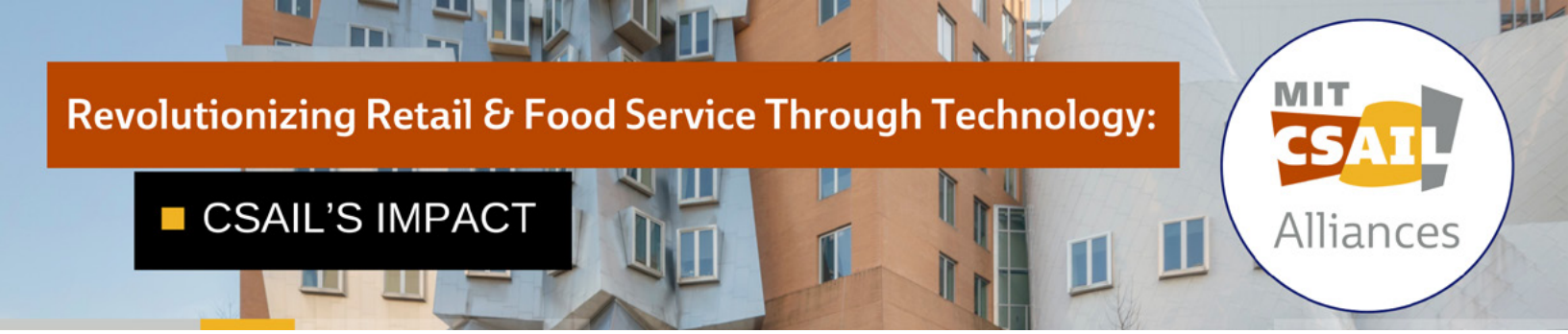

Revolutionizing Retail & Food Service Through Technology:

CSAIL'S IMPACT

MIT CSAIL Alliances

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Computers have become ubiquitous in all modern markets, commercial services included. From touch screens to touchless checkout, there are numerous situations in which food service is adopting novel technologies to respond to the demands of modern customers, adjust to worker shortages, and stay competitive. Retail, too, has shifted with the advent of online shopping, personalized ads, smart try-on programs, and automated manufacturing. Shoppers and customers are interacting with stores in an entirely new way, often from the comfort of their homes. This means businesses selling consumables must not only adapt to a customer base rapidly adjusting to the convenience and speed facilitated by technology but also anticipate the innovative ways the industry might change going forward.

Researchers at MIT CSAIL are addressing current industry challenges and developing technology that will revolutionize the field in the next five to ten years.

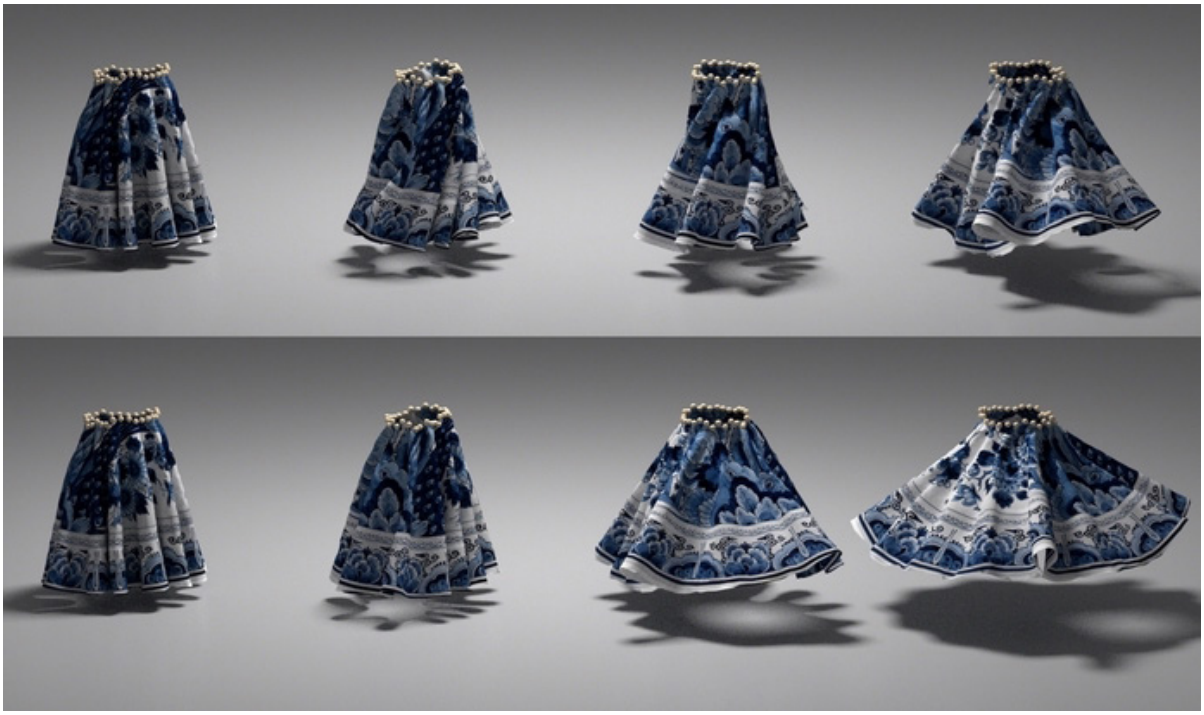
Here is a breakdown of some groundbreaking recent projects by CSAIL researchers that could affect the future of retail and food service:

Manufacturing:

- 3D printing offers exciting potential for the consumables industry, with the promise of print-on-demand goods and increasingly personalized products. To tackle some of the major roadblocks in commercial 3D printing, Professor Wojciech Matusik's group has worked on real-time error correction and computer vision systems which allow printers to adjust while printing, minimizing costly errors and shortening the pipeline of prototype to shippable product.
- Also in the subfield of 3D printing, CSAIL researchers have developed a semiautomated pipeline for developing new printing materials. While current 3D printing relies largely on expensive trial-and-error, often under the guidance of an expert chemist, this new process would help users to quickly find the material that would be best for their given needs. This research could be expanded into many potential 3D printing uses, such as optimizing clothing materials, shoe rubber, and more.
- For current manufacturing pipelines, AI solutions can ease the burden on overworked system engineers and help optimize difficult production processes. For example, Professor Matusik's group created a method that automates assembly planning for maximum efficiency based on a physics-based simulation.
- Adding more intelligence to the manufacturing process, researchers in Professor Stefanie Mueller's group developed a smart laser system that can detect what kind of material it's cutting. This system could allow for engraving on multiple materials such as shoes and phone cases and would improve safety in precision cutting tasks by protecting users from potential hazardous chemicals and accidents.
- Robots assisting workers in factories or fast-food kitchens might not be a new idea, but as the technology improves, these machines can provide greater benefits such as improved efficiency, worker safety, and balancing employee shortages. Research coming out of CSAIL groups such as those of CSAIL Director Professor Daniela Rus, Professor Russ Tedrake, and Assistant Professor Pulkit Agrawal are leading to improved robot dexterity, grip, intelligence, ability to use tools, and more, which will have far-reaching consequences in any industry which must produce goods at scale.

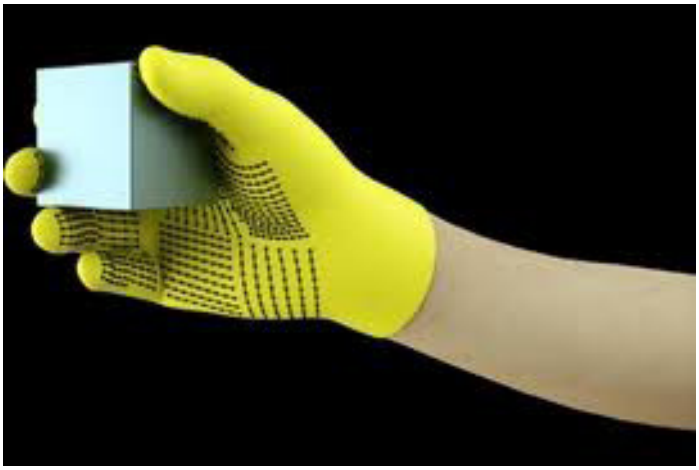
Design:

- Many of the design tools coming out of CSAIL have to do with the specifics of image generation. For example, Professor Phillip Isola's pix2pix helps translate one image into another through conditional adversarial networks. This program makes it possible to create realistic images from simple sketches or to experiment with various colors in a design. Another example is a pose generator by Professors Fredo Durand and John Guttag, who created a computational way to take an image of a person in one pose and generate an image of them in a different pose, which could be applied to representations of new products, virtual fitting rooms, and advertisements. Finally, Professor Justin Solomon's work on the vectorization of line drawings could help fashion designers or product artists computationally trace their sketches for easier use and applicability.
- Several CSAIL researchers are working on ways to make generative AI more creative and therefore a more useful tool in conceptualizing novel design ideas. Professor Isola's group is expanding the ability of generative AI models to "riff" on a given image and offer alternative colors, shapes, and ideas. Professor Jacob Andreas is studying the mysteries behind how generative AI learns, which could expand use case scenarios going forward. And improving on machine learning—the necessary process behind all AI training—CSAIL researchers are proving that generative AI can be used to create synthetic data sets to augment and even replace real-world data, improving efficiency, privacy, and training time.
- One important element in coming up with new design ideas—whether it's a clothing style or a restaurant layout—is being able to visualize it in 3D. A helpful tool for this could be a CSAIL research project that used light field networks to render 3D scenes from 2D observations, offering a faster and cheaper method to allow for real-time rendering. Another potential tool being developed in Professor Matusik's lab is DiffCloth, which improves on current state-of-the-art cloth simulators.
- When it comes to design materials in both food service and fashion, CSAIL has created several new options that could be used to push the boundary of what consumables look like such as color-changing fibers, reprogrammable self-assembling materials, and materials that can sense their own movement.



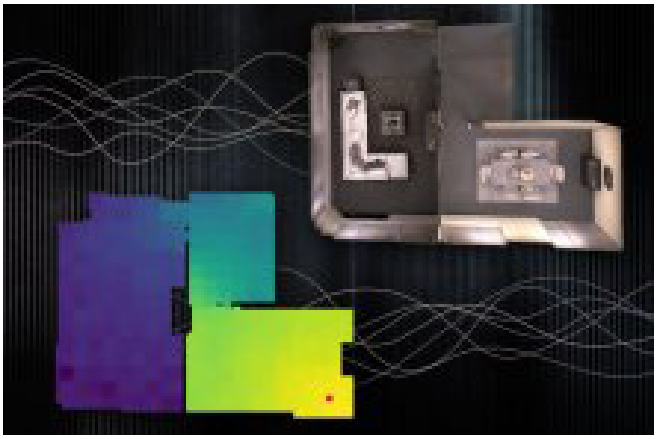
Employee Augmentation:

- In the face of broad workforce shortages, many storefronts are turning to automated services and machines to fill the gap. CSAIL-developed robots can brush hair, help people get dressed, use tools, and moderate their efforts for specific tasks and the safety of the human workers around them. CSAIL researchers are also working on ways to quickly re-train existing robots for new tasks, design and manufacture the best robots for a given application, and help robots handle deformable materials like dough or fabric.
- Another option to maximize employee efficiency without straining the existing workforce is the idea of wearable robotics or combining human and robotic effort. Toward that vision, CSAIL researchers such as Professor Rus are working on gloves that incorporate soft robotics and pneumatic actuators to assist human gripping. Her lab is also working on ways to teleoperate robots—using brain waves to instruct machines—and designing robots that can read human muscle signals and therefore naturally integrate into manual tasks like lifting, moving, and carrying. Similarly, Professor Julie Shah is pursuing several projects that help robots work with humans as a team, adjusting to the unpredictability of human behavior and collaborating on key tasks.
- Many of today's exciting automation ideas, such as touch-free checkout and virtual in-store assistants, require advanced levels of computer vision. CSAIL Professors Durand, Isola, and Antonio Torralba are improving how computers process visual data and use it to interpret the world. Furthermore, Senior Research Scientists Aude Olivia and James Glass are developing ways for computers to understand the world in multiple modalities, combining video, sound, and text to bring AI closer to real human intelligence. Combined, this research could have implications for how customers can interact with and use machines for smoother, faster, and more streamlined buying experiences.
- Another dimension to the problem of labor shortages, especially in food and retail, is the challenge of training new employees. Tasking existing workers with time-consuming instruction periods can strain already-overburdened staff and exacerbate the issue. This is why wearable devices that can sense motion or understand how users are interacting with them—such as those coming out of Professor Mueller's lab—could be key for improving training pipelines and speeding up the process of onboarding new labor, particularly as these industries become more technically advanced.



Customer Interface:

- The first thing that comes to mind when thinking about business-customer interaction might be chatbots. Almost every major corporation now utilizes some kind of chatbot or automated messaging technology. However, the chatbots of today can be slow, frustrating, and circular, with limited application. To improve this, CSAIL researchers are studying large language models (LLMs), testing them in new situations without the need for retraining, integrating explainability features like compositional explanation of neurons, and generally improving upon the existing technology to bring models such as GPT-3 closer than ever to real human-like conversation. Such LLMs could be useful assisting with online shopping, easing the burden on call centers, and even offering fully automated ordering systems in fast food restaurants.
- Beyond LLMs, CSAIL researchers are working on improvements to AI models that can make them smarter in every application, including customer interaction. For example, Professor Rus's lab has created a new kind of neural network called liquid time-constant networks which are causal, flexible, and more robust than previous methods. Several CSAIL labs are working on AI for medical applications—such as helping doctors ask the right questions or detect certain diseases—which could be expanded into situations like detecting defective products, identifying key concerns in customer service, or understanding consumer preferences.
- Something humans still do far better than computers is understanding facial expressions and, by extension, customer mood. Such understanding can be critical for managing difficult interactions such as angry buyers or distressed patrons. To help computers in such situations, Professor Joshua Tenenbaum's group is working on methods that will help models understand faces in the same way humans do. Dr. Olivia is also using neuroscience to transfer human brain processes to AI, which could lend machines more human-like capabilities when deployed in commercial environments.
- Virtual fitting rooms, digital assistants, and product visualization all depend, at least in part, on video generation. The ability of a system to generate video data on demand would increase the ability of customers to picture what they might want to buy, not to mention help with advertising. Therefore, projects like Professor Torralba's efforts to generate video based on scene dynamics could be helpful to offer real-time and dynamic video data. Expanding on this idea, Professor Matusik's work on holograms could even bring such video generation into the 3D world, with fully realized digital assistants and interactive product displays.



Security & Privacy:

- Security is a necessary aspect of every business, especially those that sell physical goods with real-world storefronts. Improving upon security footage possibilities, CSAIL researchers have developed ways to detect and magnify tiny changes in video and use video data to visualize unseen areas, such as around corners or blind spots.
- Effectively using security feed information can be a challenge for two reasons: privacy and data overload. To address the first issue, Professor Hari Balakrishnan created Privid, which applies differential privacy—or adding "noise" to a dataset to cover individual details—in a way that allows analysts to search video datasets without revealing personally identifiable information. For the second challenge, Professor Samuel Madden created Vaas, or Video analytics at scale, which enables users to rapidly solve video analytics tasks, such as searching for instances of a specific event.
- No less important than physical security is digital security, which includes protecting one's online presence and data against hackers. This is why CSAIL Assistant Professor Mengjia Yan's group is identifying and addressing key microarchitecture vulnerabilities such as side-channel attacks, providing users with methods to keep their systems safe from malicious online activity.
- For obvious reasons, businesses don't want to share information about recent security breaches. However, the only way for companies to learn about and therefore prepare for the most common security failures is to study the aggregate data. Therefore, SCRAM—linked to both CSAIL and MIT's Internet Policy and Research Initiative (IPRI)—is using homomorphic encryption to make computations on private data without decrypting it, thus compiling sensitive cybersecurity results while keeping individual company information private. Such methods could be applied to many different kinds of sensitive data, such as sales, customer trends, and market weaknesses, allowing companies to gain insights together without having to share details about internal business matters.
- As new privacy laws emerge like the GDPR, businesses must consider new tools to allow for commercial activity without collecting unnecessary information or compromising user privacy rights. Toward that end, CSAIL researchers are developing privacy-preserving methods such as federated learning for AI, targeted advertising methods that ensure user privacy, search engines that do not collect data on individual search queries, and more.
- Related to the above, the CSAIL Alliances research initiative Future of Data has launched a research sandbox focused on creating accountability and traceability options for dealing with consumer data. This research aims to address the two-pronged problem of declining consumer trust and increasing government regulation by offering new technical infrastructure for businesses that allows for the collection and application of personal data in ways that are trustworthy, legal, and scalable. Some of the topics being explored in this realm are: multi-enterprise or cross-enterprise audit and traceability protocols; privacy-preserving data analytics; database architectures for accountability, traceability, and personal data governance; and user experience design for accountability and traceability.

Conclusion

CSAIL research has already had a significant footprint in many commercial industries, with spinoffs like additive industrial manufacturing platform Inkbit, computer vision system Leela AI, data-visualization interface Einblick, and privacy-preserving AI-training method DynamoFL. Today's projects look to improve automation and security, keep workers safe from dangerous or monotonous tasks, and transform commercial services. Connecting with CSAIL Alliances allows companies to be in-the-know about tomorrow's industry-shifting ideas and to stay informed about what's happening at MIT CSAIL.

Learn more about how to get involved at https://cap.csail.mit.edu/ or reach out to Lori Glover, Managing Director of CSAIL Global Strategic Alliances, at lglover@mit.edu.