The challenges of **complexity**

Professor Hassan Noura

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The Department of Electrical Engineering at the United Arab Emirates University provides world-class education while conducting cutting-edge research in a number of areas. Through close collaborations with major industrial partners, they provide solutions and advice for real-world problems.

A car which drives you from home to work at the touch of a button, with no intervention required. An aeroplane which can land itself in the middle of the thickest fog, without the hand of a pilot at the controls. A robot submarine which can travel for weeks under the polar ice, with nothing more than a vague command to explore the area. Only a few short years ago these would have been dismissed as pure science fiction, but today all of them are real.

The rise of autonomous vehicles, (drones, if you will), is the most visible change that has been brought about by rapid advances in the field of automation. Thanks to vast increases in computing power and program complexity, it is possible for a computer to take input from a number of sources and then decide how to achieve its goal – all without human intervention. Robot cars are obvious beneficiaries, but complex automation finds its way into manufacturing, toll booths, ship stabilisation and more.

The down-side of complex automation, of course, is that there is a far greater scope for something to go wrong – and no amount of engineering can completely prevent faults from occurring. Automated systems thus need to be able to detect, and correctly react to, faults before they affect the entire process – this is known as Fault Tolerant Control, (FTC).

Fault tolerant control relies on the existence of diagnostic modules, which provide a continuous stream of information on the health and status of the system they are monitoring. When a fault occurs, diagnostic modules inform the central automating system, which can then compensate for the change – thus keeping conveyor belts running and aeroplanes in the sky.

What are the requirements for a diagnostic module? It needs to be fast enough to respond to changes in the system, it is no good knowing that the brakes have failed after the car has hit the post-box, after all. It must also be able to accurately diagnose, to determine just what the problem is. This is a surprisingly complicated requirement, as it often requires the module to make a best guess as to what is happening in the face of conflicting information. Accurate diagnostics modules use comprehensive knowledge models of the system combined with complex decision-making algorithms to make sense of these situations.

Quis creat custos?

The development of these systems requires significant expertise, and this is where scientists such as Professor Hassan Noura come in. A well-known researcher in the field of fault tolerant control, his expertise has been called upon for fields ranging from helicopters and microchips to fuel cells and unmanned aerial vehicles. Currently the Chair of the Electrical Engineering Department at the United Arab Emirates University, he began his research career in 1990 as a PhD student at Lorraine University, France. There he was one of the first researchers in France to work on fault-tolerance in automated systems, using a heating system which could adapt to failures on the fly. His career rapidly progressed, with an Associate Professorship at Lorraine University being quickly followed by a full Professor position at Aix-Marseille University. He moved to the UAE in 2007, before taking up the Department Chair position in 2011.

Throughout this time he has specialised in the development of fault tolerant control systems for a various problems, often in collaboration with industry partners. Automation has spread throughout many facets of modern industry, and the basic approach to fault-tolerant design is inherently flexible, allowing the same paradigm to be applied to many different areas.

Indeed, renewable energy in remote locations has become a minor focus of the group, with research being performed on diagnostics systems for fuel cells, wave energy convertors, and solar plants. Fuel cells, which convert chemical energy directly into electricity, are often used in remote situations for power generation. Collaborative research between UAE University and the Japan Co-operation Centre, Petroleum has begun with the aim of developing diagnostics modules for fuel cells, particularly in high-temperature situations – a natural concern for a desert state. A small-scale wave energy generator has recently been installed at the university, and will act as a basis for work both for the control and diagnostics group and for others in the electrical engineering department. Renewable energy is a surprising choice in the UAE, which is one of the world's largest exporters of petrochemicals, but represents a general move by the UAE over the last few years to diversify their technology and economic base.

Flying free

But Professor Noura's main interest lies not in the ocean, but in the skies. At his urging the United Arab Emirates University has recently launched a dedicated facility for work on Unmanned Aerial Vehicles, where students and researchers can develop new methods for both autonomous control and fault tolerance. The group focuses on rotary-winged UAVs, such as quadcopters, (the four-rotor drones often seen in your local park), or octocopters (their eight-rotor big brother). The UV Lab Family, as they call themselves, focus their research on the design of both fault-tolerant control components and the associated software – with the ultimate goal of designing a UAV which can remain flying in the face of multiple failures. As a plummeting UAV can do significant damage to property, (damage which is often specifically excluded from insurance policies), being able to prevent this is a valuable goal to have.

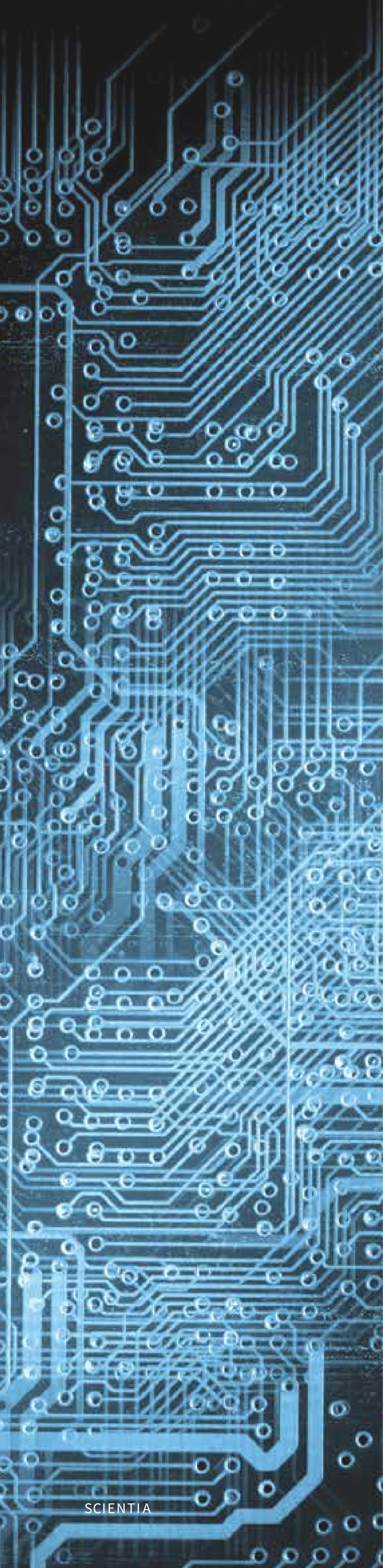
In a world of complex automated systems, what happens when a part breaks? Less than you would think, thanks to the work of researchers such as Professor Noura.

Their expertise in these areas has led to a number of contacts with industrial aerospace firms, as it can be directly applied to the more traditional type of aeroplane as well. The majority of modern aeroplanes use 'fly-by-wire' controls – in which electrical signals, rather than mechanical pulleys, convert pilot actions into movements of the control surfaces. These systems are lighter and allow for automated flight stabilisation, but are more susceptible to the failure of control modules. As such,

diagnostics modules and fault-tolerant systems are a necessity for modern aeroplane design, particularly when working with high performance fighters which may be damaged in combat. Part of Professor Noura's work is done in collaboration with Dassault Aviation, manufacturers of various aircraft including the hypersonic Mirage and Rafale, to create systems which can handle failure at high speeds and low altitudes.

These developments are also applicable to civilian craft, a further collaboration with Eurocopter involves improvements in diagnosing changes in helicopter drive-trains. Failures of the drive-train, which couples the engine to the rotor, have led to numerous crashes – and thus early identification of discrepancies in the system can allow preventive maintenance before catastrophic failure.

The fields of automation and automated process control have taken a long road to reach their current state. Shall we start in the whistling of steam engine governors from James Watt's time, or the gentle glow of the failure-prone vacuum tubes running the first automatic telephone switchboards? Compare this to today, in which factories can run for months without human intervention, and autonomous aircraft can patrol the oceans for weeks. The expansion of the power and reach of automation requires a corresponding growth in the ability to control these systems under imperfect conditions. It is this next stage, the creation of truly adaptive, fault tolerant systems, where researchers such as Hassan Noura are leading the way.



Researcher Profile

Professor Hassan Noura
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Professor Hassan Noura is the Chair of the Electrical Engineering Department at the United Arab Emirates University. With a PhD from Lorraine University, France, in 1993; followed by Professorships at both Aix-Marseille University, France and UAE University; his career has been highly international both in location and collaboration. Professor Noura has had a long and distinguished career in the field of fault-tolerant control systems, developing automated systems which can work in the presence of failed components or errors. This work is applicable to a number of fields, and he has performed a number of joint projects with world-leading industry partners. He is also responsible for the development of the first unmanned vehicle laboratory at UAE University. He teaches a number of subjects involving automation and control, and has supervised 12 PhD students. During his career, Professor Noura has been the author of one book, three book chapters, and numerous journal and international conferences articles.

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FUNDING

UAE University Program for Advanced Research
Japan Cooperation Center, Petroleum (JCCP)
Dassault-Aviation
Abu Dhabi Autonomous Systems Investments (ADASI, UAE)
Abu Dhabi Police

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