Professor Guoqing Xu is dedicating his career to revolutionising the way we travel. Here, he talks in detail about his research, ‘intelligent’ vehicles and what his colleagues can learn from robotics.

How would you describe the central aims of your research projects?

My work mainly focuses on energy conversion and control. The main applications for this research are high-speed electric multiple unit (EMU) trains and electric automobiles. We are interested in developing novel methods for integrating power electronics and driving technologies, so as to improve aspects of systematic performance such as reliability, cost, size, efficiency and so on. In addition, with multi-energy systems such as hybrid energy technology, which use both fuel cell power generation and batteries, it is of great importance to improve the system’s efficiency through better energy distribution and optimisation.

Can you go into more detail about your work developing a so-called ‘intelligent’ electric vehicle (EV)?

We believe the key to intelligent vehicles lies in studying the differences between EVs and conventional automobiles so as to further explore novel methodologies. For example, the electrical driving system at the core of EVs has many merits compared with conventional internal combustion engine cars, such as faster torque response, better energy recovery ability and the electrification of subsystems. Utilising such advantages as fully as possible will play an important role in the future development of EVs, eg. the short driving range on a single charge remains a bottleneck for the industrialisation of EVs, making energy saving and charging technologies very important. Studying how to achieve deep energy recovery and high energy efficiency during braking is also crucial to our work.

What role do safety considerations play in your studies, and how important could they be to the successful realisation of EVs?

Since the charging action of EVs interacts with the grid, we have to consider both the efficiency and safety of the technologies we are developing, as well as other issues. In terms of safety, because the EVs’ electric driving/braking force is very fast, control of vehicle dynamics and active safety need to be reconsidered. Interestingly, EVs are actually quite similar to mobile robots, so we are looking into the possibility of combining robotics and automobile technologies. Such R&D will have a significant impact on future vehicles.

Your research has already borne fruit in a number of ways, such as your high-security energy regeneration methods. Could you tell us more about those?

One of the highlights of our research so far has been our successful integration of independent driving technology, energy recovery technology and fast wheel slip prevention control. This breakthrough has contributed to the recovery of the vehicle’s kinetic energy, maintaining stability during braking and recovering a significant quantity of the energy normally wasted in conventional vehicles. Considering that braking energy generally accounts for between 40 and 60 per cent of the traction energy in typical driving cycles, this approach can prolong the range of EVs on a single charge by approximately 20-30 per cent for central drive and 30-40 per cent for four-wheel independent drive vehicles. If you consider the enormous global market for trains and automobiles, the energy saving potential of this technology is huge.

Finally, what is the rationale behind your decision to develop four-wheel independent drive and four-wheel steering?

We first developed this technology in 2006, and it has generated a great deal of interest from around the world. With car ownership increasing worldwide, limited parking space in cities is becoming a serious problem. Using the technology of four-wheel steering, it is possible for a car to move directly in a lateral direction and achieve pivot turning, providing the greater flexibility needed for manoeuvring into narrow parking spaces. Furthermore, using a folding chassis can further reduce the parking space required, meaning the city’s space utilisation will be further improved.
Towards an electric future

Cutting-edge research at The Chinese University of Hong Kong is making great strides in a bid to design, patent and develop the next generation of road and rail vehicles.

As global fossil fuel resources steadily deplete and the effects of anthropogenic climate change take hold, there is widespread consensus that our modes of transport – a significant factor in both these trends – must become more efficient, sustainable and environmentally friendly. One way this could be achieved is a move away from petrol and diesel to vehicles powered by electricity. The transition to electric vehicles (EVs) would not only remove the need for environmentally harmful carbon combustion, but would also open the door to a wide range of innovations in almost every aspect of vehicle design. Given the huge number of people around the world who rely on rail and road-based vehicles for work and leisure on a daily basis, even small-scale improvements in technology could have an enormous net benefit.

Committed to making EVs the transport of the future, researchers at The Chinese University of Hong Kong (CUHK) have already broken significant new ground in a variety of transport-related technologies. Working on a comprehensive range of improvements across a plethora of research arms, the team at CUHK is striving to design, patent and deliver intelligent vehicles that could have an important social, economic and environmental impact.

**Vehicle-to-grid technology**

One particularly promising form of electric car already commercially available is the plug-in hybrid electric vehicle (PHEV). Given the growing popularity of these automobiles, and with an increasing number of manufacturers releasing their own models, attention within the research community has turned to improving the accompanying vehicle-to-grid (V2G) technology. The term V2G describes a system in which, using bidirectional power conversion, PHEVs are capable not only of withdrawing power from the grid, but of feeding electricity from on-board batteries back into it. In this way, domestic vehicles could potentially double up as distributed energy storage devices for the power grid. Using a combination of mathematical modelling, case studies and investigations into the impact of V2G on regulated charging, the researchers at CUHK are optimistic about the possibility of smoothing the load variance in household microgrids by regulating the charging pattern of PHEVs. Given their early success in this area, the team is confident that this breakthrough will soon lead to improvements in the efficiency and reliability of the power grid, as well as reducing both the costs and carbon emissions of EV usage.

**Collision prediction**

A further area of research amongst the group at CUHK concerns trajectory planning in driver-assistance systems during lane-change scenarios. Proposing a novel model which reflects established driver control strategies of adjusting both longitudinal and latitudinal acceleration whilst changing lanes, the team’s approach allows for different individual driving styles by using appropriate model parameters. Compared with current technologies, the dynamic models being trialled at CUHK fit real-world lane-change trajectories much more accurately, leading to more efficient collision prevention. The researchers’ promising field tests have already demonstrated that the dynamic models they have designed are capable of computing the minimum gap and time to collision during lane changes. Once integrated into the human-machine interface, this technology will enable drivers to quickly and easily recognise safe times, areas and trajectories to perform lane changes, preventing large numbers of potentially fatal collisions.

**Improving battery technology**

In order for the widespread transition from traditional fossil-fuelled vehicles to EVs to become a reality, battery charge times will have to be significantly reduced. Professor Guoqing Xu, Director of the Shenzhen Institutes of Advanced Integration Technology, Chinese Academy of Sciences and The Chinese University of Hong Kong (CAS-CUHK SIAIT), has led investigations into the potential of a fast-charge-framework built around model predictive control. If successful, this could not only reduce charge duration – and with it out-of-service time – but also the current increase in temperature during charging which makes the process both energy inefficient and potentially dangerous.

The cutting-edge model, which predicts the future state of charge, also consists of a single-mode lumped-parameter thermal model and a neural network trained by...
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accurate experimental data. As a result, it has been possible for the researchers to predict temperatures in both simulated and experimental scenarios. Following on from this, the team used a genetic algorithm to determine the optimum charge sequence, minimising both charge duration and temperature increase. In both simulated and experimental trials, this technique has proven superior to the established constant current constant voltage (CCCV) method of battery charging, raising hopes that it could one day become the norm.

PATENTS
Evidencing the value and originality of the research being conducted at CUHK, the laboratory has been successful in bringing out a number of patents for specific technological and methodological advances. In 2008, for example, a worldwide patent was created for the team’s energy management system for hybrid EVs, comprising both a load forecast system and vehicle management system. The former is set up in such a way as to receive and process input information in order to generate a future load level, which the management system then receives and processes to determine optimal future power output. In doing this, the system is capable of coordinating the engine’s operation, maximising energy efficiency without compromising performance.

Additionally, the team has brought out a patent for their method and system of determining collision severity, further enhancing the safety of EVs. The system has a number of resourceful features, including subsystems which can detect rapid decreases in speed, minor bumps, airbag activation, brake failure and even vehicle rollover. Incorporated into this technology is a controlling unit which ascertains the severity of any collision, making the car’s response as appropriate and safe as possible.

Most recently, in December 2014, the researchers were granted a patent for a method and system of detecting slip rates in EVs. Slip rates refer to the proportion of a sliding component in wheel movement and, in an EV, can be calculated by measuring the motor voltage, motor current and rotational speed of the drive motor. The novel system devised by the researchers at SIAIT features detection units which take each of these measurements before relaying the values to a slip rate calculation unit, configured with a formula determined by the drive motor type. The novelty of the patented system lies in its ability to solve existing problems of calculation delay and poor provision of real-time results. The outcome is an accurate, real-time application which can be used in both two-wheel and four-wheel drive EVs.

COMMITTED TO PROGRESS
In support of the growing importance of technology in transport applications, and building on the crucial work being carried out by CAS-CUHK SIAIT and others, the China Instrument and Control Society has recently set up an Intelligent Vehicle and Robotics Committee. As Xu explains, the Committee has been hugely important for cross-pollination: “Through this network, we are not only able to exchange knowledge and expertise between academic institutions – combining intelligent technologies, robotic technologies and EV technologies – but between universities and industry partners”. Across China, the Society has over 100 affiliates, making it an ideal stage for establishing the dialogues needed for technological innovation.

ELECTRIC LOCOMOTIVES
On top of the significant work Xu and his colleagues have conducted in making electric cars more efficient, safe and affordable, they have also carried out research into electric locomotives. Having highlighted the calculation of wheel-rail adhesion stability as one of the most important factors in guaranteeing the safety of modern, high-speed locomotives, the team has designed an innovative system capable of successfully performing this role.

In accurately measuring the wheel drive torque and wheel rotation speed, the design constitutes a groundbreaking adhesion stability detector, removing the need to capture the challenging and unreliable data required by previous systems. Further, the team’s new system can calculate the adhesion state irrespective of wheel-rail conditions, with mathematical modelling having reinforced the effectiveness of this approach.

By developing valuable and diverse innovations in both rail and road-based vehicles, the researchers at CAS-CUHK SIAIT have created a strong platform for ensuring that the transport of tomorrow is safer, cheaper and more environmentally friendly.