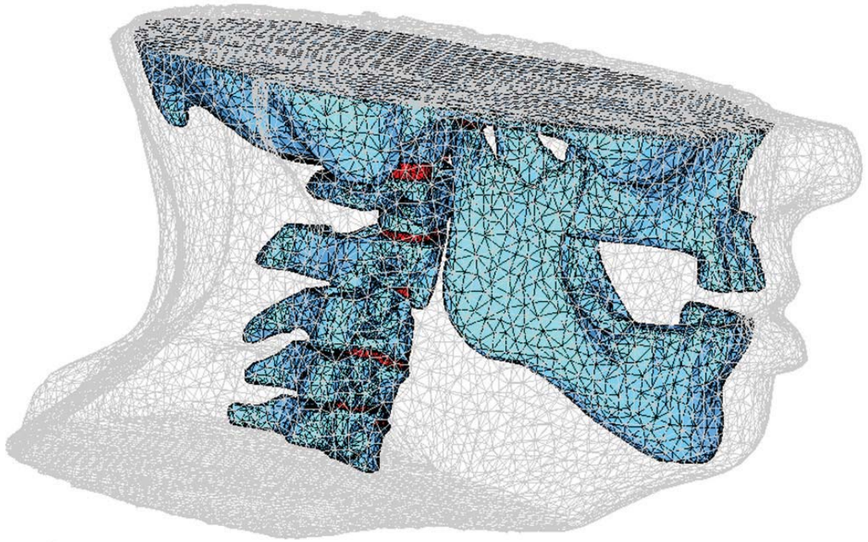
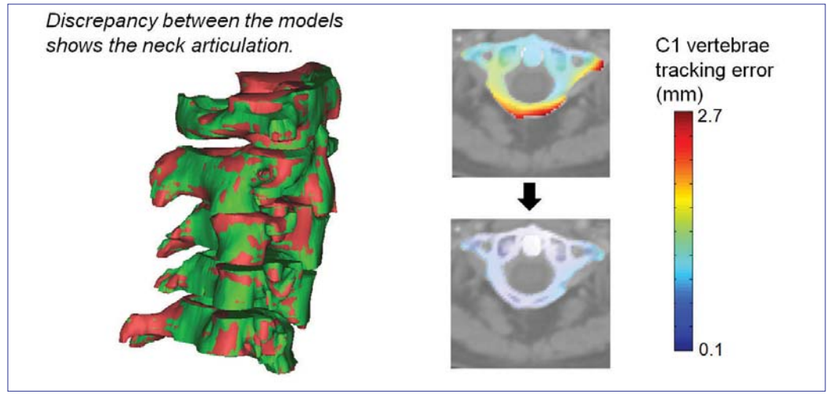


LEFT: A computer simulation model of human head-neck system can mimic anatomical variations occurring over the course of radiation therapy.

RIGHT: Fundamental theory of mechanics can bring advancement to medical image processing, thereby improving quality of cancer treatment decisions. Tracking movements in the five cervical vertebrae were refined by incorporating a commonly acceptable fact, the distance between any two given points of a rigid body remains constant, into the image processing algorithm.



Algorithmic Synthesis

Improving Systems, Creating Solutions

Research in the Algorithmic Synthesis Laboratory (ASL) led by ME Professor **Kazuhiro Saitou** continues to stretch the traditional boundaries of mechanical engineering. The innovations Saitou and his students are developing are anything but conventional, and their work in the fields of biomedical systems and bioinformatics is being recognized for its impact and potential.

IMPROVING RADIATION TREATMENT PLANNING

Together with graduate student **Jihun Kim** (PhD ME '15), Saitou has led development of the computer code that improves the accuracy of radiation treatment for cancer.

Even small changes in patients' anatomy throughout the course of treatment can affect how well the therapy works. Saitou and his group have developed the code to enhance the current digital image registration algorithms used in treatment planning. These algorithms enable geometric mapping of anatomical changes so treatment can be adjusted based on the variations. The code provides new biomechanical guidance via tissue-specific constraints on physically realistic variations, and finite element methods that assesses the quality of image processing.

Saitou and Kim collaborated with professors **James Balter** and **Martha Matuszak** in the U-M Radiation Oncology department. The work was supported by the National Institutes of Health. The code has been incorporated into Elastix software, an open source medical image registration platform considered the de facto standard by researchers worldwide.

Kim will go on to serve as a postdoctoral fellow at Massachusetts General Hospital, under the supervision of a faculty member at Harvard Medical School.

PREDICTING PROTEIN BEHAVIOR

Predicting the behavior of protein structures is important to understanding countless biological processes, including the causes and development of many neurodegenerative diseases such as Alzheimer's and Parkinson's.

For his dissertation, postdoctoral research fellow **Jungkap Park** (PhD ME '13) achieved record accuracy in predicting the behavior of protein structures. Specifically, Park developed a new multibody statistical potential function to characterize the atomic-level interactions of tightly folded proteins.

The new potential function is the first to explicitly take into account a chemical bond's rotameric states, something previous work had not considered. Rotamers are low-energy conformations of protein side-chains. Park and Saitou named the new potential ROTAS, for ROTamer-dependent Atomic Statistical potential.

Benchmark tests on the standard test problems show that ROTAS predicts protein structures better than any existing potential functions. The new ROTAS potential function can be applied to the improved development of many applications in medicine (e.g., drug design and molecular docking simulation) and biotechnology (e.g., mutation analysis and novel enzyme design). Park and Saitou have made it publicly available at **https://sites.google.com/a/umich.edu/rotas/.**

AUTOMATED CHEMICAL ANNOTATION

Researchers who use chemical databases may soon have more information at their fingertips, thanks to an early version of ChemReader, an automated annotation system.

The image-based annotation technology was conceived of by Park, Saitou and Professor **Gus Rosania** in the U-M Department of Pharmaceutical Sciences. ChemReader recognizes chemical structure diagrams in research articles and links them to chemical database entries using common, searchable file formats to enhance the information available to scientists.

Under Saitou's leadership, the team has developed an initial version. With continued development enabled by seed funding from the U-M Center for Entrepreneurship, the latest version of the software is being evaluated for potential adoption by several pharmaceutical companies.

IMPROVING MEDICAL IMAGE GUIDANCE

With funding from MCubed, Park developed a tracking system to model uncertainties in image-guided medical interventions. The system includes a simulation component to predict needle trajectory, an imaging component to observe the actual trajectory, and a tracking filter to integrate predicted and observed data.

> The[se] accomplishments show the real benefit of applying our mechanical engineering training and insights to conventional biology, medicine and bioinformatics.

Park and Saitou devised the needle insertion simulation algorithm and validated it experimentally in collaboration with ME Professor **Albert Shih.** The algorithm is capable of predicting needle deflection from effects of the bevel-tip as well as tissue deformation from interactions between the needle and tissue.

After earning his PhD and spending a year as a postdoctoral research fellow in the ASL, Park accepted a position in the Computational Biology & Bioinformatics group at Pacific Northwest National Laboratory, where he works in the area of computational proteomics.

"Both Jihun [Kim] and Jungkap [Park] have been very successful in producing high-quality work that is getting well-deserved recognition," said Saitou. "Their accomplishments show the real benefit of applying our mechanical engineering training and insights to conventional biology, medicine and bioinformatics."

AN UNCONVENTIONAL CONCEPT

Again pushing traditional boundaries, Saitou and two students recently won $10,000 in a design competition for their innovative, lightweight vehicle architecture concept. The competition was part of the Lightweighting Technologies Enabling Comprehensive Automotive Redesign (LITECAR) Challenge sponsored by Local Motors and the Advanced Research Projects Agency-Energy (ARPA-E).

Saitou and **Yuqing Zhou,** an ME doctoral student, worked with **Jeff Xu,** an undergraduate of the Stamps School of Art & Design, to develop and illustrate their ideas. The architecture relies upon several innovative concepts to significantly reduce weight in a 5-passenger sedan, including a doorless and windowless cabin, rear-facing, detachable seating and an unorthodox tire layout that eliminates the heft of a differential gear box and oversized suspension systems.

"This was a fun challenge," said Saitou. "We proposed a really crazy concept, but we were backed by solid engineering knowledge about vehicle body architecture and engineering requirements. The project was a great example of how mechanical engineers and graphic artists can collaborate to produce scholarly work in a medium other than archival journals and conference proceedings."