Advanced Development and Implementation of the High Mobility Manufacturing Robot

An NSRP RA Project

Weld Panel Presentation

Robotic Technologies of Tennessee

Edison Welding Institute

Vigor Shipyards

Cahill Consulting

Focus on improved tool for weld mechanization

Background: SHIPYARD ROBOTICS CHALLENGES

Shipyard Characteristics

- Large structures
- Variable weld types
- Poor fit ups
- Hard to access spaces

Limit Automation & Robotics To:

- Spaces that are relatively easy to access
- Robots that can be stationary or guided by track, adjacent surfaces or gantries
- Materials that can be brought to robots

Current solutions:

Limitations/opportunities

Challenge with existing solutions:

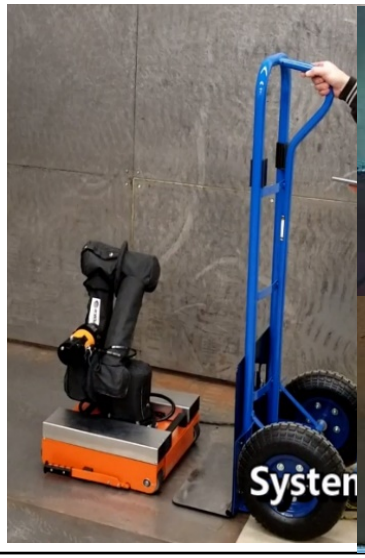
- High cost
- Difficult to scale
- Lose effectiveness as product moves out of Panel lines
- Rely on accurate Cad models
- Do not cope well with un-modeled staging

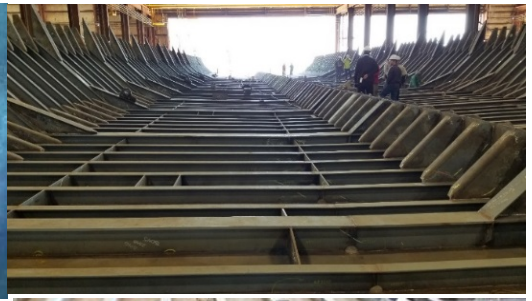
Recent/Continual Advances in robots

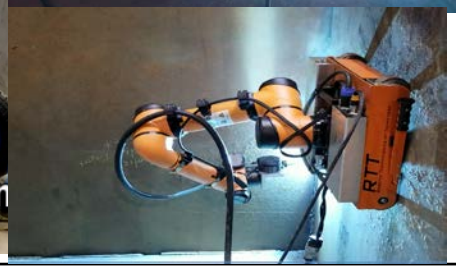
- Advanced mobility
- Collaborative robots
  - Full 6 dof pose
  - Lighter, safer, cheaper
  - Enhanced sensing, actuators

PROPOSED SOLUTION

HMMR:
High Mobility
Manufacturing Robot







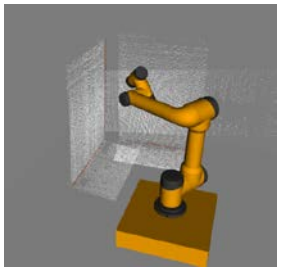
RTT Prior Projects Addressed (RA-2017-427)

1. Integration of HMMR hardware

2. Robot control system and interface

3. Developed man-portability around shipyard

4. Automated weld-path training (using lidar mapping)

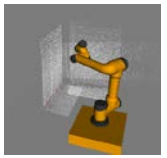


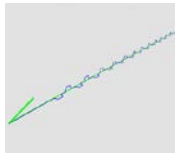
5 . Validated weld operations in 2F/3F positions (horiz./vertical fillets)

Primary Technical Tasks

- Improved weld-seam sensing to be robust to non-ideal fitup

  Improved weld-seam sensing and algorithms for automated weld-path training



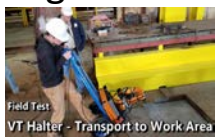


- Adaptable welding options: open-loop and closed-loop weld capability

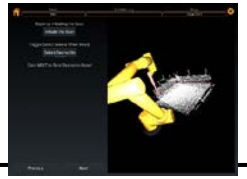
- Advanced workspace mapping for real-time obstacle avoidance

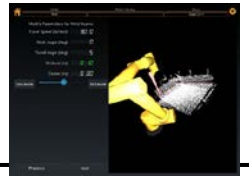
  Advanced Lidar options + SW

- Develop supports and guides to aid in-field use



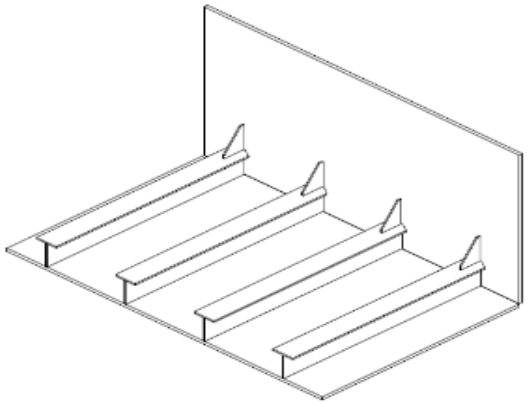
- Improved operator interface and experience





Early Task Selection: Vigor Shipyards

Welding stiffeners and gussets at intersection between deckplate and bulkhead



Challenges

- Non-mechanized welding tasks in this region
- Difficult positions to reach
- Wrap-around welds require inspection and some amount of rework

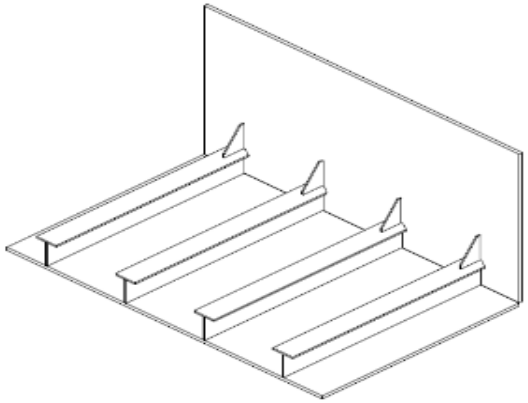
Approach:

Prototype Platform with Hardware (HMMR)

- Modes of operation:
  - Drag-through teach mode
  - Teach job positioning mode
  - Automatic job positioning mode
- Base: Magnetic switchable
- Arm: Aubo i5 commercial cobot
- End-effector: Supports torch and user interface
- Algorithms: Control robot motion, path and job planning

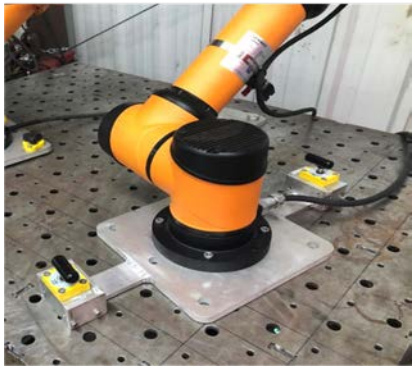
Target Job:

Welding stiffeners and gussets at intersection between deckplate and bulkhead



Preliminary Approach and Hardware

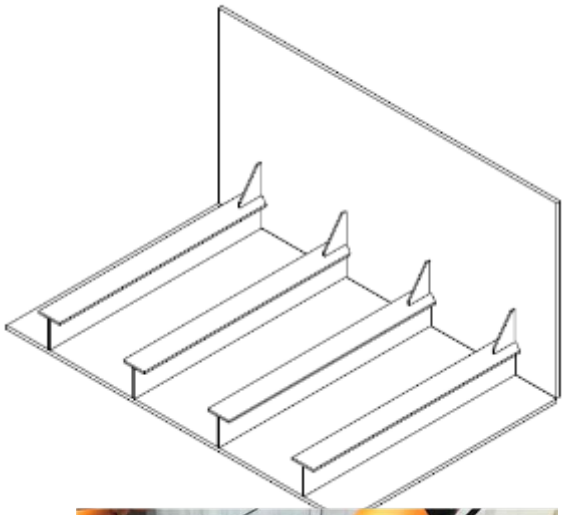
- HMMR is man portable (approx. 50 lb)
- Operator places HMMR on the flange of a stiffener approximately 2 feet from the bulkhead
- Switchable magnetic base secures robot to stiffener



- HMMR measures key points on the stiffener to teach weld path

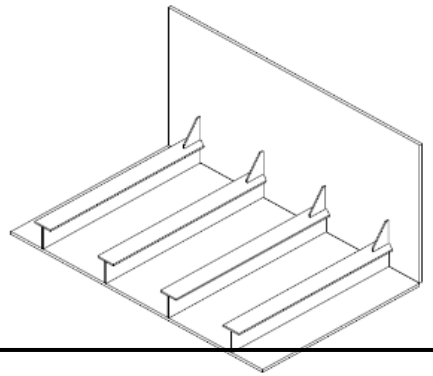
Mobility Requirements

- Task: T-Stiffener with gussets welds at deck plate and bulkheads
- Task workspace: ~300mm (12 inch) sphere
- HMMR workspace: ~ 950 mm (37 inch) sphere
- HMMR positioned on stiffener



Prototype Mobile Base

- Mobile Base is magnetic switchable base to attach to top of stiffeners
- To be moved by operator
- Weight of Arm and base is ~50 lbs.



Mobile Base Testing

- Mock-up of weld task constructed
- Full-scale testing to include sensor and weld testing
- Robot able to reach weld jobs with full orientation capability
- Tested motion and live weld testing

Mobility Requirements for Arm:

- Arm Specs to meet weld requirements
- Tool motions tested at 600 ipm

Axis/Joint	Range	Speed	Torque
• Axis rotation base J1	(+/-) 175 °	150 ° / sec	207 Nm (153 ft-lb)
• J2 axis rotation shoulder	(+/-) 175 °	150 ° / sec	207 Nm(153 ft-lb)
• J3 Elbow rotation axis	(+/-) 175 °	150 ° / sec	207 Nm(153 ft-lb)
• J4 rotation axis wrist	(+/-) 175 °	180 ° / sec	34 Nm (25 ft-lb)
• J5 wrist axis	(+/-) 175 °	180 ° / sec	34 Nm (25 ft-lb)
• J6 rotation axis wrist	(+/-) 175 °	180 ° / sec	34 Nm (25 ft-lb)

Prototype hardware, base + Arm + Torch:

- Modes of operation:
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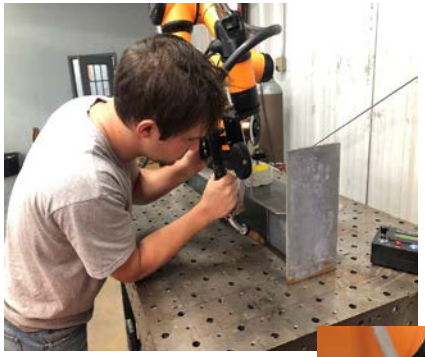
Strategies

Algorithms developed

- Path planning
- Mapping Weld path to robot frame
- Torch wire-tip sensing
- Laser-based point sensing
- Laser-base line sensing



Preliminary Testing

Testing covered:

- Wrap-arounds *
- Vertical up fillets *
- Horizontal fillets*
- Teaching weld paths
- Weld Job alignment

* All welding guided by EWI

* Powerwave 450, Pulse mode, Tregassis torch

Video demonstration

https://vimeo.com/463090662/3c813a4745