



Changing Face Of Robotics

Mechatronics and Symbolic Model Formulation Techniques are driving innovation in the Robotics field, from Humanoid Robots to Autonomous Cars, and beyond.

Robotic technology has improved dramatically in the past decade, and applications are getting more exciting as well. Robots are cool again, and for engineers, designing the new generation of robots is one of the most exciting types of projects. While the prior generations stunned the world by sending men to the moon in the 1960s, this generation will soon make a robot dance better than Michael Jackson.

Popularity of youth competitions have grown in the past few years, including the high-school FIRST Robotics (For Inspiration and Recognition of Science

and Technology) contest and the FIRST Lego League for younger children. Nowadays, every toy store in the industrialized world is crammed with computer-controlled toys that would have been labelled as state-of-the-art robots only 20 years ago. The quirky Roomba autonomous vacuum cleaner was launched as the world's first robotic household cleaning device. Although its capabilities as an effective vacuum cleaner are debated, its introduction has resulted in the development of derivative products that provide accessible platforms for learning and exploring real robotics techniques.

Beneath all of this is a whole new generation of engineering and scientific techniques that empower and fuel the rapid pace of innovation within the modern robotics community. In the end, what was once the stuff of science fiction seems to be within reach for the engineering community.

Emergence of mechatronics

Arguably, one of the most important techniques that emerged from the engineering community over recent decades is mechatronics, or the computerized control of complex mechanical-electronic systems. Once engineers figured out practical ways of implementing digital control using computer chips, the world had a workable framework for intelligently controlling very complex machines. The word mechatronics was coined in Japan in the late 1960s by Japanese engineers in industrial machinery design. Today, mechatronics techniques are heavily used in a range of industries, including automotive, aerospace, manufacturing, power, and of course, robotics. Reflecting on roughly 50 years of mechatronics history brings awareness of accelerated change.

Like every other technology-driven segment, robotic developments have advanced at an exponential rate. However, as with many technology segments, there are natural limits to the effectiveness of traditional techniques and tools.

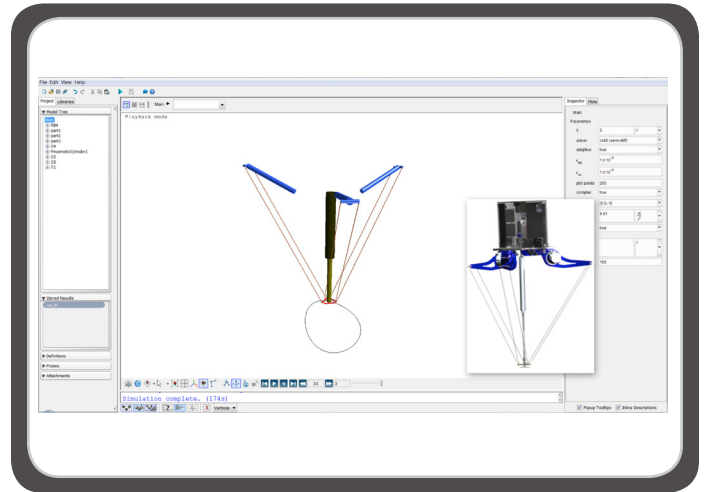
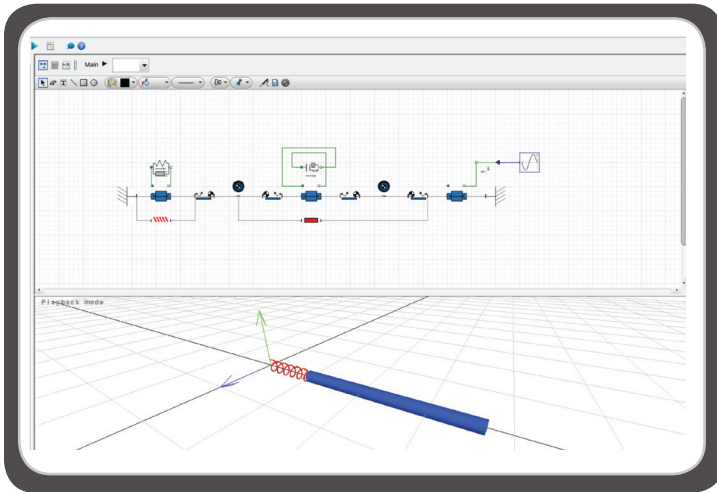
For example, within the auto industry, the members of the Plant Modeling Consortium (PMC), an industry think-

tank led by Toyota and the modeling software vendor Maplesoft, are discussing the challenges in modeling and designing control systems for the next generation of cars. Complex applications such as hybrid electric vehicles (HEV) or fully electric vehicles are presenting some fundamental hurdles that have triggered a rethinking of modeling processes. The multidomain nature of HEV requires more sophisticated techniques and greater flexibility from software tools to properly integrate the various domains. With the emergence of hardware-in-the-loop (HIL) simulation as a key testing step for complex systems, the required models often cannot run fast enough for the real-time clock speeds. Consequently, engineers are forced to make major approximations and simplifications within the model that many feel defeat the purpose of higher fidelity modeling.

This trend is also noticeable in the field of robotics, though not as formalized as the PMC for automotive technology. In the late 1990s, the Canadian Space Agency (CSA) introduced a new technique for increasing the modeling fidelity of the robotic manipulators that were deployed in the Space Shuttle and the International Space Station (Canadarm and Dextre). CSA engineers

were among the first to develop software tools to automate and optimize the derivation of dynamic model equations. The inherent complexity of these manipulators made traditional manual derivation of the equations impossible. To fully capture critical system dynamics, CSA engineers needed to develop a technique for automating the equation derivation and automatic generation of C-code for real-time simulation testing. They developed a system called Symofros, which is based on a symbolic computation system. Symbolic computation was used to perform the algebraic steps of model derivation, model simplification, and the conversion of the resulting mathematical expressions to C-code. The result was a substantial reduction in model development time, an increase in the fidelity of the model, and feasible speeds in real-time via the C-code. This was one of the first major deployments of what would become a very useful new modeling approach for modern robotics.





Symbolic model

Over the past decade, a wide range of engineering and research groups began exploring the potential of symbolic model formulation and automated code optimization. An industrial example is a recent product from AEMK Systems called DeltaBot, a new delta-style robot for picking and placing. The Deltabot differs from other delta-style robots by using cables instead of conventional rigid links. This allows for faster and more precise response, elimination of backlash, and significant increase in payload capacity. Dr. Amir Khajepour, AEMK's founder and president, applied symbolic techniques to develop the dynamic models for his design. Khajepour found that a general-purpose symbolic system allowed him to capture the core dynamics of the cable system and significantly reduce prototyping time and cost. Khajepour continues to explore symbolic modeling techniques using newer modeling tools.

These two case studies highlight how a modest tweak in the simulation toolchain can improve results. The tweak involves an extra step in the first stages of a modeling process: equation derivation. At the time of the first applications, the symbolic technology was not new. As was the case with both the CSA and Deltabot, the symbolic tools were mature, and the

language was at a sufficiently high level to make the programming task efficient. Even with these early experiments, the conclusions were clear. Direct user-level access to the model equations during the model formulation process via symbolic computation tools will result in more efficient models. Furthermore, continuing to apply symbolic techniques through latter stages, including real-time plant code generation, can resolve HIL bottlenecks as well.

Since then, the use of symbolic techniques has rapidly evolved, and many more streamlined products are beginning to enter mainstream engineering. One example using symbolic techniques is the MapleSim system, the engineering modeling descendant of the original general-purpose Maple product. Aside from the introduction of a component-based physical modeling graphical user interface, there are other technological advancements under the hood. For multibody systems, the symbolic formulation is done by applying linear graph theoretic techniques. Linear graph theory allows representation of core model topology via mathematical graphs, then systematically associates graph elements with mathematical relationships describing the physics. In the end, linear graph theoretic techniques

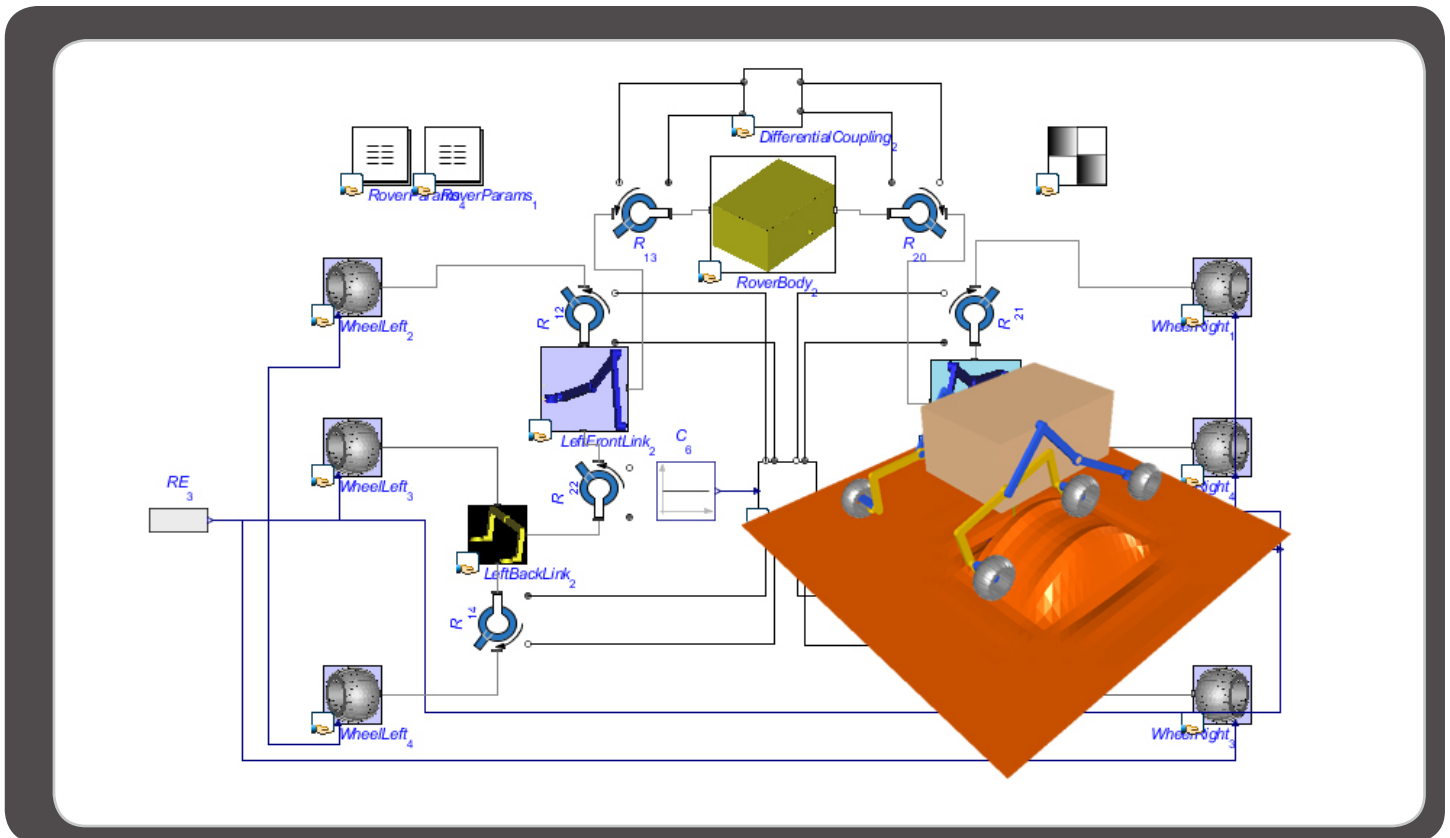
can efficiently derive a compact set of differential equations, which minimizes the total numbers of equations, variables, and model complexity. The symbolic framework ties the graph theoretic tools to the Modelica language, which takes care of the other physical domains. These advanced mathematical algorithms, which are rooted in symbolic computation, rapidly and accurately produce the desired equations in a useful mathematical form.

In the long term, symbolic computation will likely be an invisible part of the tool set. Users will not need to concern themselves with symbolic techniques, as they will simply be part of the internal machinery. These more ambitious modeling techniques enable a wide range of new devices that were the stuff of science fiction only a decade ago.

Autonomous vehicles

One such area is that of autonomous vehicles, such as unmanned aerial vehicles (UAV) or ground-based vehicles (UGVs). These space-age vehicles are capable of very complex movements and are intelligently guided by on-board algorithms. Although exclusive groups like the military have had such technology for years, these devices are now available for experimentation and research by a much broader range of engineering groups. For example, Quanser Consulting, a company focused on mechatronics experiments for research and teaching, recently introduced its Qball-X4 quadrotor helicopter system. It supports a range of experimentation from basic flight control to multi-agent mission scenarios. The Qball is the latest in a series of Quanser devices that provide an effective

and affordable platform to learn and refine UAV technology. The engineers at Quanser have been leading proponents of symbolic model derivation for years, and claim that high-fidelity, mathematics-rich modeling is a key to quickly prototyping advanced systems. By effectively using available symbolic technology, the company has been able to test for possible dynamics and design defects before expensive prototypes are built. The Qball, according to mechatronics expert Dr. Jacob Apkarian, Quanser CTO and founder, is the first of its devices that was completely modeled using MapleSim, which supports a standard symbolic model formulation stage in the company's workflow.



<http://www.controleng.com/industry-news/more-news/single-article/changing-face-of-robotics/61e78287b9.html>
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Humanoids, new space race

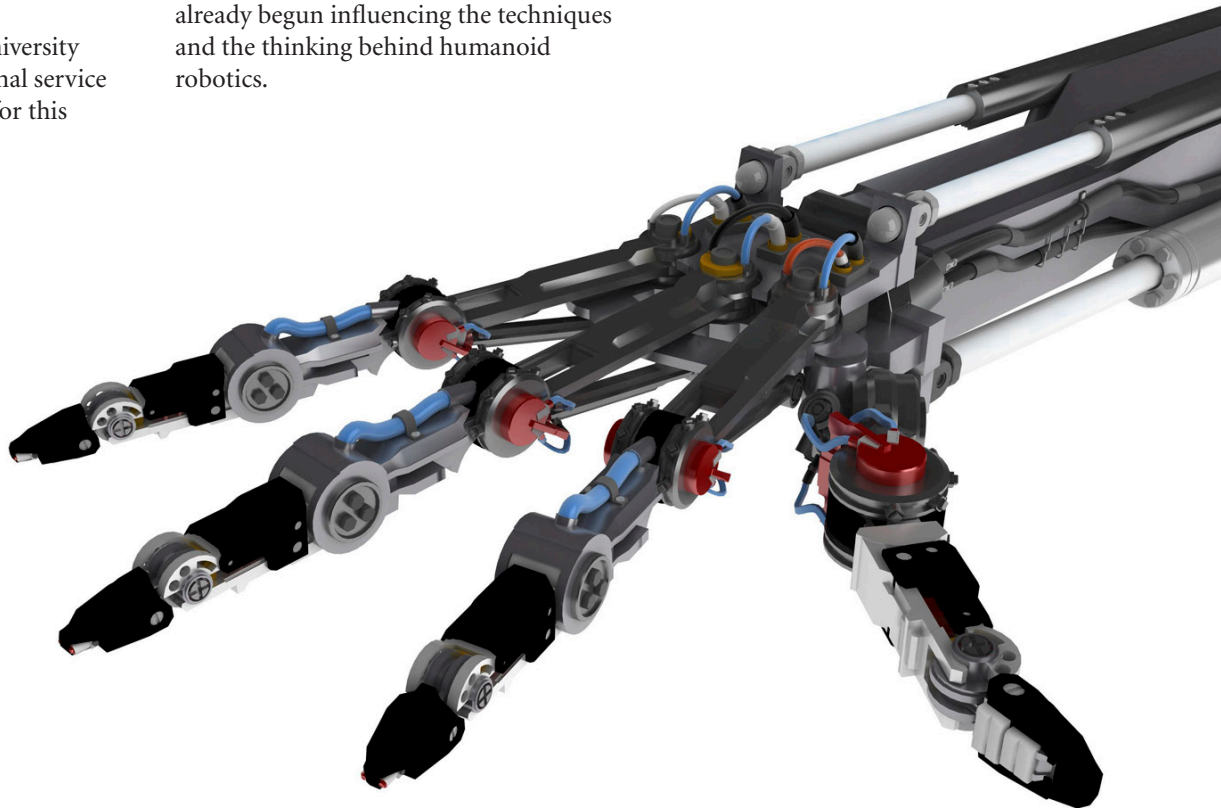
Nothing seems to amaze today's engineer more than humanoid robots. Although humanoids are often considered by Western engineering communities as eccentric and not entirely practical, everyone admits they are interesting and challenging applications. In countries like Japan and Korea, humanoid research is a highly competitive and prestigious endeavor. Many Japanese auto firms maintain an active and well-funded humanoid research group. The famed ASIMO from Honda is the result of that company's humanoid activities. Toyota also is engaged through ongoing research collaboration with the famed Takanishi Laboratory of Waseda University in Tokyo. The Takanishi Lab has produced a staggering range of futuristic robots, including its most famous humanoid, WABIAN. The lab has robots that can play musical instruments, show facial emotion, or carry a full-sized person safely up and down stairs.

Although government and university officials point to future personal service robots as a strong motivator for this

research, there is another goal that fuels this activity. Dr. Paul Oh, director of the Drexel Automous Systems Laboratory (DASL), said that humanoid research and development (R+D) constitutes a modern "space race" for Japan, Korea, and other nations. It is a highly visible articulation of technological capacity and creativity. Dr. Oh also points out that the potential of such futuristic work to motivate younger generations is also very important. This motivational effect is likely strong for generations that grew up with Lucasfilm Ltd. Star Wars robots C-3PO and R2-D2.

Of course, achievements in humanoid robotics are also tied to progress in modeling techniques. Humanoid research shares the same dependence on multi-body dynamics theory and HIL testing as its counterparts in other robotic domains. Indeed, symbolic derivation and code optimization have already begun influencing the techniques and the thinking behind humanoid robotics.

It has been a remarkable couple of decades for robotics. The romantic image of intelligent, useful, powerful, friendly, and occasionally evil robots has been a recurring theme in our popular culture from the mid-20th century onward. The emergence of flexible automation robots for manufacturing applications took hold in the 1980s, and for a while, the concept of robots was somewhat boring and overly practical. Just as computing technology blew open the doors to new possibilities in so many fields, roboticists are now enjoying prominence with new initiatives that are amazing. Smarter modeling technology continues to be a key part of this revolution, as the triple threat of decreased model development time, increased model fidelity, and faster HIL performance are so important to the robotics field.



<http://www.controleng.com/industry-news/more-news/single-article/changing-face-of-robotics/61e78287b9.html>
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