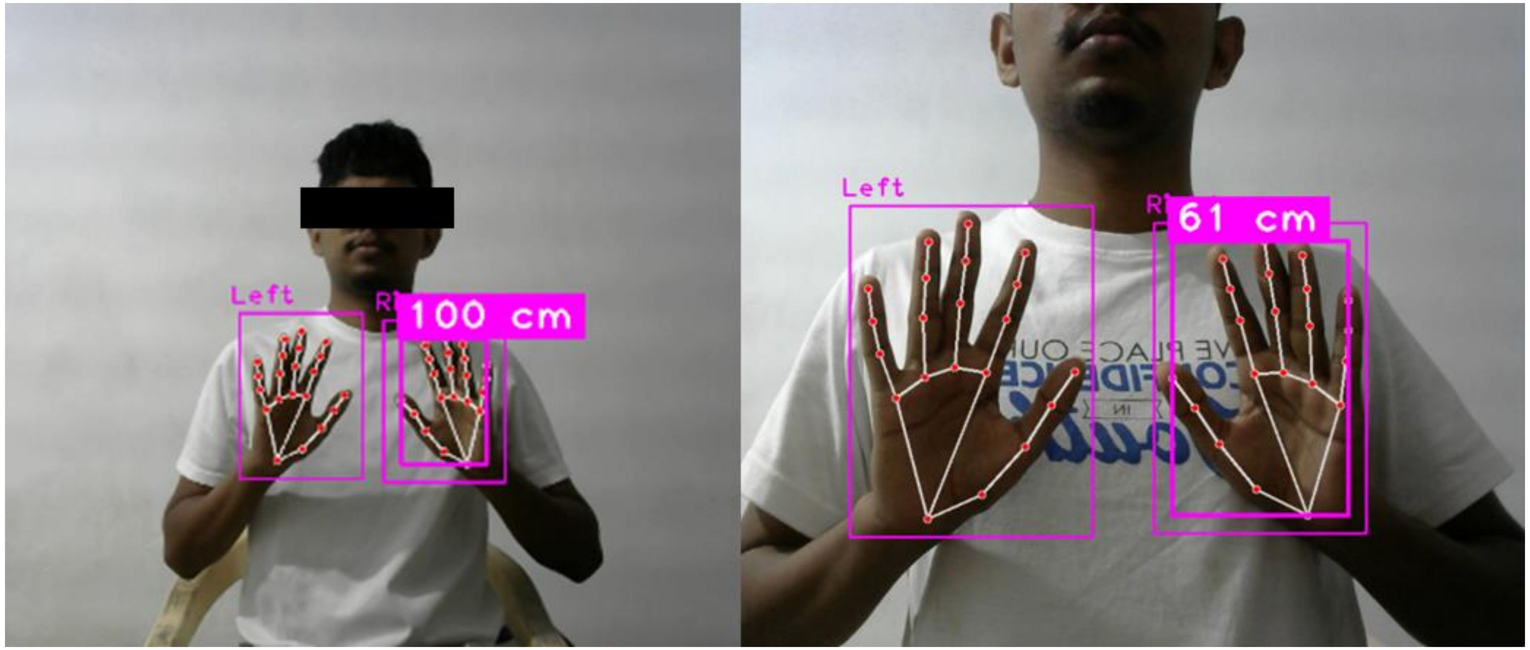
Current Progress

Development of Navigation Testing Platform

Navigation Testing Platform

Current Progress

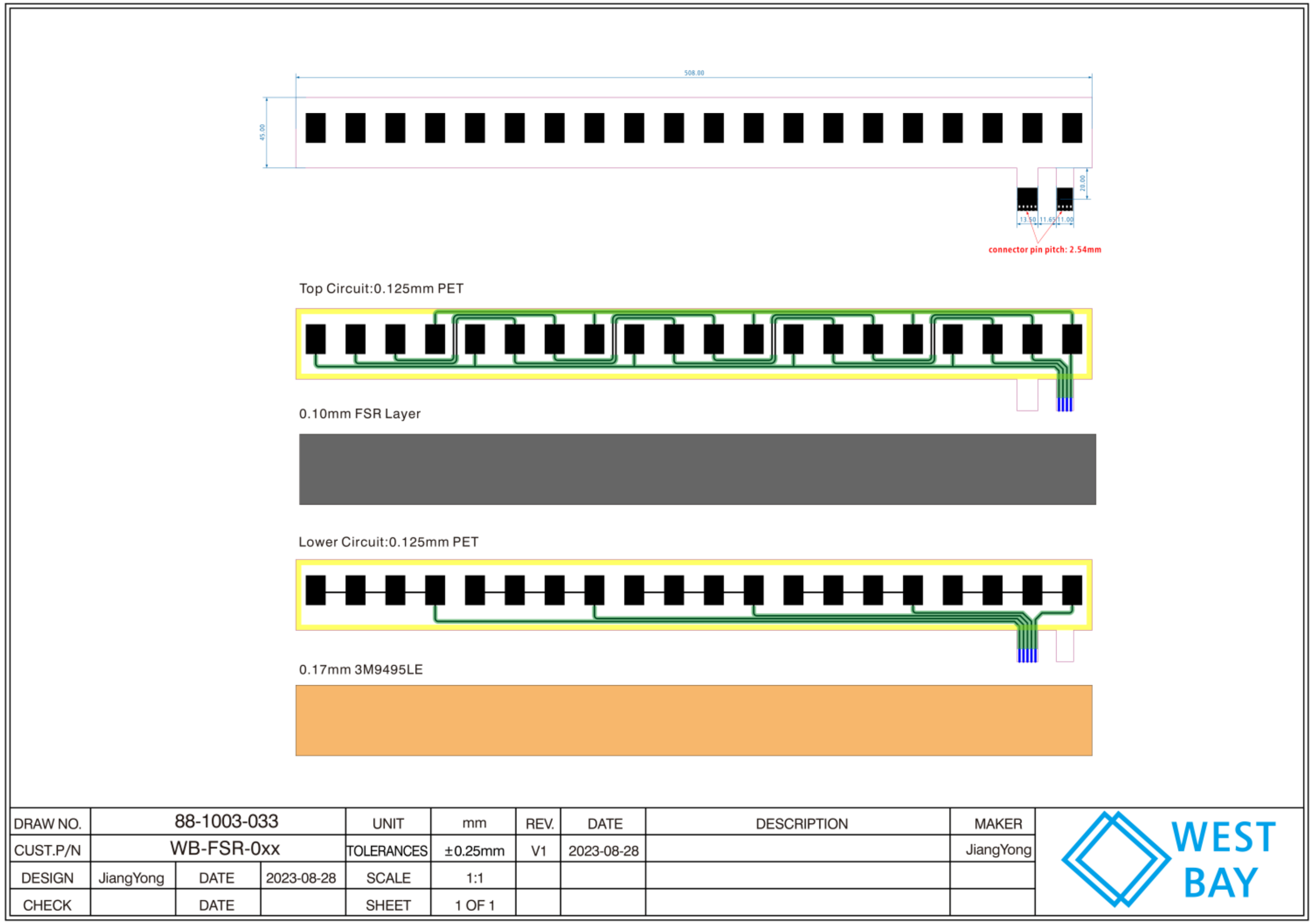
Gesture Recognition and Distance Estimation



Gesture Recognition and Distance Estimation

Current Progress

Impedance Control for Walking Guidance System



Force Sensitive Resistor Matrix
to be placed under the forearm
for velocity control

Current Progress

Initial CAD Design of Robotic Walker

Proposed Design of Robotic Walker

Thank you!