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# Hexapod Welder:

**AI Driven Robotic Welder for Field Applications**

Rev 1

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# Project Summary: AI-Driven Hexapod Robotic Welder for Field Applications.

## Project Overview:

Develop an advanced, insect-like (hexapod) robotic field welder designed for autonomous operation across various surfaces, including pipes, tanks, and vessels. This robot would use AI for navigation, welding control, and quality assurance, aiming to transform the welding industry by addressing key challenges in industrial maintenance and construction settings.

The main goal is to create a flexible, AI-driven welding robot that can deliver high-quality welds in tough environments, such as pipelines, storage tanks, and complex industrial structures. By combining cutting-edge robotics, artificial intelligence, and expert welding techniques, the product would boost welding efficiency, consistency, and safety.

The robot's hexapod design with electromagnetic powered feet would let it move over and stick to various ferritic surfaces, reaching areas that are dangerous or hard for human welders to access. This innovation tackles common industry problems like labor shortages in specialized welding roles and the safety risks of welding in hazardous environments. The demand for this product comes from its potential to cut project timelines and costs while improving weld quality and consistency.

As industries around the world push for higher productivity and strict safety standards, this robotic welder would offer a modern solution that fits the trend of industrial automation and smart manufacturing. Initial conception sees it providing real-time monitoring and data collection, meeting the growing need for thorough quality checks and documentation in important infrastructure projects.

A company contracting field welders using this AI-driven tool could foreseeably receive economic benefit between 1.5 to 3x multiplier in current welding costs, adding up to millions of dollars each year for large industrial sites that employ many welders.

## Key Features:

1. Compact, insect-like design with electromagnetic feet for adherence to ferrous metals
2. AI-driven movement and welding control systems
3. Stick welding capability with potential for MIG/TIG adaptability
4. Onboard rod magazine system
5. Wireless control interface with real-time monitoring
6. AI-assisted welding parameter optimization

7. Lightweight, heat-resistant frame construction

## Technical Specifications:

1. Frame: Aluminum alloy (e.g., 6061-T6) with selective brass plating for heat shielding
2. Power: Derived from welding leads (20-40V AC converted to DC)
3. Movement: Servo or stepper motors with precision gear reduction
4. Welding Capacity: Half sleeve of welding rods (approximately 25-30 rods)
5. Control Range: Wireless operation up to 100 meters (adjustable based on requirements)
6. Weight: Target under 10 kg for portability
7. Dimensions: Approximately 50cm x 30cm x 20cm (adjustable based on final design)

## AI and Control Systems:

1. Dual AI systems: One for movement/navigation, one for welding control
2. Machine learning models trained on expert welder data
3. Computer vision for surface analysis, navigation, and weld quality control
4. Sensor integration: Accelerometers, proximity sensors, thermal sensors
5. Intuitive user interface similar to drone control systems

## Further Specification Detail and Design Overview

### 1. Structural Design:

- Form Factor: Hexapod configuration for stability and maneuverability
- Dimensions: 50cm length x 30cm width x 20cm height (adjustable based on final design)
- Weight: Target under 10 kg for portability

### 2. Frame Construction:

- Primary Material: 6061-T6 aluminum alloy

Rationale: Excellent strength-to-weight ratio, corrosion resistance, and machinability

- Heat Shielding: Selective brass plating on high-exposure areas

Rationale: Enhanced heat resistance and weld spatter protection

- Modular Design: Easily replaceable components for maintenance and upgrades

### 3. *Locomotion System:*

- Six articulated legs with 3 degrees of freedom each
- Actuators: High-torque servo motors with precision gear reduction
- Foot Design: Electromagnetic pads with variable force control

Rationale: Allows adherence to ferrous metals and fine-tuned force adjustment

### 4. *Welding System:*

- Process: Shielded Metal Arc Welding (SMAW/Stick Welding)
- Electrode Holder: Centrally mounted, servo-controlled stinger
- Magazine Capacity: Half sleeve of welding rods (25-30 rods)
- Automatic Rod Feeding Mechanism: Gravity-assisted with mechanical indexing

### 5. *Power System:*

- Primary Power: Derived from welding leads (20-40V AC)
- Power Conversion: High-efficiency AC-DC converter with voltage regulation
- Backup Power: Onboard lithium-ion battery for critical systems
- Power Distribution: Microcontroller-managed power routing to optimize efficiency

### 6. *Control and AI Systems:*

- Dual-Core Processor: Separated cores for movement AI and welding AI
- Movement AI:
  - Terrain mapping and navigation
  - Obstacle avoidance
  - Gait optimization for various surfaces
- Welding AI:
  - Weld path planning and optimization
  - Real-time welding parameter adjustment
  - Quality control through computer vision

#### *7. Sensor Suite:*

- Inertial Measurement Unit (IMU) for orientation and balance
- Proximity sensors for obstacle detection and surface mapping
- High-resolution cameras for weld pool monitoring and inspection
- Thermal sensors for temperature monitoring of critical components
- Force sensors in each leg for terrain adaptation and stability control

#### *8. Communication System:*

- Primary: Wi-Fi module for high-bandwidth data transmission
- Secondary: Bluetooth for close-range control and diagnostics
- Failsafe: Wired connection port for direct control in EMI-heavy environments

#### *9. User Interface:*

- Handheld controller with touchscreen display
- Intuitive path planning interface similar to drone control systems
- Real-time video feed with augmented reality overlay for weld data
- Wireless range up to 100 meters (adjustable based on requirements)

#### *10. Software Architecture:*

- RTOS (Real-Time Operating System) for critical control functions
- Machine learning models for adaptive control and optimization
- Modular software design for easy updates and feature additions

#### *11. Welding Capabilities:*

- Weld Types: Butt, fillet, lap, corner joints
- Material Compatibility: Mild steel, stainless steel, compatible alloys
- Position Capabilities: Flat, horizontal, vertical, overhead

### *12. Environmental Specifications:*

- Operating Temperature Range: -20°C to 55°C
- Ingress Protection: IP65 rating for dust and water resistance
- EMI Shielding: Protected against welding-induced electromagnetic interference

### *13. Safety Features:*

- Emergency stop function accessible via wireless controller and on-body switch
- Thermal shutdown protection for critical components
- Automatic stability control to prevent falls or tip-overs
- Weld arc radiation shielding for onboard electronics

### *14. Maintenance and Serviceability:*

- Tool-less access panels for quick field maintenance
- Modular component design for easy replacement of wear items
- Self-diagnostic system for predictive maintenance
- Firmware update capability via secure wireless connection

## **Methodology for Design and Development:**

1. Iterative Prototyping: Rapid prototyping of mechanical components using 3D printing and CNC machining for quick design iterations.
2. Finite Element Analysis (FEA): Structural analysis of the frame and critical components to optimize for strength and weight.
3. Computational Fluid Dynamics (CFD): Analysis of heat dissipation and airflow for thermal management.
4. Machine Learning Training: Use of synthetic data and real-world welding data to train AI models for movement and welding control.
5. Human-Centered Design: Ergonomic studies and user testing for the control interface to ensure intuitive operation.
6. Environmental Testing: Rigorous testing in simulated field conditions to ensure reliability and durability.
7. Agile Development: Flexible, iterative approach to software development allowing for continuous improvement and adaptation.

## Development Phases:

1. Conceptual Design and Feasibility Study (2-3 months)
2. Prototype Development
  - a. Mechanical Design (3-4 months)
  - b. Electrical Systems Design (2-3 months)
  - c. AI Development - Movement System (4-6 months)
  - d. AI Development - Welding System (4-6 months)
3. Integration and Initial Testing (3-4 months)
4. Field Testing and Refinement (4-6 months)
5. Certification and Compliance Process (3-4 months)
6. Production Planning and Scaling (3-4 months)

Total Estimated Development Time: 24-36 months

## Estimated Development Budget:

1. Research and Design: \$500,000 - \$750,000
2. Prototyping and Materials: \$300,000 - \$500,000
3. AI Development and Integration: \$1,000,000 - \$1,500,000
4. Testing and Refinement: \$400,000 - \$600,000
5. Certification and Compliance: \$200,000 - \$300,000
6. Marketing and Pre-production: \$300,000 - \$500,000
7. Staffing (Engineers, Programmers, Welding Experts): \$2,500,000 - \$3,000,000
8. Miscellaneous and Contingency: \$500,000 - \$750,000

Total Estimated Development Budget: \$5,700,000 - \$7,900,000



## Estimated Cost Price of Final Product:

The cost price will depend on production volume, but for initial small-scale production:

1. Materials and Components: \$4,000 - \$5,000
2. Assembly and Quality Control: \$1,000 - \$1,500
3. Software Licensing and Updates: \$500 - \$1,000
4. Overhead and Marketing: \$2,500 - \$3,500

Estimated Cost Price per Unit: \$8,000 - \$11,000

Suggested Retail Price: \$20,000 - \$30,000 (based on standard markup, adjustable based on market analysis)

## Gross Estimates

There are approximately 650,000 welders between Canada and the United States, of which roughly 35,000 are contractors. It is realistic that initially 1 in 10 contractors would opt in to purchase the hexapod welder, inferring 3500 potential customers. At a unit sales price of \$25,000, gross revenue from that cliental would be approximately \$87,500,000. Although, this estimate is likely to increase over time due to up-sales, part replacements, financed purchases (in-house financing) and tapping into wider target markets such as selling to prime contractors, plants, energy and mining companies directly. Further, a momentum effect amongst contractors is expected as those who adopt this revolutionary technology will receive significant economic benefit prompting a higher conversion rate amongst contractors. In summary, the gross estimate at the 5-year mark is ranged between 70 and 105 million.

## Additional Considerations:

1. Regulatory compliance and certification costs may vary by region
2. Intellectual property protection costs (patents, trademarks)
3. Potential for government or industry partnerships to offset development costs
4. Scalability of production to reduce per-unit costs over time
5. Ongoing costs for software updates, customer support, and maintenance programs

This robotic field welder design integrates advanced mechatronics, AI, and welding technology into a compact, efficient package. The emphasis on modularity, adaptability, and user-centric design aims to create a versatile tool capable of enhancing productivity and quality in challenging welding environments.