Just-in-Time Learning for the Factory Floor

Interactive virtual reality for teaching best practices through crowdsourcing

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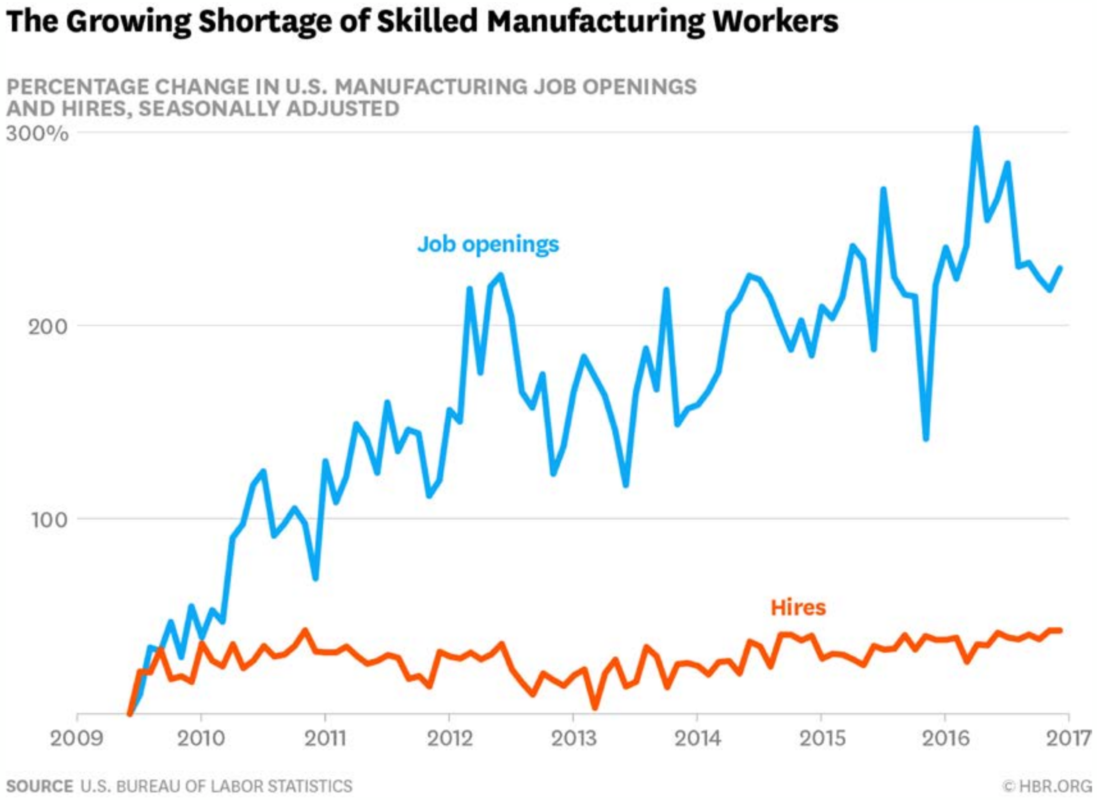
What is the Problem?

Training laborers for a particular process is time consuming and expensive!

- Manufacturing industry faces a shortage of skilled and semi-skilled labor.
- Many industries are changing product lines very quickly, especially high-tech products.
- It takes time to retrain the workforce to support the new production needs.
- Each person needs to be trained, and experience gained by one individual is not easily conveyed to another individual.
- Rapid training is essential for cross-training which is key to a more reliable workforce and improving employee moral.



Abraham, M., & Annunziata, M. (2017). Augmented reality is already improving worker performance. *Harvard Business Review*. Retrieved from: https://hbr.org/2017/03/augmented-reality-is-already-improving-worker-performance

Basic Idea Behind *Just-in-Time* Learning

- Augmented Reality (AR) and Machine Learning (ML) are combined to observe, train, and assist in the assembly/test/maintenance of complex assembles.
- Machine learning can *reduce the time to create augmented reality content.*
- Machine learning can, with training over time, improve the guidance given to the line workers using augmented reality by *sharing best practices and past solved problems*.

First Generation Systems are Starting to Appear

Not looking to build a Borg Collective, but sharing knowledge and experiences broadly can improve efficiency!

Picture source: http://philosophicaldisquisitions.blogspot.com/2014/06/is-big-data-creating-borg-like-society.html

Early Uses of AR Concepts in Manufacturing

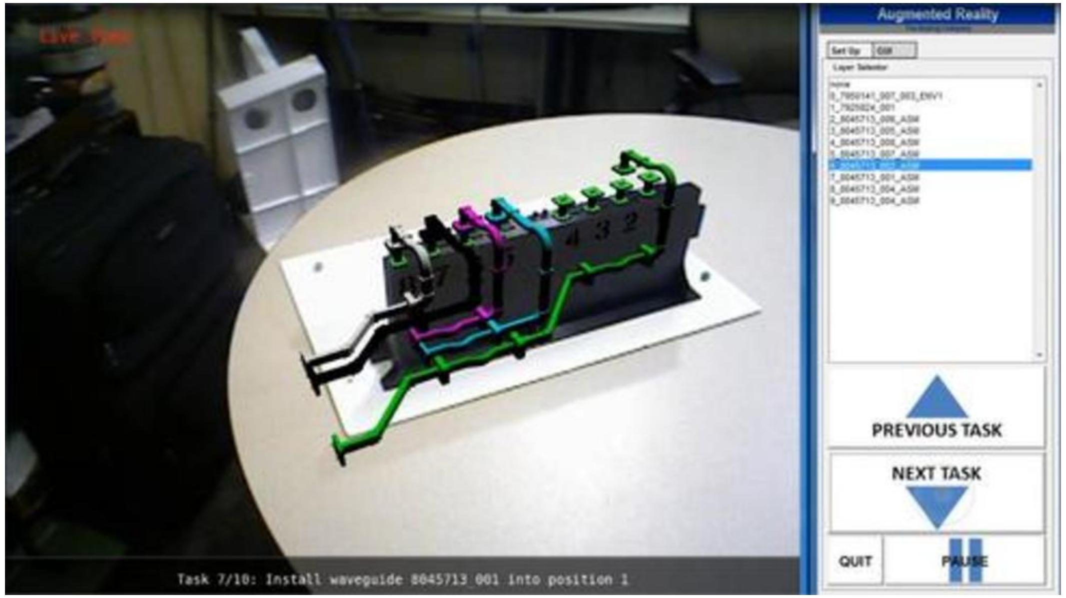


Figure: Boeing AR Table Tool for Assembly Lines (Wheeler, 2015)

Success Stories

- A Boeing study that found that "AR improved productivity in wiring harness assembly by 25 percent" (Wheeler, 2015).
- GE Healthcare, "a warehouse worker receiving a new picklist order through AR completed the task 46 percent faster than when using the standard process, which relies on a paper list and item searches on a work station" (Kellner, 2018).
- "Additional cases from GE and several other firms show an average productivity improvement of 32 percent."

Kellner, T.. (2018, Apr 19). *Game On: Augmented Reality Is Helping Factory Workers Become More Productive*. Retrieved from: https://www.ge.com/reports/game-augmented-reality-helping-factory-workers-become-productive/
Wheeler, A. (2015, May 5). *Boeing's AR Tablet Tool for Assembly Lines*. Retrieved from: https://www.engineering.com/AdvancedManufacturing/ArticleID/10069/Boeings-AR-Tablet-Tool-for-Assembly-Lines.aspx

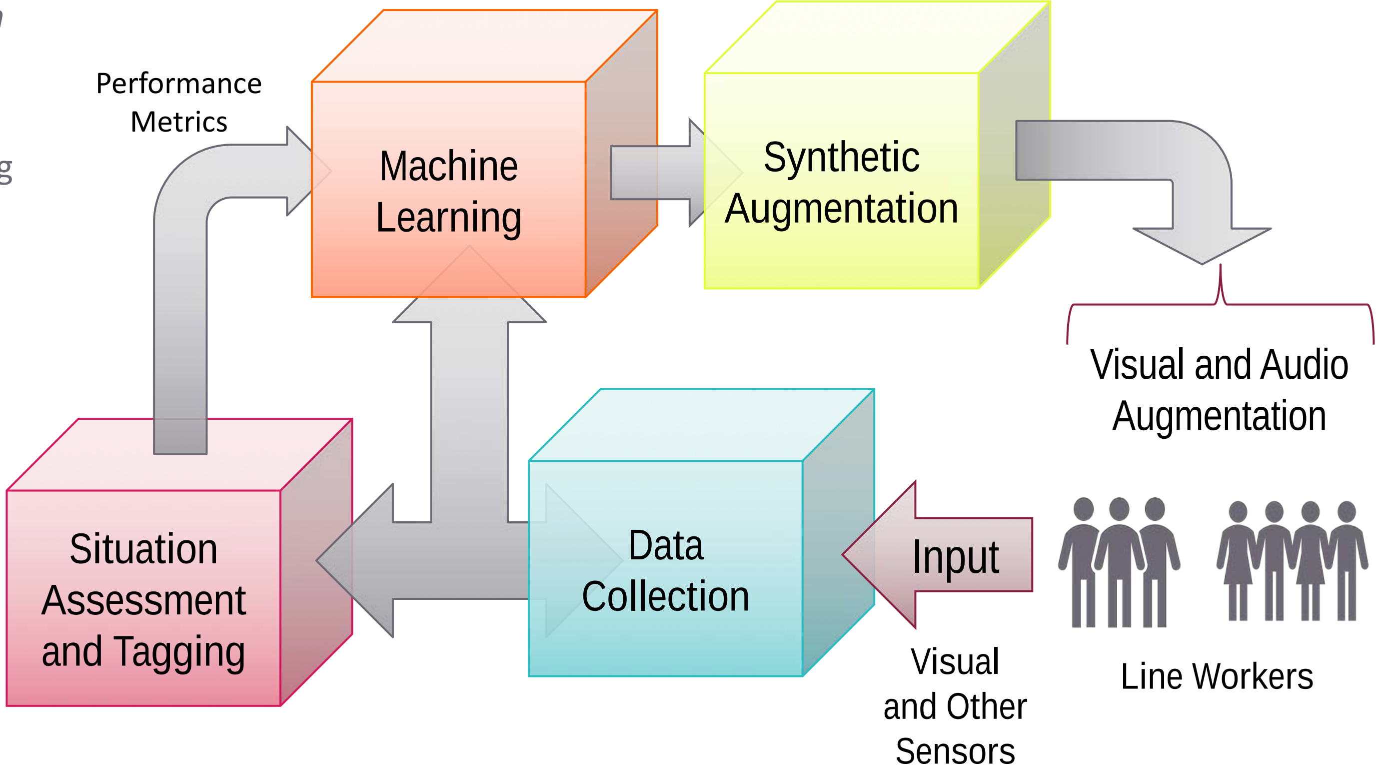
What will be Deliver?

- An augmented reality (visual and audio) system that provides instructions to workers enabling them to be semi-skilled workers.
- A system that automatically creates augmentation based on observing human activity.
  - Image and audio tagging
  - Image segment and audio clustering (unsupervised learning)
  - Image prediction (deep learning image prediction) and synthetic image generation
- A system that learns best practices (and mistakes) from prompting certain actions via augmented reality visuals to learn best processes.
  - Inspired from genetic algorithms and artificial immune system (AIS) theory
  - Borrows from education assessment methodologies to develop metrics (psychology of learning)
  - Borrows methodologies for cognitive radio design (AI techniques) and Radio Environment Maps (REMs)

Research will result in a live demonstration of all of these principles.

Why is the Problem Hard?

1. Need a New Methodology for AR and ML
   - Essentially a new form of human computer interface – *closed loop interactive system with complexity of human behavior in that loop*
   - Rapidly produce initial augmented reality content
   - Continuously update AR representation through learning from many individuals and using individuals to probe solutions.
2. Scalability Issues
   - Communication issues: interference and inverted traffic volume flow.
   - Collection, storage, retrieval, and processing massive amounts of data
3. High Precision Augmentation
   - Recognizing objects
   - Placing augmented reality in the field of view with precision



Not only hard, but cross-disciplinary hard!

How is Training and Process Refinement Solved Today?

Training (mostly like it was done a hundred years ago!)

- Individualized instruction
- Written directions

Improving through collaboration

- Industrial engineers – optimize process and human factors
- Team discussions – lacks scalability
- Lots of paper work!!!

Augmented reality for manufacturing (just beginning)

- Intensive development effort
- Continued manual refinement with a human in the loop

What's New and Why it can be Addressed Now?

New breakthroughs or potential breakthroughs in several areas

- *Wireless communications* – low latency, high bandwidth, high capacity, high density, and improved SWAP (e.g., IEEE802.11ad and 802.11ay)
- *Edge computing* – low latency
- *Augmented reality* – display, image alignment, bandwidth reductions
- *Sub-centimeter Indoor localization* – necessary for image augmentation
- *Machine learning* – deep learning and beginnings of understanding how it works
- *Revolution in processors* – AI/ML specific processors and graphics processors for vector image operations.
- Success in Related Applications – Cognitive Radio has similarities

Image from http://media.theindependent.sg/wp-content/uploads/2016/09/2-5.jpg

What is the Impact if Successful?

Direct Impact on Manufacturing

- Knowledge and experience transfer from one individual to the next
- Ease cross-training effort among workers
- Faster production with fewer production errors
- Reconfiguration of assembly line reductions
- Day-to-day improvement in productivity
- Reduction of time for maintenance (lower down time)

Broad Impact Beyond Manufacturing

- Tools for quick deployment of AR
- New human to machine interactive interface using image augmentation and machine learning
- New mode of learning for those people who learn visually
- Fundamental contributions to indoor location precision, machine learning production of AR, training from large human population and generalization of knowledge
- Easier access to data – context aware
- Lower the education level needed to complete a task for many fields

How will the Demonstration Program be Organized?

Four Phase Program

- Phase 0: Overall systems engineering
- Phase 1: Address tough challenges $15M
- Phase 2: Sub integration and testing $10M
- Phase 3: Full integration and testing $5M

Measuring Success

- Goals set for each phase with Go/No-Go decision points.
- Backup technologies are considered for various high-risk technology components to be able to test larger concepts.
- Defined series of test cases for individual technologies.

Summary – Research with a Series of "Firsts"

- Automated and rapid AR (video and audio) instruction generation
- Dynamic motion AR-based human to machine interface
- Crowdsource learning of best practices from line workers
- Assessment metrics that blend human and machine learning
- Day to day improvements in productivity