Human, Machines, and the Future of Work

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3 Drivers for Change

1 Advances in computing, storage, communication

2 Cost of X is Decreasing
   • Computing: $/M transistors - 33%/year
   • Storage: $/GB – 38%/year
   • Bandwidth: $/Gb/s – 27%/year
   • Solar power: cents/kW.hr – 75% in 5 years
   • Magnesium
   • Poly Vinyl Chloride
   • Fabrication

...
3. Speed

3-D Printing

- **2013**: 10 cm³ hr⁻¹
- **2018**: 40 cm³ hr⁻¹
- **2023**: 80 cm³ hr⁻¹

Dan Huh, Bioengineering, UPenn
1 Cost of creating hardware and software is decreasing

2 Time to ideate, create, test and redesign is decreasing
The Game of Technology

More players…

More shots on goal…

More scores…

Higher scoring game …

Attract better talent …

The rate of technology innovation is accelerating!
Aerial Robotics
We are here!
Aerial Robots

We are here!

Small Safe Smart Speed Swarms
## Light weight sensing

<table>
<thead>
<tr>
<th>Model</th>
<th>Range</th>
<th>Resolution</th>
<th>Weight*</th>
<th>Power</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDL-64E</td>
<td>120 m. 26.8° vertical FOV</td>
<td>&lt; 2 cm. 0.08° (azimuth) 0.4° (elevation)</td>
<td>13.2 kg</td>
<td>60 W</td>
<td>$75K</td>
</tr>
<tr>
<td>HDL-32E</td>
<td>100 m. 41° vertical FOV</td>
<td>±2 cm. 0.1° - 0.4° (azimuth) 1.33° (elevation)</td>
<td>1 kg.</td>
<td>12 W</td>
<td>$30K</td>
</tr>
<tr>
<td>VLP-16 (Puck)</td>
<td>100 m. 30° vertical FOV</td>
<td>±3 cm. 0.1° - 0.4° (azimuth) 2° (elevation)</td>
<td>830 g.</td>
<td>8 W</td>
<td>$7999</td>
</tr>
<tr>
<td>VLP-16 Lite</td>
<td>100 m. 30° vertical FOV</td>
<td>±3 cm. 0.1° - 0.4° (azimuth) 2° (elevation)</td>
<td>590 g.</td>
<td>8 W</td>
<td>$9399</td>
</tr>
</tbody>
</table>
## Light weight computing

<table>
<thead>
<tr>
<th>Computer</th>
<th>Intel NUC (i3-5010U)</th>
<th>Intel NUC (i5-5250U)</th>
<th>Intel NUC (i7-5557U)</th>
<th>Odroid XU3 (Exynos 5422)</th>
<th>Qualcomm Eagle (Snapdragon 801)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cores</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Clock Speed (GHz)</td>
<td>1.7</td>
<td>2.1</td>
<td>3.1</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>MFLOPS (Single-Core)</td>
<td>1900</td>
<td>2730</td>
<td>3440</td>
<td>1030</td>
<td>1200</td>
</tr>
<tr>
<td>MFLOPS (Multi-Core)</td>
<td>4250</td>
<td>5400</td>
<td>7480</td>
<td>4270</td>
<td>4350</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>210</td>
<td>210</td>
<td>210</td>
<td>38</td>
<td>27</td>
</tr>
<tr>
<td>MFlops / g (Single-Core)</td>
<td>9.05</td>
<td>13</td>
<td>16.38</td>
<td>27.11</td>
<td>44.44</td>
</tr>
<tr>
<td>MFlops / g Multi-Core)</td>
<td>20.24</td>
<td>25.71</td>
<td>35.62</td>
<td>112.37</td>
<td>161.11</td>
</tr>
</tbody>
</table>
Recent advances

• Systems can learn to be autonomous
  – Data driven approaches to perception, action

• Systems can share data, learn from each other
AI: 6 myths/challenges

• The ability to crunch through large amounts of data (which we sometimes mistakenly call learning) does not translate to knowledge

• The ability to make complex calculations rapidly does not translate to autonomy

• 99.99% correct is exponentially harder to achieve than 90% correct

• Perception + action is exponentially harder than just perception

• Tasks with physical contact is exponentially harder than tasks like driving or flying

• Human machine collaboration is impossible unless they share representations. We only know how to do this at some very simple levels.
AI, Autonomy and Society
Democratization of S&T (opportunity and threat)
Democratization of Technology

RATS! NOW ANYONE CAN RIDE!

3 MORE JOBS, LOST TO TECHNOLOGY!
Social Challenges

Democratization of S&T (opportunity and threat)

Jobs
<table>
<thead>
<tr>
<th>Type of Job</th>
<th>Qualification</th>
<th>Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly skilled, analytical, making decisions</td>
<td>Advanced degree, tech skills balanced with emotional judgment</td>
<td>$$$$$</td>
</tr>
<tr>
<td>Analytical, drawing inferences</td>
<td>College degree</td>
<td>$$$</td>
</tr>
<tr>
<td>Modest skills, some labor</td>
<td>High school education</td>
<td>$$</td>
</tr>
<tr>
<td>Unskilled labor</td>
<td>reading/writing</td>
<td>$</td>
</tr>
</tbody>
</table>
## Social Disruption

### 2020

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<tr>
<th>Type of Job</th>
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</tr>
<tr>
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<td>High school education</td>
<td>$$</td>
</tr>
<tr>
<td>Unskilled labor</td>
<td>Manual skills</td>
<td>$</td>
</tr>
</tbody>
</table>
Social Challenges

Democratization of S&T (opportunity and threat)

Jobs

Asymmetric threats (easy to write “bad” programs)

Safety

Cyber physical systems security

Privacy
Summary

Autonomy in Cyber Physical systems (as we imagine) will be difficult to achieve

Time scale of technology change (years) is much shorter than time scale of a human (decades)

Our role

- Safety
- Security
- Privacy
- Education/training