Breakout 2.2: Designing the Optimal Telelabor Program – ARPA-E Questions

Wednesday, April 27, 2:10-3:55

Objective: The goal of this breakout is to determine what ARPA-E can hope to achieve in a program, define metrics for success, and identify methods for transition after the program concludes.

Program Focus Areas

Based on research to date, ARPA-E plans to focus the program on the following thrust areas:

- Low-cost arms and manipulation systems
- Sliding autonomy
- High-quality, transparent user interfaces
- Effective user performance and acceptance studies

Do these appropriately capture a significant portion of the problem space for developing a widely adopted telelabor system? If not, what are we missing?

Time and Resources Required

ARPA-E wants to ensure that performers are given the appropriate amount of time and resources to develop telelabor technology for an appreciable energy impact.

1. How much time would be necessary to make substantial progress towards our goals?
2. How much would it cost? What significant non-labor expenses should we anticipate?

Government Furnished Equipment (GFE)

We understand that funded teams will need access to commercial arms and manipulators to conduct certain aspects of the research proposed earlier in this breakout. Should ARPA-E identify and provide the same system to each team to promote fairness? Or would it be more beneficial to permit teams to identify and request what type of system they'd like to use, giving each team an equal budget for GFE?

Demonstration

What would make a useful and convincing demonstration that clearly shows an advancement of capability at the conclusion of the program? Are there specific tasks in our identified use cases that performers should demonstrate to prove capability? Would a telelabor competition serve as an appropriate demonstration AND be interesting and engaging to the community?

Metrics for Success

Earlier in this breakout session, we defined ARPA-E's core set of focus areas for research and development. Given these focus areas, what should we use as metrics for success? How do we measure if the newly developed technologies meet these metrics?

Plans for Transition

The primary goal of this program is to develop technologies that will transition directly into the target markets for refinement, or progress far enough that the target markets would be willing to pick up R&D from where ARPA-E left off. What strategies and considerations need to be made throughout the life of the program to ensure successful technology transition?

Breakout Session 2.2: Feedback

Program Focus Areas

- Need to consider sensors for human feedback as part of the arm development.
- ARPA-E has proposed relevant user cases.
    - Another suggestion is remote senior care.
    - Service and maintenance application need this solution more than production. Production will be mostly automated.
- Mobility should also be included. Manipulation would be designed differently if it were on a mobile platform. Forces you away from CNC machine-like. (Mobility means it can be easily moved, even if it's not moving itself)
- Should focus on unstructured environments, where dexterity and judgment are required.
- User interface:
    - VR user interface? Doesn't give you good input, but does give you good situational awareness.
    - How much does the input device have to be anthropomorphic? Or can it be three arms – you don't have that part of your brain. Shared autonomy filling in the gap?
- Disagreement on whether ARPA-E proposed thrusts (Human computer interaction, hardware (manipulator) development) could/should be separated programmatically. Some groups thought that the HCI work could be done with gov't furnished equipment while the manipulator development basically had to be done in parallel with the human interface. Other groups thought that the back and forth required between groups working on each would be inefficient and burdensome.
- Disagreement about need for skin/haptics.
    - Diversity and density of sensors in the skin. Getting data out is tough. Doesn't scale—can't have hundreds of wires… especially since it needs to be compliant. What would we even do with this?
        - Once we get really dense haptic sensors, then even if we can allow the human operator to be fully aware of it- can the human operator really use this sensing information to do something. Very limited to what a human can do with it. Can we use visual feedback to compensate for this?
    - Humans adapt. Bomb disposal can be done without haptics.
- Gearboxes are half the weight of any robot. Huge problem

Time and Resources Required

- Designing new ideas for HCI will take 2-3 years.
    - 2.5-3 people for 2-3 years. $1 – 1.5M
- All groups seemed to agree that while HCI is a hard problem, it is likely to be solved in less time than the manipulator.

Government Furnished Equipment

- Disagreement between groups about GFE. Some thought it would be useful (or necessary) for developing the HCI thrust. Others thought that hardware procurement could end up taking a long time and that teams would blame their own failures on the GFE. The latter groups advocated for letting proposing teams pick their hardware.
- Do we set a limit on the purchasing budget to force a percent of the team's whole budget on labor?

Demonstration

- If a factory or warehouse is truly telelabor remote, lots of energy costs could be saved from things like moving the warehouse closer to distribution centers, closer to natural resources, etc.
- Let's define a canonical task like assembling a door lock that has lots of springs and flexible components and hard to see components, things that robots would never be able to do right now.
- Needs to be an unstructured task that is not easy to automate. (e.g. trash sorting, schoolyard janitor, etc.).
- Competitions do a better job at engaging the public.
- Let industry drive the competition requirements. Consider an incremental, multi-year challenge that increases in complexity.

Success Metrics

- We still haven't even found out if this can be done at all at any cost, let alone trying to do it at a very low cost. The only argument for making cost a metric is to constrain feasibility of the technology being used.
- Suggest not putting in a cost metric and instead force people to consider that it must be able to be costed down in the future.
    - For manipulation systems, can you accomplish a task, how small are the tasks, how quickly can you do it. Maybe make it compared to what a human can do for the particular task. Think of it in terms of human metrics.
    - For sliding autonomy, consider cognitive load, ability to deal with latency, humans' ability to deal with task.
    - For user interface, time taken to learn and setup the interface compared to time taken actually doing work, use an ideal simulation behind the interface to level the playing field and separate effects of different arms.
    - Maybe set it up like qualifying exam, give list of problems and let them choose a subset of those problems to work on.
    - For human-like capability, we're still 10X off the cost
- Fatigue metric, intuitiveness
    - How long are they able to do the task
    - Metric can be performance – do it as fast as a human
- 100 Hz actuator at 10 W/kg with 10^4 dynamic range.

Transition

- Need to put emphasis on interoperability so that it's easy for future people to integrate.
- Do not force it to be all open source, it will discourage participation from commercial entities.
- Differentiator from DARPA is that we can fund smaller entities, and focus on transition. We have the availability to give people flexibility compared to DARPA programs, makes it more practical to run from a program sense.

Suggested In-Scope and Out-of-Scope

In Scope:

- New types of actuators to enable new tasks
- Generalizability of the autonomous algorithms
- Situational Awareness for the User
- Tactile Sensing
- Proprioceptive Sensors
- Visual Servoing of Arm by Human
- Identifying intention of human to reduce cognitive load
- Manipulation Generalization
- Visual characterization of an object for grasping

Out of Scope:

- Another PR2
- Network Infrastructure
- Mobility
- Tactile Display (will be done by video games)
- High Level Planning/Behaviors in autonomy
- Visual identification of an object (done by community)