Robotic Manufacturing

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Opportunity

- Rapidly growing industry need for flexible automation in manufacturing
  - For repetitive, tedious, and hazardous tasks still prevalent in manufacturing (e.g. assembly, warehousing, food production) – an opportunity for innovation
  - To cater to increased product variety, smaller batch production
  - For competitiveness through greater speed, efficiency, and productivity
- To take advantage of recent advances in robotics and intelligent automation
  - Cage-less robots with “human” traits of perception, dexterity
  - Low cost sensors, artificial intelligence
- Need for future workforce educated and trained in robotic technologies relevant to manufacturing
  - Application of robotics in manufacturing is not “plug-and-play” – requires intimate knowledge of manufacturing processes and robotics (e.g. robotic machining)

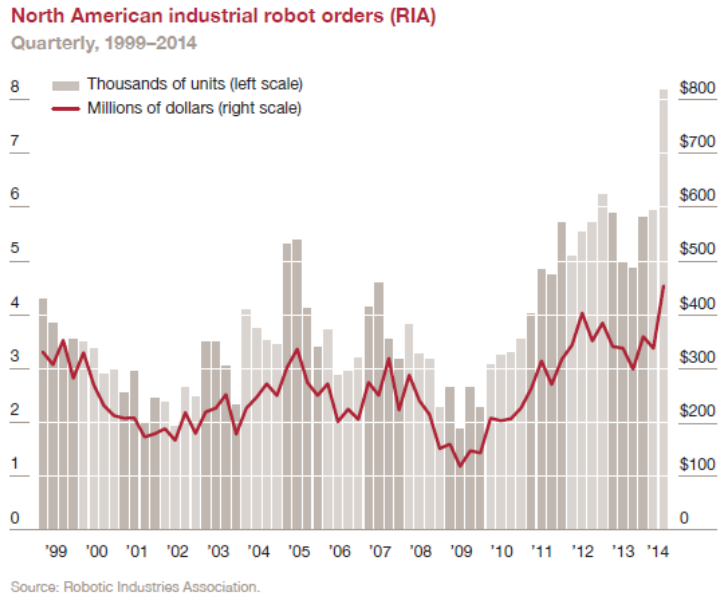
Proposed Solution

- Establish an interdisciplinary activity in robotic manufacturing that leverages GT's core strengths in manufacturing and robotics
  - Collaboration between GTMI and the Institute for Robotics and Intelligent Machines (IRIM)
  - Industry partnerships to guide research

Georgia Tech Robotics & Intelligent Machines

Industry and Federal Landscape

- Sharp growth in industrial robot orders in recent years
  - Automotive, Food and beverage, Plastics, Metals, Warehousing/Logistics, Electronics
  - Percentage of manufacturing tasks performed by robots projected to rise from 10% to 25% by 2025 (BCG report, 2015)
- DoD investments
  - ARM Manufacturing USA Institute
  - Interest in robotics for MRO applications
- Multi-agency National Robotics Initiative 2.0
  - Focus on collaborative robotics



(pwc, 2014)

ARM ADVANCED ROBOTICS FOR MANUFACTURING

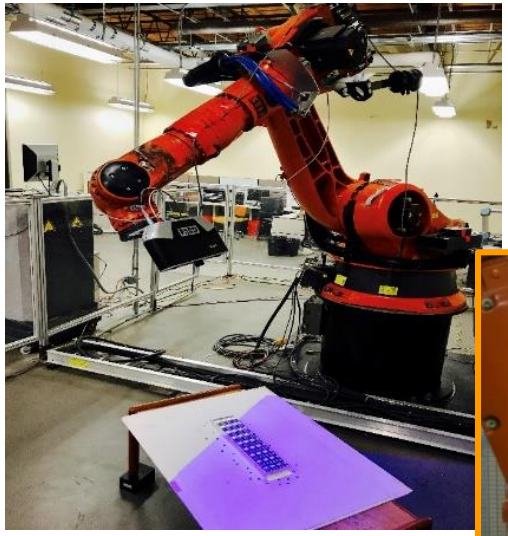
NSF

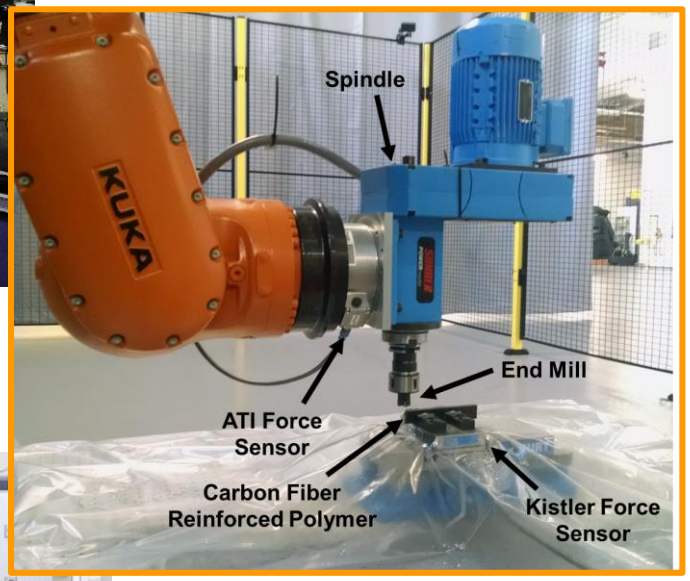
Relevant Competencies @ Georgia Tech

- GTMI
  - Additive Manufacturing (Das, Rosen)
  - Composites Manufacturing & Repair (Zhang, Kalaitzidou, Colton, …)
  - Precision Machining (Kurfess, Liang, Melkote, Saldana)
  - Inspection & NDE (Ruzzene, Ume, …)
  - Logistics (White, …)
- IRIM
  - Human-robot collaboration (Chernova, Balakirsky, …)
  - Sensing & Perception (Lee, Batra, Kira …)
  - Autonomy (Arkin, Boots, Egerstedt, …)
  - Food Processing/Agriculture robotics (McMurray, Hu, Dellaert …)

Synergistic Areas of Focus*

- Robotic Assembly
- Flexible Process Automation
  - Additive Manufacturing
  - Machining
  - Joining
  - Maintenance, Repair, Overhaul
- Human-Robot Collaboration in manufacturing environments
- Sensing and Perception
- Autonomous navigation for factories

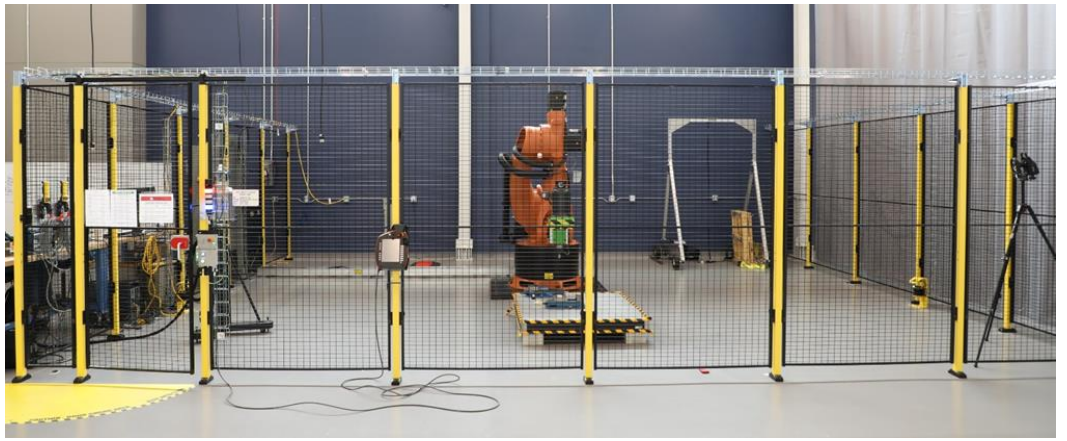




* Several of these topics are also identified as critical capabilities for manufacturing in the 2016 Roadmap for US Robotics (CCC, 2016)

Ongoing GTMI – IRIM Collaboration

- Accurate Robotic Machining – collaboration with Boeing Manufacturing Development Center @ AMPF (Melkote & Balakirsky, ~$1.1M over 2 years)
- Robotic Precision Grinding of Bearing Components (Timken, $150K + in-kind over 2 years, Melkote)
  - IRIM provided space and $$ to build testbed
- Robotic Grinding and Inspection of Forged Aerospace Parts (Arconic, 2+ year project in development, Melkote)
- Human-Robot Collaboration (Hitachi, $100K, Chernova)



Accurate robotic machining testbed @ AMPF

Robotic grinding testbed under construction at IRIM Techway Robotics Lab

Examples of Potential Future Projects

- Human-robot collaboration during assembly – a labor intensive and slow process.
- Develop sensing and control techniques to enhance the accuracy of industrial robots for high precision additive/subtractive manufacturing
- Mobile robots (e.g. drones) for inspection/NDE during manufacturing and assembly, especially for large/hard to access part surfaces.
- Use of machine learning / AI to adapt to a changing manufacturing work environment.
- Improve software tools to simplify redeployment of robot to new tasks and products.

Target Industries

- Discrete Parts Manufacturing
  - Aerospace, Automotive, Electronics
- Food, Agriculture
- Supply Chain and Distribution Centers
- Small and Medium-sized Enterprises (SMEs)

Possible Next Steps

- Internal workshop to bring together GTMI and IRIM affiliated faculty to brainstorm and identify
  - unique strengths that complement other national efforts
  - synergistic topics for collaboration
  - technical gaps
  - strategies to grow collaboration in robotic manufacturing
- Approach NSF Manufacturing Machines & Equipment Program for possible funding for a national workshop
- Meet with industry and other USG institutions to discuss workforce development for adv. manufacturing and robotics