Revolutionizing Healthcare Through Technology:

CSAIL'S IMPACT

MIT CSAIL Alliances

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The field of medicine has always been quick to adopt new technologies. In their mission to save lives and improve health outcomes, hospital staff and medical researchers understand the transformative potential of innovative solutions. From X-ray scanners to penicillin, healthcare must constantly be on the lookout for work that will change the future of disease treatment, hospital management, research methods, and—most importantly—patient care.

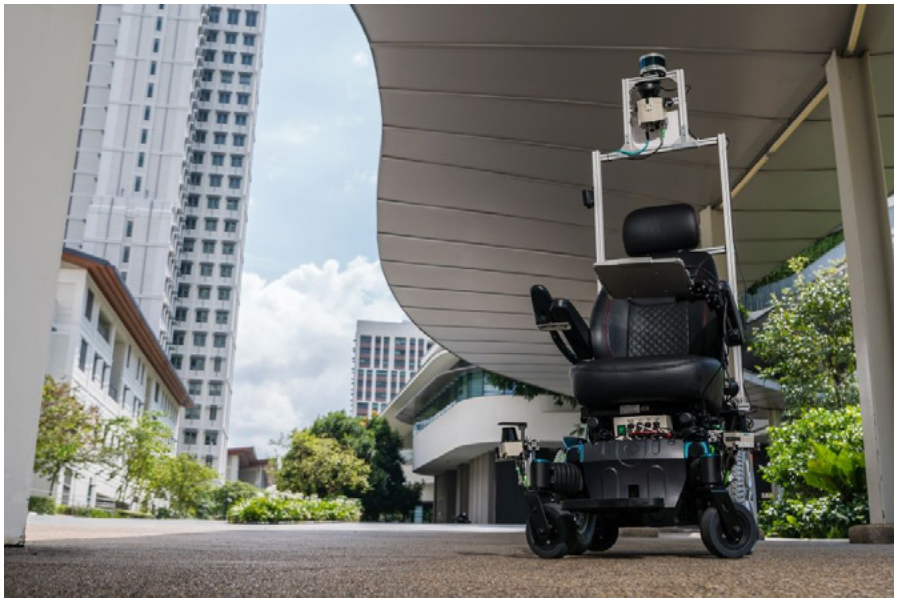
Researchers at MIT CSAIL are exploring ideas that will revolutionize the field in the next five to ten years. Here is a breakdown of some groundbreaking recent projects by CSAIL researchers that could affect the future of healthcare:

Caregiver Assistance:

- One exciting category of healthcare tools coming out of CSAIL are the various AI models trained to assist medical professionals in diagnostics, patient management, and treatment. For example, MIT researchers have developed models that can detect a patient's risk for lung cancer, estimate the risk of cardiovascular death, minimize the use of unnecessary antibiotics in UTI's, and detect depression in conversations with patients. AI can also be helpful in training medical staff, generating examples of images such as brain scans for teaching purposes or making it easier to find information in electronic health records to speed up the learning process.
- CSAIL researchers such as Professor Dina Katabi have worked extensively on the idea of using wireless devices for various medical purposes, like monitoring patients suffering from infectious diseases from a safe distance or tracking the progression of degenerative illnesses from the comfort of a person's home. These solutions—which make it easier for physicians and caregivers to remotely provide assistance—could have huge implications for the growing problem of providing elder care, preparing for future contagious diseases, broadening the ability of patients to partake in treatments such as physical therapy, and ensuring proper adherence to treatment plans for maximal effect.
- Many areas of medicine rely on properly visualizing what's going on inside a human body to diagnose issues. The technology used to generate such images has come a long way since the first X-rays and ultrasounds, but there are still key situations where contemporary solutions fall short. Addressing one current limitation of imaging equipment, CSAIL Professor Polina Golland's group has created a new method to build a 3D map of the placenta, allowing providers to flatten this vital organ and proactively identify problems. Models like these could be applied to other complicated internal organs, offering a new way to picture, identify, and treat internal problems.
- Robots aren't foreign to the medical field, as robot-assisted surgeries and care plans are rapidly becoming more common. But one innovative idea coming out of CSAIL is that of ingestible robots used to deliver interior medical treatments without the need for surgery. These "origami robots" can fold up into an easy-to-swallow pill and then be magnetically activated to, for example, patch up a wound in the stomach. Solutions such as this could minimize the need for invasive procedures in common accidents, such as children swallowing watch batteries.

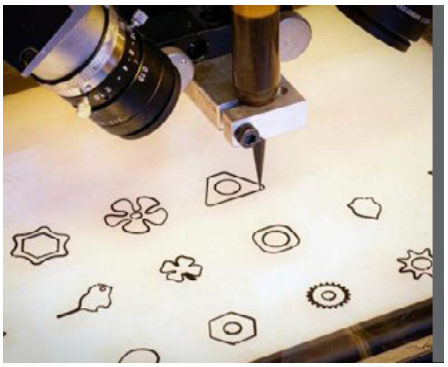
Patient Assistance:

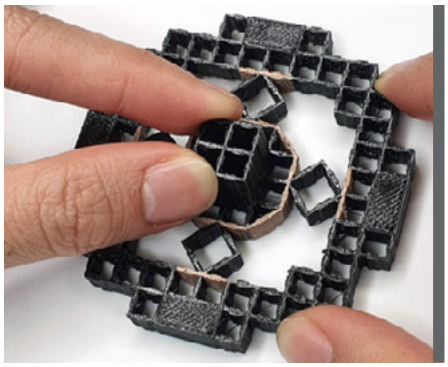
- With projected caregiver shortages and an aging population, there's an increasingly large demand for technical options that will help patients heal and age in-place, minimizing the burden on hospitals and care centers. One way to facilitate that vision is the idea of wearable devices that can sense movement and/or augment human effort. For instance, Professor Stefanie Mueller's lab is working on motion sensing devices that can monitor muscle signals and detect hand gestures. Similarly, CSAIL Director Professor Daniela Rus along with Professor Wojciech Matusik have created assistive wearable gloves that can help patients with compromised motor skills grip and hold. This research opens up the frontier of wearable robotics, which could be expanded to various assistive elements and use case scenarios.
- Another way technology can help patients in the comfort of their own home are robots which can assist with daily tasks that might become difficult due to injury, aging, or disease. For example, CSAIL has worked on robots that can help patients get dressed, brush their hair, and do kitchen tasks like baking or cooking. Research in Professor Rus's lab has also explored the idea of teleoperating robots—or controlling robotic technology with only brainwaves or muscle signals—which could give those with mobile restrictions the capacity to direct machines to help with straightforward household tasks they wouldn't otherwise be able to do.
- Autonomous cars are big news right now, but the same algorithms powering automobiles can also be applied to other, smaller motor vehicles such as wheelchairs and scooters. With the original goal of helping move patients around hospitals—relieving one major burden on healthcare staff—autonomous wheelchairs could offer a promising solution to the elderly and disabled who might not have the muscle strength to power a traditional wheelchair but would still like to enjoy a greater degree of independence. And, as intended, such technology could be transformative in busy hospital environments.
- While medical instructions or take-home devices can seem simple when first offered, it can often be challenging for patients to keep track of various medicines, tools, or procedures when they're back in the routine of normal life. That's why Professor Mueller's invisible machine-readable labels could offer a promising solution, allowing patients to use their phones or personal devices to scan objects and get fast and easy-to-understand information or instructions. As technology becomes more ubiquitous everywhere—including medical care—ways to scan objects to see what they are will become an important part of keeping patients and laypeople informed.



Manufacturing & Design:

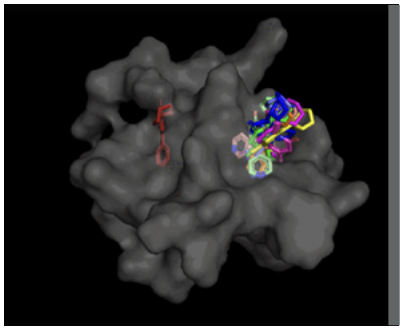
- A pivotal aspect of the healthcare pipeline that isn't often discussed is the manufacturing of medical tools, treatments, and other important solutions. As medical tools become more complex and capable of ever more impressive technical feats—such as the MIT-developed robotic thread that can navigate the blood vessels of a human brain to treat strokes and brain blockages—then mass-producing these devices and tools becomes an important looming question. For that, CSAIL scientists like Professor Matusik are working on automated assembly programs that can efficiently plan the process of producing objects with multiple components, such as robots. This relieves the burden on systems engineers, who are already in short supply, and speeds up the process of taking a prototype to shippable, commercially viable product.
- Similarly, CSAIL research is using computers to help design new tools, as with Professor Matusik's project using computer assisted design to optimize complex fluidic devices such as hydraulic pumps. His system makes it faster and cheaper to create designs for a variety of applications—from research to patient care—and could be expanded to computationally propose key parts for other challenging use cases such as surgical robots, implants, and life-saving medical technologies.
- 3D printing offers an exciting array of potential functions, particularly in medicine. Already there is research exploring the use of 3D printed organs, medical tools, and drug treatments. But one major hurdle to overcome in the widespread use of trustworthy 3D printing—especially in safety-critical situations like organ transplants—is error correction. To address this issue, Professor Matusik's group has worked on applying computer vision to error-correction in 3D printing, designing printers that can watch the printing process as it's happening and make improvements in real-time. This cuts down on expensive trial-and-error waste and speeds up the timeline of production. Relatedly, CSAIL researchers are also accelerating the discovery of new 3D printing materials with computational optimization, expanding on the areas 3D printing can be applied to.
- Furthermore, CSAIL's work on reprogrammable materials could offer benefit in both manufacturing and in operating rooms or hospital centers. CSAIL research has led to robots that can change their shape, fabrics that can be reprogrammed for various visual effects, materials that can self-assemble or sense how they're being moved, and more. Such smart objects and materials offer an opening for creative companies to imagine novel uses for them, like health-aware clothing, reconfigurable surgical robots, hospital rooms that can be automatically rearranged, and more.

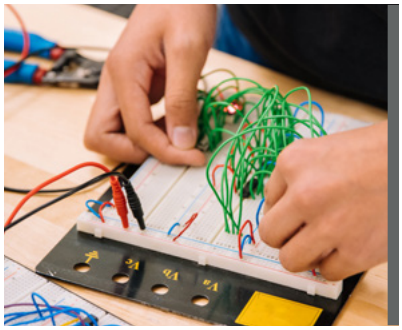




Drug Discovery & Research:

- AI is not only useful in diagnostic assistance but is also being effectively applied to the discovery of new drug molecules. CSAIL Professors Regina Barzilay and Tommi Jaakkola have worked on several projects exploring the use of deep learning and generative AI models to identify and/or design new drug options for various diseases. Their methods improve on current state-of-the-art molecule identification technology by treating the drug-identification process as a query that has multiple potential "correct" answers rather than just one, allowing the program to identify several candidates for functional protein bonding. With rising concerns about antibiotic resistance and the ever-present need to widen potential cancer treatments, their research could prove pivotal in improving the available drug options.
- CSAIL researchers are also using computational tools to answer important health-related questions about the human body and the role genetics and epigenetics plays in various conditions. For example, CSAIL Professor Manolis Kellis has studied how certain genetic factors are linked to higher obesity risk and how exercise and high-fat diets have opposing effects on the body's cellular pathways. His work has shown that exercise boosts the expression of certain genes while high-fat diets repress them. This research has important implications on the molecular pathways that affect one of the largest health-related issues in America and how obesity can be better understood through genetic and epigenetic mapping.
- To conduct medical research properly—especially as healthcare datasets get larger and privacy becomes a greater concern—researchers need access to good data management tools. Toward that end, CSAIL Professor Bonnie Berger has studied several options that could improve the way medical research is done, such as her cryptographic system that allows neural networks to identify promising drug candidates in huge pharmaceutical datasets while keeping patient data private. Professor Berger's group also released an algorithm which, inspired by panoramic photography, merges diverse cell datasets in a way that makes it easier for scientists to visualize the data.
- When it comes to medical research, there's ample data available in the volumes of clinical notes produced on a daily basis in hospitals around the country. However, a huge challenge is accessing the information in those notes quickly and in a scalable way, as clinical health records are notoriously prone to jargon and unclear abbreviations. To solve this, Professor David Sontag and Assistant Professor Yoon Kim collaborated on a project to help existing large language models extract clinical information with minimal retraining. This concept of putting models such as GPT-3 to creative new uses quickly and efficiently could be an exciting source of data in healthcare research.





Privacy, Security & Fairness:

- Security is a necessary aspect of every business, especially hospitals which must stock drugs, protect expensive equipment, and keep workers and patients safe. Improving upon security footage possibilities, CSAIL researchers have developed ways to detect and magnify tiny change in video and use video data to visualize unseen areas, such as around corners or blind spots.
- No less important than physical security is digital security, which includes protecting one's system—including electronic health records and billing infrastructure—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 computer systems safe from malicious online activity.
- As privacy laws like the GDPR become more common globally, hospitals and research centers must find ways to continue collecting and using patient data without compromising patient confidentiality or causing legal headaches. Toward that end, CSAIL researchers are developing privacy-preserving methods such as federated learning, homomorphic encryption, search engines that do not collect data on individual search queries, and more options that will allow providers and scientists to use data while preserving individual patient rights.
- New machine learning and AI tools are exciting, but it's important to keep the natural limitations of AI and ML in mind when applying computational solutions to medical, scientific, or security problems. Several CSAIL researchers are working on ways to ensure fairness in ML models trained on historically biased datasets or uneven patient populations, such as small disease-specific groups that might not represent all demographics. Professor Marzyeh Ghassemi's group is designing robust, private, and fair learning methods specifically for healthcare, addressing subgroup gaps in deep metric learning, creating methods for auditing bias in ML models, and more. This research is relevant to any hospital looking to deploy ML models such as AI diagnostic tools in a safe, reliable, and bias-free manner.

Conclusion

This list is just a sampling of the projects at CSAIL that could affect healthcare going forward. Already several CSAIL spinoffs are invigorating the field such as medical research platform Secure AI Labs, privacy-preserving AI-training method DynamoFL, data collaboration platform Einblick, AI imaging system for pathology PathAI, and model management software Verta. The work happening at MIT CSAIL now will improve AI caregiver assistance, patient monitoring, tool manufacturing, treatment generation, and much more. 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.