



# 60 Years of Computing in Victoria

14 JUNE 1956

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## WELCOME Justin Zobel

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We are celebrating the 60th anniversary of computing in Victoria. CSIRAC, Australia's first computer, resumed operations at the University of Melbourne on 14 June 1956, after being moved from Sydney.

CSIRAC is the world's oldest intact computer, and is now on permanent display at the Melbourne Museum. Many people contributed to this outcome, but in particular Dr Peter Thorne both led the technical work of restoration and made the case for it to be exhibited and conserved - thus giving us and future generations an opportunity to fully appreciate the roots of computing.

We welcome this anniversary as an opportunity to highlight the history of computing technology and its impact on our society.

Not coincidentally, we are also celebrating 60 years of computing education and research at The University of Melbourne. From small beginnings in the 1950s, the Department of Computing & Information Systems, as it is now known, has become an international leader in information technology.

During the week we look at the remarkable achievements of computing. We have commissioned a series of articles to illustrate what computing has contributed across a variety of fields of research. With industry and government leaders, we will look ahead to what the next 60 years of computing may bring. We will celebrate the women who are prominent in the field. And with our academic colleagues, and with computing pioneers, we will explore some of the landmarks in our 60 years of computing history.

I am deeply grateful to our partners and supporters: the Australian Computer Society, CSIRO, the Melbourne Museum, the Melbourne School of Engineering, the Pearcey Foundation, and the Victorian State Government, all key players in Victoria's rich history of computing.



*CSIRAC was originally built in Sydney by the CSIRO before being transferred to The University of Melbourne*

## TODAY'S SMART MACHINES OWE MUCH TO AUSTRALIA'S FIRST COMPUTER

By Justin Zobel

**Australia's first computer weighed two tonnes, filled a large room and had a tiny fraction of the capacity of today's typical smartphone. But why would such a machine continue to be relevant today?**

Originally designed and built by the Council for Scientific and Industrial Research (now known as CSIRO) in Sydney as the CSIR Mk1 in 1947-50, it was one of the very first computers to be completed and is the oldest computer that is still substantially intact.

It was relocated to the University of Melbourne in 1955 and relaunched as CSIRAC (pronounced sigh-rack) on June 14, 1956 (just a few months before Sydney's

SILLIAC, which was launched in September 1956), and operated until 1964. It is now a permanent exhibit at Museum Victoria.

The core design of CSIRAC is still the basis of computers today. It consists of a processor that executes instructions and storage used for both data and sequences of instructions – that is, programs.

Huge in size, it was tiny in terms of computational capacity. Think of a smartphone as a "unit" (call it a "smart phone unit", or SPU) of processing size then CSIRAC's capacity was roughly a millionth of that – a microSPU.

Over its 14 years or so of operating life it did about the work that a smartphone today could do in a minute. Its storage was sufficient



for rather less than one second of an MP3 music file.

But in terms of power, weight and size, it was 10,000 times larger, or, overall, ten billion times less efficient than today's processors. Scaling up CSIRAC's memory to that of a smartphone would fill the Melbourne Cricket Ground to the brim, and running it would consume all the power generated in Australia.

## More than a calculating machine

If CSIRAC was so feeble, in SPUs, what set it (and its peers) apart from the calculating machines that preceded it? Many of the tasks it was put to were calculations more or less of the kind that had been done for decades by generations of dedicated calculating machines, both mechanical and electronic.

One might expect the difference to lie in the instructions the machine can execute. A first glance at CSIRAC's instruction set could suggest that it was indeed just a kind of calculator; many of the operations are elementary arithmetic.

Other instructions concerned reading and writing of data to and from storage, and specifications for where in memory to find the next instruction to execute. Perhaps these could be seen as just feeding numbers to a calculating engine.

But these machines embodied something utterly revolutionary: the fact that instruction sequences were stored in memory, in contrast to the fixed, pre-determined structure of their predecessors.

A computer without an instruction sequence is no more than a box of components – useless and meaningless until assembled (that is, programmed). This meant that for the first time a new machine no longer required physical construction; it could be created just by altering the instruction sequence (that is, installing a new program). And the instruction sequences were themselves data – programs could manipulate programs.

## Instructing the machine

This fluidity leads to a property that is truly profound. The CSIRAC instruction set is simple and minimalistic, even primitive. But, critically, it is in a fundamental sense complete.

Just as multiplication can be defined in terms of a sequence of additions, the small CSIRAC instruction set can be used to define any more sophisticated instruction.

In terms of the computations it can undertake, the universes it can represent, the models it can build, the CSIRAC instruction set is as powerful as that of a smartphone or of a supercomputer which today might be a million SPUs (or a trillion CSIRACs).

Thus even this very first generation of computers was universal. They were a new kind of thing not seen in the world before, a device whose function could be changed to do anything that could be written down, just by changing what sequences of instructions were entered; and that "anything" could be translated to run on any computer.

Many of the innovations trialled on these early, miniscule computers are as valuable today as when they were first invented.

And for some context, take a look at the computer in the 1970 movie *Colossus: The Forbin Project*. In the movie, the US computer *Colossus* and its USSR counterpart become self-aware. As a guess, from the look of the hardware, even though *Colossus* fills a mountain it may be no more than an SPU.

Skynet, in *The Terminator* movie series, may have had less processing power than is

in the pockets of a cinema full of teenagers today – demonstrating that the potential of computers could be seen long before they were large enough for this potential to be realised.

Our computers today are in fundamental ways no more powerful than their predecessors – just faster, smaller and more deeply embedded in our lives.

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# THE HISTORY OF COMPUTING IS BOTH EVOLUTION AND REVOLUTION

By Justin Zobel

**This month marks the 60th anniversary of the first computer in an Australian university. The University of Melbourne took possession of the machine from CSIRO and on June 14, 1956, the recommissioned CSIRAC was formally switched on. Six decades on, our series Computing turns 60 looks at how things have changed.**

It is a truism that computing continues to change our world. It shapes how objects are designed, what information we receive, how and where we work, and who we meet and do business with. And computing changes our understanding of the world around us and the universe beyond.

For example, while computers were initially used in weather forecasting as no more than an efficient way to assemble observations and do calculations, today our understanding of weather is almost entirely mediated by computational models.

Another example is biology. Where once research was done entirely in the lab (or in the wild) and then captured in a model, it often now begins in a predictive model, which then determines what might be explored in the real world.

The transformation that is due to computation is often described as digital disruption. But an aspect of this transformation that can easily be overlooked is that computing has been disrupting itself.



## Evolution and revolution

Each wave of new computational technology has tended to lead to new kinds of systems, new ways of creating tools, new forms of data, and so on, which have often overturned their predecessors. What has seemed to be evolution is, in some ways, a series of revolutions.

But the development of computing technologies is more than a chain of innovation – a process that's been a hallmark of the physical technologies that shape our world.

For example, there is a chain of inspiration from waterwheel, to steam engine, to internal combustion engine. Underlying this is a process of enablement. The industry of steam engine construction yielded the skills, materials and tools used in construction of the first internal combustion engines.

In computing, something richer is happening where new technologies emerge, not only by replacing predecessors, but also by enveloping them. Computing is creating platforms on which it reinvents itself, reaching up to the next platform.

## Getting connected

Arguably, the most dramatic of these innovations is the web. During the 1970s and 1980s, there were independent advances in the availability of cheap, fast computing, of affordable disk storage and of networking.

Compute and storage were taken up in personal computers, which at that stage were standalone, used almost entirely for gaming and word processing. At the same time, networking technologies became pervasive in university computer science departments, where they enabled, for the first time, the collaborative development of software.

This was the emergence of a culture of open-source development, in which widely spread communities not only used common operating systems, programming languages and tools, but collaboratively contributed to them.

As networks spread, tools developed in one place could be rapidly promoted, shared and deployed elsewhere. This dramatically changed the notion of software ownership, of how software was designed and created, and of who controlled the environments we use.

The networks themselves became more uniform and interlinked, creating the global internet, a digital traffic infrastructure. Increases in computing power meant there was spare capacity for providing services remotely.

The falling cost of disk meant that system administrators could set aside storage to host repositories that could be accessed globally. The internet was thus used not just for email and chat forums (known then as news groups) but, increasingly, as an exchange mechanism for data and code.

This was in strong contrast to the systems used in business at that time, which were customised, isolated, and rigid.

With hindsight, the confluence of networking, compute and storage at the start of the 1990s, coupled with the open-source culture of sharing, seems almost miraculous. An environment ready for something remarkable, but without even a hint of what that thing might be.

## The 'superhighway'

It was to enhance this environment that then US Vice President Al Gore proposed in 1992 the "information superhighway", before any major commercial or social uses of the internet had appeared.

Meanwhile, in 1990, researchers at CERN, including Tim Berners-Lee, created a system for storing documents and publishing them to the internet, which they called the world wide web.

As knowledge of this system spread on the internet (transmitted by the new model of open-source software systems), people began using it via increasingly sophisticated browsers. They also began to write documents specifically for online publication – that is, web pages.

As web pages became interactive and resources moved online, the web became a platform that has transformed society. But it also transformed computing.

With the emergence of the web came the decline of the importance of the standalone computer, dependent on local storage.

## We all connect

The value of these systems is due to another confluence: the arrival on the web of vast

numbers of users. For example, without behaviours to learn from, search engines would not work well, so human actions have become part of the system.

There are (contentious) narratives of ever-improving technology, but also an entirely unarguable narrative of computing itself being transformed by becoming so deeply embedded in our daily lives.

This is, in many ways, the essence of big data. Computing is being fed by human data streams: traffic data, airline trips, banking transactions, social media and so on.

The challenges of the discipline have been dramatically changed by this data, and also by the fact that the products of the data (such as traffic control and targeted marketing) have immediate impacts on people.

Software that runs robustly on a single computer is very different from that with a high degree of rapid interaction with the human world, giving rise to needs for new kinds of technologies and experts, in ways not even remotely anticipated by the researchers who created the technologies that led to this transformation.

Decisions that were once made by hand-coded algorithms are now made entirely by learning from data. Whole fields of study may become obsolete.

The discipline does indeed disrupt itself. And as the next wave of technology arrives (immersive environments? digital implants? aware homes?), it will happen again.

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Ron Bowles at the IBM 7044, a batch processing machine with magnetic tape storage, around 1969.





# COMPUTING CAN HELP SAVE THE KOALA BY PREDICTING WHERE THEY CAN SURVIVE

By Michael Kearney

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Life is found almost everywhere on Earth, but each species is limited in the range of places and environments within which it can live. Understanding the distribution limits of a species is an old and fundamental problem in ecology. It is also an important practical problem.

We need computational tools to predict how the potential distributions of pest species, disease vectors and threatened species may change with the climate if we are to manage them properly.

One of the classic early texts in ecology is *The Distribution and Abundance of Animals*, written by Australian scientists Herbert Andrewartha and Charles Birch in 1954.

At the time it was written, tolerances and responses of animals to different environments were measured directly in the laboratory. These were then compared with weather station observations at particular sites. Distribution predictions involved hand-drawn contour maps based on this information.

## Computers can help

In the 1980s, Professor Mike Hutchinson, from the Australian National University, revolutionised the field by developing computational methods to make continent-scale gridded climate layers from weather data.

Methods soon developed to mathematically describe the suitable environmental space of a species by querying those gridded layers at places where a species

was known to occur. And the computed environmental spaces could then be projected back onto the landscape to predict the distribution of species.

This statistical approach to modelling the distribution of species has become one of the biggest fields in ecology today. A wide range of powerful computational methods are routinely used to understand where different species could occur under present climatic conditions.

These models are also being combined with the outputs of general circulation models to predict where a species might occur in the future.

## Correlation vs causation

But care should be taken when using these correlative modelling approaches. They are statistical descriptions and are thus only reliable within the range of environmental conditions under which they were developed.

When correlative models are projected to novel environments, such as future climate change scenarios, they can be misleading.

This extrapolation problem has encouraged the development of mechanistic approaches to modelling the distribution of species. These approaches start, not with known distribution, but with measured tolerances and responses of organisms.

The field is now returning to biology-driven approaches from the days of Andrewartha and Birch, but with the more powerful tools and data now available.

My research group is focused on

developing mechanistic species distribution models grounded in the physics of heat and mass exchange. We use these models to compute the inputs and outputs of heat to an organism at particular times and places in its habitat.

We develop algorithms of the behaviours and physiological responses that a species might use to buffer itself against harsh conditions. These include seeking shade, moving underground or changing colour.

We then compute outcomes, such as whether an animal could survive and, if so, how much time it would have to forage, how fast it could grow, how much energy and water it could obtain compared to what it lost and, ultimately, how many offspring it could have.

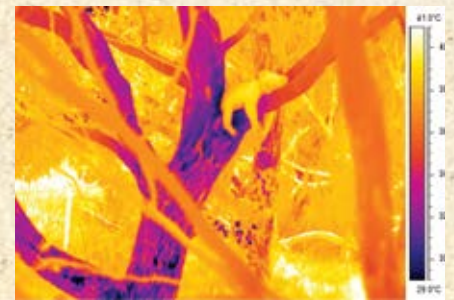
## Predicting koalas

This brings us to helping save the koala. Koalas, being warm-blooded like us, keep a very constant body temperature despite changes in their environment.

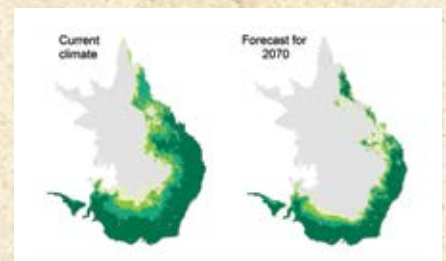
But when it gets too cold, they need to expend extra energy to produce metabolic heat. And in hot weather, they need to lose extra water for evaporative cooling.

We can compute the energy and water costs imposed by the climate at a particular location, accounting for subtle responses koalas have. For example, koalas hug cool tree trunks to lose heat without having to spend water.

This cooling behaviour is something we discovered as part of our research. Knowing how much energy and water is in eucalyptus leaves, and how this converts physiologically into the production of offspring, we can estimate whether a koala could survive and reproduce at a particular place.



Thermal image of a koala sitting in the cool fork of a tree in the heat of the day. STEVE GRIFFITHS.



Predicted potential distribution of koalas under the current and 2070 climate, based on energy and water requirements. Grey areas are unsuitable, with suitability increasing from light to dark green. MODIFIED FROM NATALIE BRISCOE ET AL. 2016.



By repeating solutions of these kinds of calculations across grid of environmental conditions, we've produced maps of potential distribution.

The value of mechanistic predictions is twofold. First, we gain a greater understanding of what limits distributions. Second, we have a robust prediction that can be extended more confidently to novel conditions.

Our predictions for the koala involved solving the heat budget algorithm 40 billion times (115,144 locations × 20 years × 365 days × 24 hours × two climate scenarios) with the aid of the Victorian Life Sciences Computation Initiative super-computing facility.

These predictions indicate substantial range contractions towards the coast by 2070, especially in northern Australia. We can use this information to prioritise conservation reserves, and possibly translocation programs, to help koalas adapt to a changing climate.

The combined computational arsenal of correlative and mechanistic tools that ecologists now have at their disposal would amaze early ecologists such as Andrewartha and Birch, and will help humans adapt to future environmental change.

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enormous amounts of data from individual brains have recently been developed.

Calcium imaging, for instance, allows the activities of many thousands of neurons to be imaged simultaneously, leading to new insights into how the brain works.

We are building models of the brain where computers simulate behaviours seen using data collected from EEG, calcium imaging and other methods. These include simulations of individual neurons that investigate how learning occurs or how a disease might result from a genetic mutation.

They also involve simulations of tens of thousands of neurons and how they interact to produce normal or epileptic activity. We are using these types of simulations to understand how the brain acts like a computer. We can then develop smarter machines that work with much less power than the devices we use today.

Computers have made it possible to do this research. It would be impossible without them as the huge volume of data that we collect must be processed and stored.

Complicated models of individual neurons are operated by solving many mathematical equations. And simulations of large amounts of neural tissue require bringing together data and equations in sometimes vast computational models.

We do this work generally on desktop and laptop computers, but increasingly we have to use supercomputers to do our larger simulations and data processing. The large simulations can be of tens of thousands to millions of neurons, and can take weeks to run on supercomputers.

## Computers to treat epilepsy

Epilepsy is a disease that affects around 1% of the world's population. Among people with epilepsy, 40% do not benefit sufficiently from medications and are threatened by seizures at any time.

That is approximately 28 million people worldwide, more than the population of Australia, who need assistance in new ways. We are using our neural models to understand why seizures occur by simulating how changes to one part of a neuron might affect its behaviour.

We are using the processing of vast amounts of EEG data to develop algorithms that can predict seizures before they happen. That way, we can give a warning to patients or their carers.

So far, such long-term monitoring has proven very successful and useful for some people, allowing them to have more normal lives. But there are some whose seizures are much harder to predict, so we still have a lot of work to do.

We are also developing computer models of thousands of neurons to investigate how to electrically stimulate the brain to stop seizures when they occur. So far, this has been successful for certain types of epilepsy, such as absence epilepsy in animals.

For the more difficult, focal seizures in humans and animals, the stimulation only

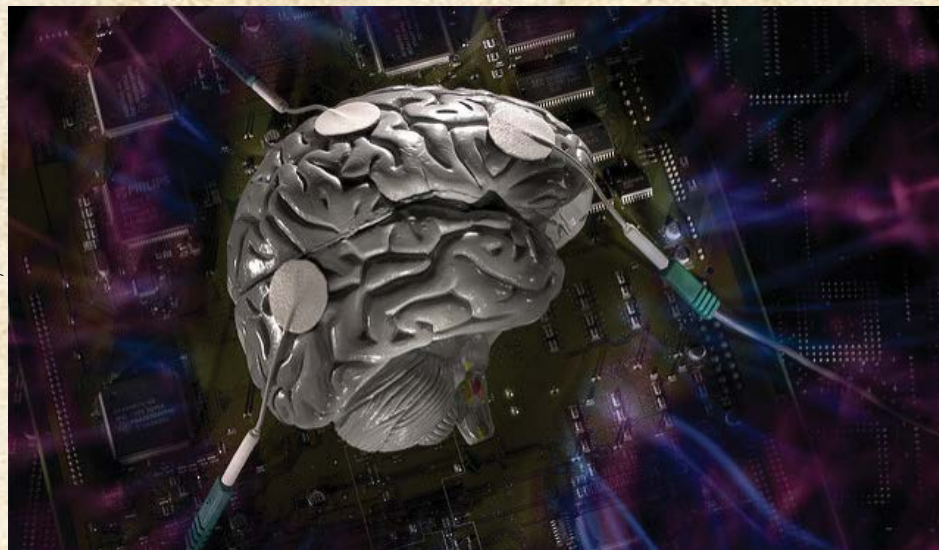


IMAGE SOURCED FROM FLICKR/AMYLEONARD

# TO UNDERSTAND THE BRAIN, IT HELPS TO MAKE A COMPUTER MODEL OF ONE

By David Grayden

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One of the greatest challenges of engineering, science and medicine is to understand the brain, which is the most complex organ and system known to humans.

A lot is already understood about how individual neurons and their components behave (the microscopic scale). A lot is also known about what parts of the brain participate and interact in sensory perception, action and cognition (the macroscopic scale).

We also know some of the detailed mechanisms of different diseases of the brain, such as Parkinson's disease and epilepsy. But very little is known about how the emergent behaviour of the brain (the macroscopic

scale), such as turning thought into movement commands to muscles, arises from individual neural activity (the microscopic scale).

And while much is understood about the causes of Parkinson's disease, epilepsy and other neurological conditions, there is still much to learn to control and treat these diseases effectively.

## Modelling the brain

A promising approach to better understand the brain is through computing. Computational models of the brain are transforming how we study it, along with the development of new technologies that interact with the organ and help to solve neurological conditions.

One of the basic data collecting methods in neuroscience is the electroencephalogram (EEG), which records the tiny voltages produced when neurons in the brain are activated. New methods of collecting



works some of the time. We need to develop improved models of the brain and to develop methods to prevent seizures from occurring at all.

Computing is, therefore, integral to the development of new technologies for interacting with the brain.

## Connected brain

We are also building brain-computer interfaces for people with spinal cord injuries and other movement disorders, and devices for other neurological diseases such as Parkinson's disease, severe depression, anxiety disorders and chronic pain.

For brain-computer interfaces, computers are essential for decoding brain signals recorded using EEG electrodes and translate this into commands for a robot or computer.

For the other diseases, computers will allow more precise control of the stimulation to make it more effective, though this is something we are still developing.

We are making enormous strides in linking computers to brains. One day, it may well be routine to treat people with simple, minimally-invasive devices that can monitor and influence the brain to help alleviate conditions that are currently so intractable.

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# COMPUTING GIVES AN ARTIST NEW TOOLS TO BE CREATIVE

By Roger Alsop

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The greatest tool of artists is their imagination but it is limited by their knowledge (try imagining something you don't know). But the diversity computing offers may address this problem.

For the creative artist, computers supply three basic tools: access to information, software, and new ways to interact.

In 1945, the American engineer and inventor Vannevar Bush predicted a world where:

[...] all forms of intelligence whether of sound or sight, have been reduced to the form



*Creating images with fractals thanks to a computer program. IMAGE SOURCED FROM FLICKR/CORNISHDAVE*

of varying currents in an electric circuit in order that they may be transmitted.

Now, information at the click of a finger can expand the artist's imagination, letting them know about the existence of things they may never have found.

In 1949, Australia got CSIRAC, its first computer, and in 1951 it played the world's first computer music, preceding the first computer image by five years.

Computer animation followed in the 1960s (see video, above) and computer music developed apace. Over the past 60 years, the creative capacity and availability of computers has developed faster than any other creative tool in history.

This has had three main effects: anyone with the right software can be creative; the tool is constantly evolving; and it is difficult to develop tradition or generational history, as aesthetic and conceptual paradigms are constantly subverted by the newest tools.

## Software

**In the arts, computers have a variety of uses, based on software, that range from implementing the artist's ideas to creating ideas.**

Adobe, Avid and word processing software suites represent the artist's ideas. While they offer convenient ways to test ideas, they mostly implement the artist's imagination, and are based on pre-computer processes.

OneManBand and Band-in-a-Box help make artworks using generative algorithms that semi-independently create, based on the artists input therefore contributing to the creative outcome.

AARON and Experiments in Musical Intelligence extend this by independently creating new artworks based on historic approaches and/or the artists input. These tools collaborate under the artist's instruction.

Nodal, Bloom, Silk and Context Free offer new ways of seeing, and generating artworks.

Max and PureData integrate audio and vision, and programming languages such as Processing and Python allow artists to create bespoke expressive tools. These generative tools are often used as creative, albeit somewhat independent, collaborators in art making.

Open source- and FLOSS-based (meaning free software and open source software) approaches offer tools artists can make and remake themselves or with help from a large, collaborative community.

Computing is used extensively for scheduling sound and visual effects in the performing arts, often created in the programs above. 3D animation programs are used in visualising choreography or blocking in drama performances, but are rarely used to generate new creative outcomes, Merce Cunningham being an occasional exception.

But it is possible to computer-generate cohesive text (follow the link "this application") that can be used in developing work.

This list is cursory, indicating the main approaches to computers in the arts. These may merge at their edges, and by being responsive, contributory, or generative, range from proto/mesa-creative to meta-creative tools.



*Level of computer contribution to the creative artist. Roger Alsop.*

## Interaction

Computers can blend things that may not have any obvious relationships, and can make real things not thought of, or thought possible, such as using sound to track share trades.



The artist may experience what was previously unimaginable, and be able to share it with their audience. The potential diversity of expression through computer programs and processes available puts the artist in an enviable position.

Current computer systems also make it possible for the audience to co-create the experience of an artwork, more than ever before, creating works the artist may not have imagined.

Computer creativity is very diverse. Computer-generated Rembrandt, fractal art and mathematical art are examples of meta-creative computers making beautiful and fascinating images, indicating new ways to understand Jackson Pollock's work.

Similar processes have been used in the creation of music and images in many styles.

Machines that imagine can provide a process for completely original outcomes with minimal human contribution.

To stand out, the human artist must be more creative, diversified and willing to take aesthetic and intellectual risks. They can, and must, know the field they are creating in practically and philosophically, and confidence in their position and contribution to it is essential.

Their work is seen in an almost infinite universal context. Comparisons are easily drawn, and their field is in constant flux. Uniqueness is almost impossible, yet novelty is anticipated and valued.

Computer systems offer ways to create but can retard creativity. Many artists believe that the next tool will improve their art; this is particularly problematic in music.

But while new immersive technologies such as the Hololens or RoomAlive offer new tools, they also require new ways of considering art thinking and art making.

Artists inhabit a most fertile time, with new possibilities crowding the horizon. They should, as always, use that fertility to enhance culture and society.

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IMAGED SOURCED FROM FLICKR

## COMPUTING HELPS THE STUDY OF INFECTIONS ON A GLOBAL AND LOCAL SCALE

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Millions of people suffer each year from infectious diseases which are responsible for about a quarter of all deaths worldwide. But tracking the cause of such illness and trying to avoid their spread is always a challenge.

For example, more than 15,000 Indigenous Australian children suffer from skin sores (impetigo) at any one time.

The majority of these infections are caused by a bug called Group A streptococcus (GAS).

This can trigger abnormal immune reactions that result in chronic heart and kidney disease.

Penicillin is a highly effective treatment for this condition, but the number of children infected hasn't changed in 20 years. To find solutions to this apparently intractable problem, we clearly need a fresh approach.

### Crunch the data

This is where computers can help. With funding support from the National Health and Medical Research Council, we aim to revisit 20 years' worth of study data generated by the Menzies Research Institute, in Darwin.

Using mathematical models, we hope to develop a better understanding of the drivers of high skin sore rates.

We also need to collect detailed data on the rich social connections within and between remote communities in the Northern Territory that could spread infection. We will develop computer simulation models that represent these linkages and their likely contribution to infection risk.

The findings of these models will hopefully inform consultation with communities about prevention and treatment approaches to keep children healthy.

So why hasn't this approach been used before?

### Better computing power

Mathematical and computational models of infection are not new. But their capacity to deal with multiple data sources, and represent

detailed human interactions and differences, has dramatically increased in recent years due to advances in technology.

Increased computing power lets us combine diverse and complementary information to provide a richness that is difficult to capture with a single study. We can combine data from disease surveillance systems, observational studies and clinical trials.

With such data from many countries and regions we can then estimate the global number of infections and associated deaths.

This process is particularly helpful for diseases of poverty, such as skin sores, as the greatest burden is usually experienced in settings where resources are constrained and health information systems are often limited.

Using computer models we can fill the gaps in incomplete, uncertain and variable data. We can also reflect data uncertainty through best-case and worst-case estimates.

### On the move

New methods for collecting data on human movements, and the social interactions responsible for the spread of infections, have led to fresh opportunities for incorporating behavioural aspects into models. Mobile phone data allows for high-resolution patterns of social behaviour and mobility.

Wearable sensor devices that monitor movement, closeness to others and speech patterns can be used to collect data on short and long-range social connections, even in remote and hard to reach areas.



Insights into attitudes that underpin health-related behaviours, such as choosing whether to immunise, may be studied using social media. But given the vast amounts of data available through these sources, separating signal from noise remains a significant challenge.

Faced with such diverse sources of information, the next step is to make sense of it all.

## Simulations of disease spread

Computers have made it possible to simulate populations and the disease transmission process in very fine levels of detail.

Individual-based models (IBMs, not to be confused with the computer tech company IBM) can explicitly represent each member of a population, and their demographic and health characteristics (think of *The Sims* computer game, but with more sneezing). We can then simulate how interactions between people lead to the spread of disease.

Prior to the advent of modern computing, the calculations required for this type of model would have been prohibitive. IBMs were first used to model disease transmission in the 1970s to simulate the spread of influenza in a population of 1,000 people. Each person was represented by a single punch card!

Distributed computing now makes it possible to simulate populations containing millions of people.

IBMs are an important tool for understanding how complex patterns of geographic distribution, transport and mobility and social behaviour underlie the emergence and spread of epidemic diseases such as pandemic influenza and Ebola.

Obviously, the behaviour of individuals and their impact on disease transmission, cannot be determined exactly. But, once again, advances in computing have allowed us to accommodate this variability by incorporating an element of chance in models.

Rather than running a single “what if” scenario, we can produce millions of alternatives, representing many possible pathways of infection spread. These simulations help us understand the variation observed in patterns of disease in different populations, and explore the full range of outcomes that might be witnessed in the future.

This process helps assess risks and develop locally applicable public health management plans for efficient and effective disease prevention and control.

Optimising intervention strategies in this way is particularly useful when health sector resources are thinly stretched.

We won't eradicate infectious diseases, but computers provide us with new tools and approaches to reduce health inequalities and their associated long-term disease burden.

*This article was originally published in The Conversation (theconversation.com)*

# COMPUTING HELPS WITH THE COMPLEX DESIGN OF MODERN ARCHITECTURE



*The impressive computer aided design of the atrium at Melbourne's Federation Square.*

IMAGE SOURCED FROM FLICKR/CHANG



*The multipurpose use of the space inside the atrium at Melbourne's Federation Square.*

IMAGE SOURCED FROM FLICKR/COOLEYD

**By Paul Loh**  
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**In 1960, when the America computer scientist Ivan Sutherland developed Sketchpad, described as the first computer graphical user interface, it changed the course of architecture.**

It was the first recorded tool enabling designers to interact with the computer graphically, using a light pen on the monitor.

This laid the foundation for computer aided design (CAD), which, over the next 60 years, replaced the drafting pen and tracing paper with the mouse and monitor in most architectural practices.

But while, for most, computing in architecture is a replacement technology, there are always rebels who want to experiment.

Architects think and draw at the same time, at the design stage as well as detailing the building for construction. And it quickly became apparent that no software can think or design as fast as a doodle on paper (or the infamous napkin). Nor could a program replace the lateral problem solving ability of a human.

All CAD software has limitations. Developers simply cannot program enough tools within the software environment to cater for all the possible applications, let alone to condition creative and lateral thinking.

## The architect programmer

But why only work within the software written by others when you can write your own? Since the 1970s, a number of pioneering architects and designers have taken it on themselves to be both programmer and designer. In other words, they started to program design.

What emerges at first are the use of algorithms in design to develop forms and

spatial organisation through programming logic. With advancement of software and interjection from other disciplines such as film, aerospace and product engineering, architects are now designing ever more complex geometries to explore unprecedented spatial conditions and relationships.

A built example is the Atrium at the Federation Square, in Melbourne, Victoria, by LAB architecture studio. This urban atrium not only constructs new relationships between the city and the river, it also creates a multi-layered space for social encounter and art installation. Structures like these are difficult to conceive in the human mind.

This experimentation in programming design has surfaced as the main stream of architecture design in the past ten years. Computing in architecture is having a deeper impact than ever before: from complex analytical and design tools that allow us to understand the spatial syntax of cities to fully integrated three-dimensional models (commonly known as Building Information Modelling or BIM) and, eventually, linking design with structural analysis to name a few examples.

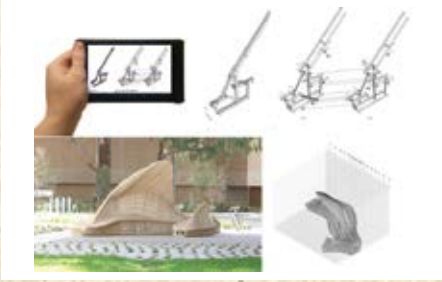
## Programming materials

When an architect thinks through drawing and three-dimensional modelling, this is essentially stimulating what the real materials (brick, concrete, steel or timber) can or could be. That's to say we design in a virtual environment before implementing it in the physical world.

With the recent availability of 3D printers and numeric control machinery, such as CNC routers and laser cutters, designing with computers is bringing architects closer to the material.

Not surprisingly, computer aided manufacturing (CAM) has a history as long as CAD. It was originally designed as a parallel workflow by computer scientist Patrick Hanratty in 1958.





*Artulated Timber Ground, research pavilion at Melbourne School of Design. Paul Loh, University of Melbourne. IMAGE FROM AUTHOR*

The first known CAD/CAM software is called PRONTON (program for numerical tooling operations). CAM software translates drawing directly into machine code which can be used to cut, print or shape material.

Thanks to the pioneering work of Hanratty, designers can now “talk” directly from computer to machinery. This direct interface with the computer allows us to build very complex geometry.

The Artulated Timber Ground pavilion is recent design research project at the Melbourne School of Design (MSD). Consisting of 1,752 unique components, the pavilion changes its form throughout the sections.

The geometry captures the various ergonomic positions from seating to lounge position. Here, computing allowed us to generate an integrated three-dimensional model for digital fabrication.

The model contained the geometric information, ergonomic data, structural analysis as well as fixing and joint detailing. The position of every single drill hole was defined using a custom algorithm.

The entire pavilion took two days to install with prefabricated parts. It also challenged the way we usually communicate building information through indexing and reading the data for assembly using a tablet.

In the same way as designers start to program design, we can now program how we build things. In other words, we can program material. If we understand its behaviour, we can start to manipulate this as well.

Research at the ETH Zurich, in Switzerland, has developed a number of research pavilions that explore precisely this method of designing using robotics.

At this level of computing using numeric control tools, materials can be stretched and transformed into shape. Our research is developing a new way of fabricating a uniquely curved wall system that can be used as a temporary meeting pod in a flexible working and learning environment.

From the straight line of early CAD software to free form geometry, computing has liberated the creativity of the profession in the past 60 years. The impact of computing in architecture is immense and this will continue to shape the future of our cities.

Imagine the day where our building materials are programmable to suit any design.

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*Viewers can now select what they want to watch and when they want to watch it. IMAGE SOURCED FROM FLICKR*

## COMPUTING CHANGED THE ‘FLOW’ OF WATCHING TELEVISION

By Bjorn Nansen  
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**Celebrations of 60 years since Australia’s first university computer was switched on coincide with the anniversary of another significant technology – television.**

Australia’s first television transmission also started in 1956, first in Sydney and days later in Melbourne.

These two technologies developed along largely separate paths. One was hidden away in government and research institutions, the other was more prominent as a domesticated and commercial media platform within family life.

That is until the switch from analogue to digital signal, finally completed in 2013. This digital transition brought them together in ways that have forever changed the way audiences consume television content.

### From mass media to ‘new media’

Historically, we used to think of television as part of the mass media, along with radio, newspapers and so on. But with the turn to computational media, sometimes known as “new media”, we began redefining established questions around audiences and ownership of media.

This computational shift is particularly evident if we contrast the experience of television from an early broadcast in 1956 with today.

At 7pm on Monday November 19, 1956, the ABC launched its Melbourne TV station

(ABV2). The programming schedule for that evening began with an official opening from the Minister for Labour Harold Holt and ABC executives. This was followed by interviews with Olympic athletes (Melbourne was hosting the Olympics that year).

The rest of the evening’s programming went as follows:

- 7.30pm: the Frankie Laine show
- 8pm: the crime drama, Fabian of Scotland Yard
- 8.30pm: a special This Is The ABC featuring interviews with popular radio presenters and behind the scenes look at production
- 8.50pm: a live variety show, Seeing Stars
- 9.15pm: a wartime documentary War in the Air
- 9.45pm: transmission ceased.

### Let it flow

This brief summary of an evening’s broadcast signals very clearly the concept of flow that influential British cultural historian Raymond Williams famously described as the defining characteristic of broadcast television.

Flow, Williams notes, was the planned organisation of discrete programs into a sequence that determined a coherent experience of “watching TV”. He says this planned flow was initially borrowed from older forms of media entertainment, such as radio, before television developed its own generic forms.

Flow speaks to the experience of watching TV, that is continuous and, paradoxically, fragmented. Programs bleed into each other, without definitive intervals between, while trailers promote other programs during ad breaks.



Flow, then, is the pre-computational experience of analogue television that we were once familiar with, in which the broadcaster determined the schedule. It included transmission technology continuously broadcasting on television screens into private homes.

Then, there was the financing of commercial television by advertising with planned flow to capture and retain audiences. And finally, there were the all-important programs produced to fit these contexts, such as the sitcom or later lifestyle and reality programming.

The viewer was positioned as a passive receiver while also part of an imagined public audience.

## The viewer decides what to watch

The nightly experience of viewing enabled by computing technology is in some senses radically different to the concept of flow described by Williams. Yet at the same time it can be seen as just a re-arrangement.

Computational television is understood through the metaphor of a file rather than a

flow. The file is a discrete unit of audiovisual content that can be viewed, stored, aggregated or shared across multiple devices.

As a file, digital television is not transmitted into homes, but accessed from different screens at any time or place via the internet (providing the internet connection doesn't fail).

While we can identify a range of technologies shaping these developments (from video software formats to personal video recorders and file-sharing sites), a clear example is through subscription streaming websites, such as Netflix.

Launched only a year ago in Australia, Netflix exemplifies the experience of file viewing. Each person's sequence of viewing is not planned by the broadcaster, but assembled through individual preferences from the available catalogue of shows.

## But it still flows

Yet, the sequential arrangement of files can still be understood as a flow – though an idiosyncratic one – determined by the viewer rather than the broadcaster.

Digital TV, like other kinds of digital media, tends to be framed within a

democratising or participatory media discourse. The formerly hierarchical models of mass media are replaced by the personalised productive dynamics of digital media.

At the same time, we need to consider how computing has not simply reorganised the ways media are produced, distributed and consumed in terms of empowering people, but also how notions such as flow have become re-articulated. This is made visible in the operations of computer algorithms on sites such as Netflix that recommend programs based on past patterns of viewing.

Recommender algorithms and features such as autoplay, can be viewed as creating a more individually curated experience of what ostensibly remains television flow – a series of units assembled into a period of viewing.

What computation does is remove files from mass planned flow, and allow them to be re-assembled into individualised flows in our viewing lives. Freed from scheduled transmission, yet fragmented by taste and technology, it raises new questions about the status of the audience as a public.

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# COMPUTING TOLD US HOW CLOSE WE CAME TO A GLOBAL PANDEMIC OF A DRUG-RESISTANT FLU

By James McCaw

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We usually consider the scientific study of infection by a virus, bacteria or parasite as the domain of clinical and biomedical research. Surely, the study of a virus invading our cells, hijacking our genetic replication system and then producing millions of copies of itself is no place for a mathematician or computational scientist.

But driven by the massive increases in computational resources now at our disposal, mathematical scientists are making significant contributions to the study of infection.

Over the past 20 years, mathematical and computational biologists have developed new models that describe the process of infection within a human host.



Computer modelling can help in the fight against the spread of disease. IMAGE SOURCED FROM FLICKR/RINGAI

These mathematical models are built on the same principles that help physicists study the interactions between fundamental particles, or climate scientists model the causes and potential impacts of climate change. The models capture how a virus enters a host and then replicates within cells.

The cascade that is triggered leads to an exponential increase in both the number of viral particles in the host and the number of infected cells. This chain reaction is only curtailed when the host's immune system is activated.

Depending upon the details of the biology, the host may either clear the infection or enter a state of chronic infection. For example, we usually feel better after a few days of the common cold but the HIV virus is chronic and needs a lifetime of treatment to avoid clinical illness (AIDS).

## How bad is that flu?

So how does this work in practice? Between May and September 2011, in the Hunter New England region of New South Wales, a cluster of drug-resistant influenza viruses of type A(H1N1)pdm09 were detected through routine surveillance. The strain was a direct descendant of the 2009 "swine flu" pandemic.

This cluster of drug-resistant viruses represented the first occurrence of community transmission of drug-resistant A(H1N1)pdm09 influenza anywhere in the world.

The immediate questions were: Will the viruses spread more widely? And are the frontline drugs used to treat influenza about to become redundant?

Clearly, it was neither practical nor ethical to conduct direct human experiments on the



likely transmission potential of the virus. So mathematical and computational approaches proved vital to answering these questions.

## Modelling the flu

World Health Organization influenza scientists, based at the Peter Doherty Institute in Melbourne, teamed up with computational biologists from the University of Melbourne to do some carefully controlled experiments using an animal model of infection.

Detailed measurements of how rapidly and efficiently the drug-resistant virus invaded the host were made in the laboratory. These data were then paired with newly developed mathematical models of infection.

The aim was to determine if the drug-resistant variants replicated more or less efficiently than their drug-sensitive counterparts.

The mathematical models developed in the study had to be applied to the data to draw inferences on the likely transmission potential of the drug-resistant viruses.

The computational requirements were significant. It took three months of computation time on high-performance computing clusters at the University of Melbourne and the Victorian Life Sciences Computational Initiative.

What did these combined experimental-computational studies find? The drug-resistant viruses were more capable of spreading through the community than their drug-sensitive counterparts.

Given the continued spread of influenza viruses in late 2011, we would have predicted that the drug-resistant viruses would have outcompeted the drug-sensitive ones to become established in the wider, perhaps even global, population.

But today our drugs continue to be effective against influenza. Why? We think it all came down to a bit of luck.

## A close call

The drug-resistant viruses arose during the influenza season, in winter 2011 but remained localised to the Hunter New England region.

By that spring, all influenza viruses had begun to be less effective at spreading through the community. It seems that the drug-resistant viruses, despite being the most capable viruses at infecting humans in the region, were doomed.

Since then, further virological, mathematical and computational analysis has confirmed that the drug-resistant viruses identified in 2011 contain genetic variations that enhance their fitness.

There is now a global effort to monitor for those genetic variations, in order to provide an early warning system for detecting potential outbreaks of drug-resistant influenza.

This is but one story of how mathematics and computation play a crucial role in the scientific study of infection. Computational biology researchers are currently asking

questions such as how do different elements of the immune system contribute to the control of influenza infection?

## The future

We are only just beginning to make full use of the wealth of clinical and experimental data on how pathogens infect a host.

The perspective brought from mathematics and computational science is transforming how we view the disciplines of virology and immunology. We are arguably in the midst of a change from laboratory-based to systems science-based research on infection.

And what does the future hold? With increasing sophistication in models, advances in computational capacity and the

experimental data to match, we will soon be able to simulate infection across multiple scales.

Detailed models of infection and immunological responses at an individual level will be coupled together on a massive scale to consider how infections spread through whole communities. This will bring together two established areas of research: modelling of host infection and epidemiological scale modelling.

It will provide new opportunities to study infection and improve the health of populations. And with those opportunities will come new challenges in computation.

*This article was originally published in The Conversation (theconversation.com)*



*Computers may be smarter than humans at some things, but are they intelligent?*

IMAGE SOURCED FROM FLICKR/JDHANCOCK

# COMPUTERS MAY BE EVOLVING BUT ARE THEY INTELLIGENT?

By Leon Sterling

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The term "artificial intelligence" (AI) was first used back in 1956 to describe the title of a workshop of scientists at Dartmouth, an Ivy League college in the United States.

At that pioneering workshop, attendees discussed how computers would soon perform all human activities requiring intelligence, including playing chess and other games, composing great music and translating text from one language to another language. These pioneers were wildly optimistic, though their aspirations were unsurprising.

Trying to build intelligent machines has long been a human preoccupation, both with calculating machines and in literature. Early computers from the 1940s were commonly described as electronic brains and thinking machines.

## The Turing test

The father of computer science, Britain's Alan Turing, was in no doubt that computers would one day think. His landmark 1950 article introduced the Turing test, a challenge to see if an intelligent machine could convince a human that it wasn't in fact a machine.

Research into AI from the 1950s through to the 1970s focused on writing programs



for computers to perform tasks that required human intelligence. An early example was the American computer game pioneer Arthur Samuels' program for playing checkers. The program improved by analysing winning positions, and rapidly learned to play checkers much better than Samuels.

But what worked for checkers failed to produce good programs for more complicated games such as chess and go.

Another early AI research project tackled introductory calculus problems, specifically symbolic integration. Several years later, symbolic integration became a solved problem and programs for it were no longer labelled as AI.

## Speech recognition? Not yet

In contrast to checkers and integration, programs undertaking language translation and speech recognition made little progress. No method emerged that could effectively use the processing power of computers of the time.

Interest in AI surged in the 1980s through expert systems. Success was reported with programs performing medical diagnosis, analysing geological maps for minerals, and configuring computer orders, for example.

Though useful for narrowly defined problems, the expert systems were neither robust nor general, and required detailed knowledge from experts to develop. The programs did not display general intelligence.

After a surge of AI start up activity, commercial and research interest in AI receded in the 1990s.

## Speech recognition

In the meantime, as computer processing power grew, computer speech recognition and language processing by computers improved considerably. New algorithms were developed that focused on statistical modelling techniques rather than emulating human processes.

Progress has continued with voice-controlled personal assistants such as Apple's Siri and Ok Google. And translation software can give the gist of an article.

But no one believes that the computer truly understands language at present, despite the considerable developments in areas such as chat-bots. There are definite limits to what Siri and Ok Google can process, and translations lack subtle context.

Another task considered a challenge for AI in the 1970s was face recognition. Programs then were hopeless.

Today, by contrast, Facebook can identify people from several tags. And camera software recognises faces well. But it is advanced statistical methods rather than intelligence that helps.

## Clever but not intelligent – yet

In task after task, after detailed analysis, we are able to develop general algorithms that are efficiently implemented on the computer, rather than the computer learning for itself.

In chess and, very recently in go, computer programs have beaten champion human players. The feat is impressive and clever techniques have been used, without leading to general intelligent capability.

Admittedly, champion chess players are not necessarily champion go players. Perhaps being expert in one type of problem solving is not a good marker of intelligence.

The final example to consider before looking to the future is Watson, developed by IBM. Watson famously defeated human champions in the television game show Jeopardy.

IBM is now applying it Watson technology with claims it will make accurate medical diagnoses by reading all medical research reports.

I am uncomfortable with Watson making medical decisions. I am happy it can correlate evidence, but that is a long way from understanding a medical condition and making a diagnosis.

Similarly, there have been claims a computer will improve teaching by matching student errors to known mistakes and misconceptions. But it takes an insightful teacher to understand what is happening with children and what is motivating them, and that is lacking for the moment.

are many areas in which human judgement should remain in force, such as legal decisions and launching military weapons.

Advances in computing over the past 60 years have hugely increased the tasks computers can perform, that were thought to involve intelligence. But I believe we have a long way to go before we create a computer that can match human intelligence.

On the other hand, I am comfortable with autonomous cars for driving from one place to another. Let us keep working on making computers better and more useful, and not worry about trying to replace us.

*This article was originally published in  
The Conversation ([theconversation.com](http://theconversation.com))*



## HAPPY 60<sup>th</sup> BIRTHDAY

**The Hon Philip Dalidakis MP**  
MINISTER FOR SMALL BUSINESS,  
INNOVATION AND TRADE,  
VICTORIA STATE GOVERNMENT

**In the 60 years since CSIRAC was welcomed to Victoria, Melbourne has grown to become a magnet for global tech investment because of our strong economy, cultural diversity, liveability, connective infrastructure and most importantly our people.**

In the past six months alone we have seen major global tech players like Slack, Square, Zendesk and GoPro choose Melbourne to set up their regional headquarters. It is these moves that are cementing our reputation as the leading destination for business investment in the Asia Pacific region.

Innovation is not just a buzz word that politicians throw around because it's the latest fad, it is the key to our new economy, one that is in transition.

As the world becomes more digitised, digital technology becomes both more critical and more dominant in the creation of jobs, businesses and industries of the future. That is why the Victorian Government is working hard to foster a culture of collaboration and innovation in our key growth sectors through a range of initiatives including our \$60 million LaunchVic startup body and the \$200 million Future Industries Fund.

These initiatives will help our best and brightest grow their business ideas here at home and abroad as we create the jobs of the future.

We are committed to growing the competitiveness of Victoria's digital tech industry, which now employs more than 83,000 people and contributes over \$34 billion each year to the state's economy.

We must embrace technologies and the many opportunities they present to entrepreneurs, startups, not-for-profits, governments and established businesses, both large and small. I look forward to seeing continued collaboration between government, industry and our education sector – CSIRAC being an exemplary example.

Happy 60<sup>th</sup> Birthday!





CSIRAC Sign c1956. Image courtesy University of Melbourne, MSE-CIS Heritage Collection. This sign was donated to Museum Victoria as part of the CSIRAC Archive.



Team from CSIRO Division for Building research using CSIRAC from L-R: Roy Muncy, Terry Holden (at console), Bill Davern, 1958. Image courtesy CSIRO.



John Russell at the Flexowriter, reading output from CSIRAC, c1959. Image courtesy CSIRO.



Women as Computer. Female assistant using a photographic plate measuring machine to measure the precise positions of stars for the international Astrograph Project, c1905. Source: Museum Victoria.



Staff of Computation Lab, c1960. Trevor Pearcey, Ron Bowles, Kay Sullivan (Thorne), Jurij Semkiw, Geoff Hill, Frank Hirst at the University of Melbourne. MSE-CIS Heritage Collection.



Theory of Computation Students, circa 1965, University of Melbourne. MSE-CIS Heritage Collection.



Roy Muncy inputting programming into CSIRAC, 1960. Image courtesy CSIRO.



Theory of Computation II Students, 1969. MSE-CIS Heritage Collection.



Department staff photo, 1984. Image courtesy University of Melbourne.



Former and Current Heads of Department, 2013. Left-right: Professor Alistair Moffat, Professor Liz Sonenberg, Dr Peter Thorne, Professor Rao Kotagiri, Professor Leon Sterling, Professor Justin Zobel (with portrait of Professor Peter Poole). Image courtesy University of Melbourne.



Department of Computing & Information Systems staff photo, June 2016.



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## SUPPORTERS



The Australian Computer Society (ACS) is the association for Australia's information and communications technology (ICT) profession. We represent all ICT practitioners in business, government and education.



The Department of Computing & Information Systems at The University of Melbourne is an international leader in Information Technology research and teaching. It is the highest-ranked department in the field in Australia and ranked within the top 20 worldwide.



At CSIRO, we do the extraordinary every day. We innovate for tomorrow and help improve today – for our customers, all Australians and the world.  
We imagine. We collaborate. We innovate.



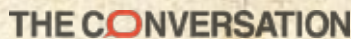
CSIRAC, Australia's first computer, is on display on the lower ground level at Melbourne Museum. Museum Victoria holds a significant collection of computing and information technology artefacts and documentation; some is accessible on the museum's collections pages: <http://collections.museumvictoria.com.au/> Parts of the collection can also be seen on the daily tours held at the collection store at Scienceworks: see <https://museumvictoria.com.au/scienceworks/whats-on/collection-store-tours/>



The Melbourne School of Engineering (MSE) is the leading provider of engineering and IT education in Australia. The Melbourne School of Engineering develops engineering and IT leaders and advanced technologies for a sustainable future. We partner with industry and government partners to build national competitiveness through productivity breakthroughs, and evolve a better, more sustainable way of life.



The Pearcey Foundation Inc. was established in 1998 to raise the profile of the Australian Information and Communications Technology (ICT) Industry and profession. It was created in the memory of one of the greatest pioneers of the Australian ICT industry, Dr Trevor Pearcey. Each year it celebrates the heroes in our industry, through national and state awards – the Pearcey Medal and Hall of Fame and the national Pearcey Entrepreneur Award selected from the seven state Pearcey Award winners. The Foundation looks to attract and encourage young Australians to be involved in debate and public policy on critical national issues such as productivity, the digital economy and national infrastructure. It has recently established the Pearcey Institute to undertake socio-economic research into the impact of disruptive and emerging technologies.



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Our team of professional editors work with university, CSIRO and research institute experts to unlock their knowledge for use by the wider public.  
Access to independent, high-quality, authenticated, explanatory journalism underpins a functioning democracy. Our aim is to allow for better understanding of current affairs and complex issues. And hopefully allow for a better quality of public discourse and conversations.



The Department of Economic Development, Jobs, Transport and Resources was established by the Victorian Government on 1 January 2015.

The Government created the department to bring together many of the key functions that drive economic development and job creation across Victoria. These include transport and ports, energy, investment attraction and facilitation, trade, innovation, regional development and small business, together with key services to sectors such as agriculture, the creative industries, resources and tourism.



