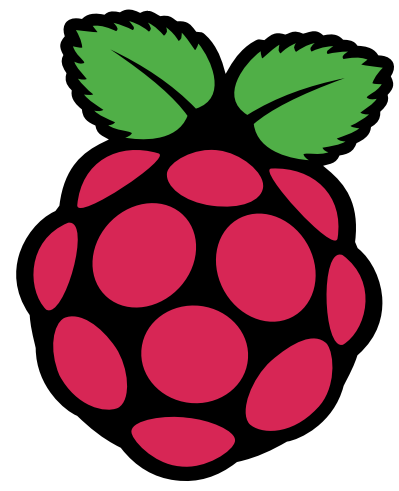


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# The *MagPi*



Issue 114 | February 2022 | [magpi.cc](http://magpi.cc)

The official Raspberry Pi magazine

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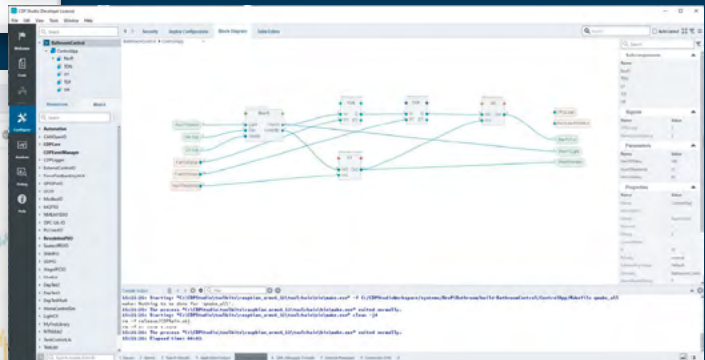
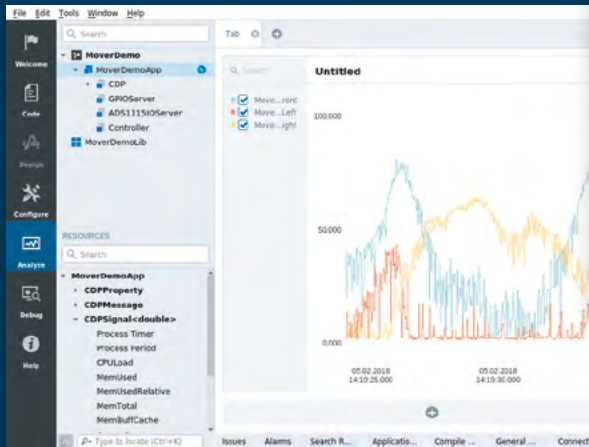
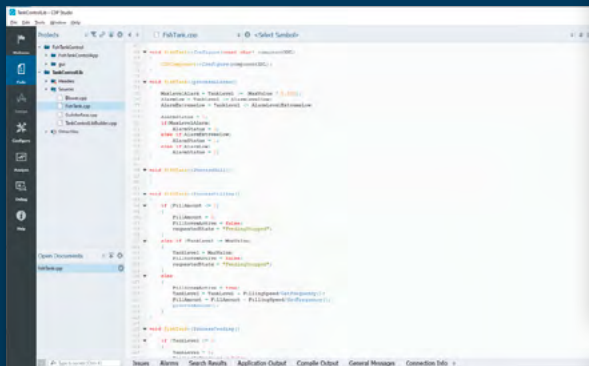
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# WELCOME

## to The MagPi 114

**I love programming.** I tapped out my first piece of code on a ZX-81 computer in junior school and I've been smitten ever since. Code controls what happens on the screen in front of you and increasingly in the world around you. Programming is an engaging process that requires thought and rewards patience. Code is good for the mind.

Here at *The MagPi*, we see evidence of Raspberry Pi computers making the world a better place every day. Raspberry Pi brings together code with projects: weather stations, video games, robots, websites, and server systems. The possibilities with a smattering of code are mind-blowing. Which, perhaps, is why it's often so hard to get started. But it shouldn't be!

This month, we've put together a feature on Practical Programming – your starter guide to picking a language, installing the tools you need, and finding the best courses to learn the basics. Then, we'll guide you towards interesting starter projects.

I believe everybody should learn to code. It teaches you a new way of thinking. And the best way to learn is with a practical project. I hope you enjoy this issue!

**Lucy Hattersley** Editor

PS: It's **#MonthOfMaking** next issue. Get your thinking caps on!



**EDITOR** Lucy Hattersley

Lucy is Editor of *The MagPi* and this month she is doing Dry January, Veganuary and humming in a mindful manner. It won't last.

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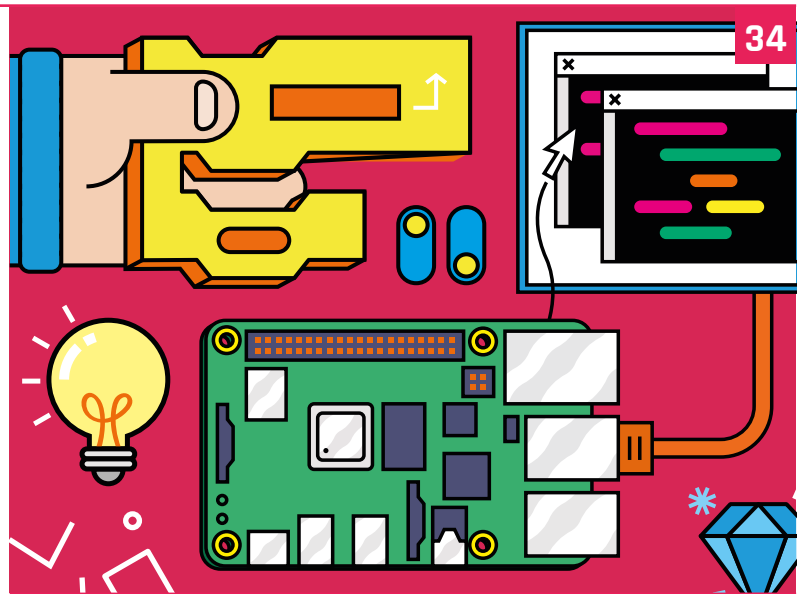
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Teasmade 2.0

Sunrise Lamp

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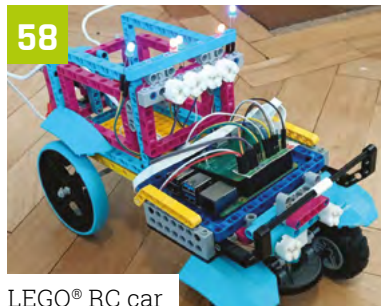
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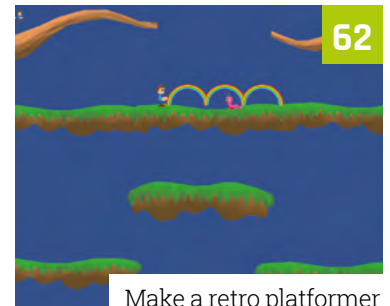
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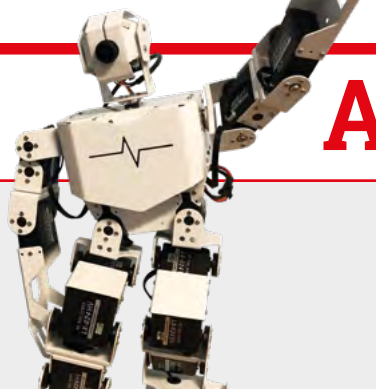
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# DeMoor Orrery

A 240-year-old orrery provided the inspiration for Chris de Moor's stunning planetarium project. **David Crookes** takes a look



**Chris de Moor**

Former programmer and enthusiastic maker, Chris founded and ran a digital agency called Est Digital until earlier this year. His website links to the required GitHub files.

[demoor-orrery.com](http://demoor-orrery.com)

**M**any people have a keen interest in astronomy, but before Chris de Moor created a project that's truly out of this world, he didn't count himself as being among them. "I didn't know anything about astronomy and that sort of stuff," he freely admits. Yet after visiting the Eise Eisinga Planetarium in Franeker in the Netherlands, he was inspired.

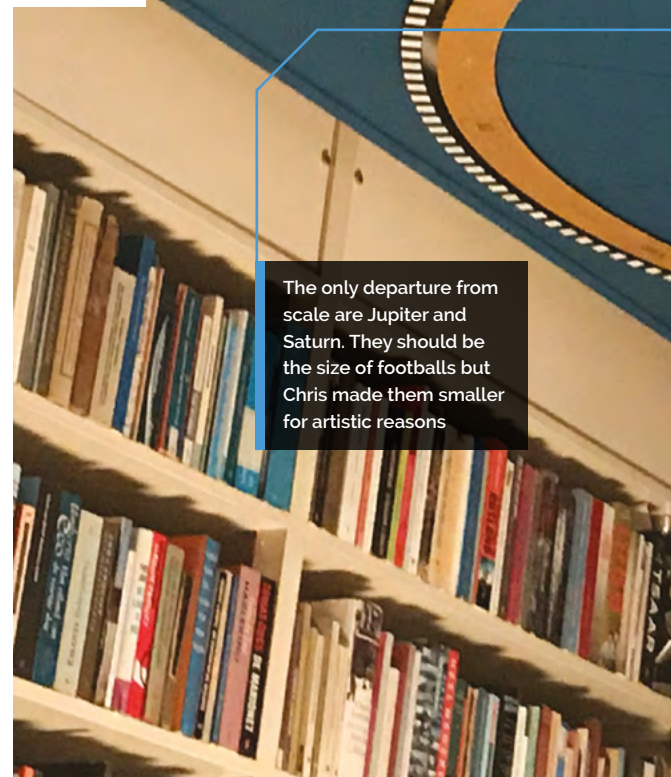
"Eise Eisinga completed an orrery in his house in 1781," Chris says, of the oldest working orrery in the world, created by the Frisian amateur astronomer. "I saw it on the ceiling and thought I wanted one just like that, thinking it would fit perfectly in my living room. At first I believed it would be a weekend project – a simple art piece – until I decided it should work as well. And then the rest came." Indeed, what followed would take him a year!

Chris set about building a replica, one that is similarly coloured and with planets fitted to copper tracks. But while Eisinga's orrery was driven by a pendulum clock driving a host of mechanics in the space above the ceiling, Chris went one better: he used six Raspberry Pi Zero computers – one for each of the six planets he decided to concentrate on.

## Planetary planning

"My first question was about scale and how big my orrery should be," Chris recalls. Ultimately, he worked out that he only had room for Mercury, Venus, Earth (plus the Moon), Mars, Jupiter, and Saturn. The next step was then figuring how spaced apart they should be, the size of each representative planet and how they would move into position in real-time.

"I'd heard about Raspberry Pi computers so I decided to experiment with them," Chris says. "I also know how to program and, while Python is not my favourite language, it was easy to learn. What I

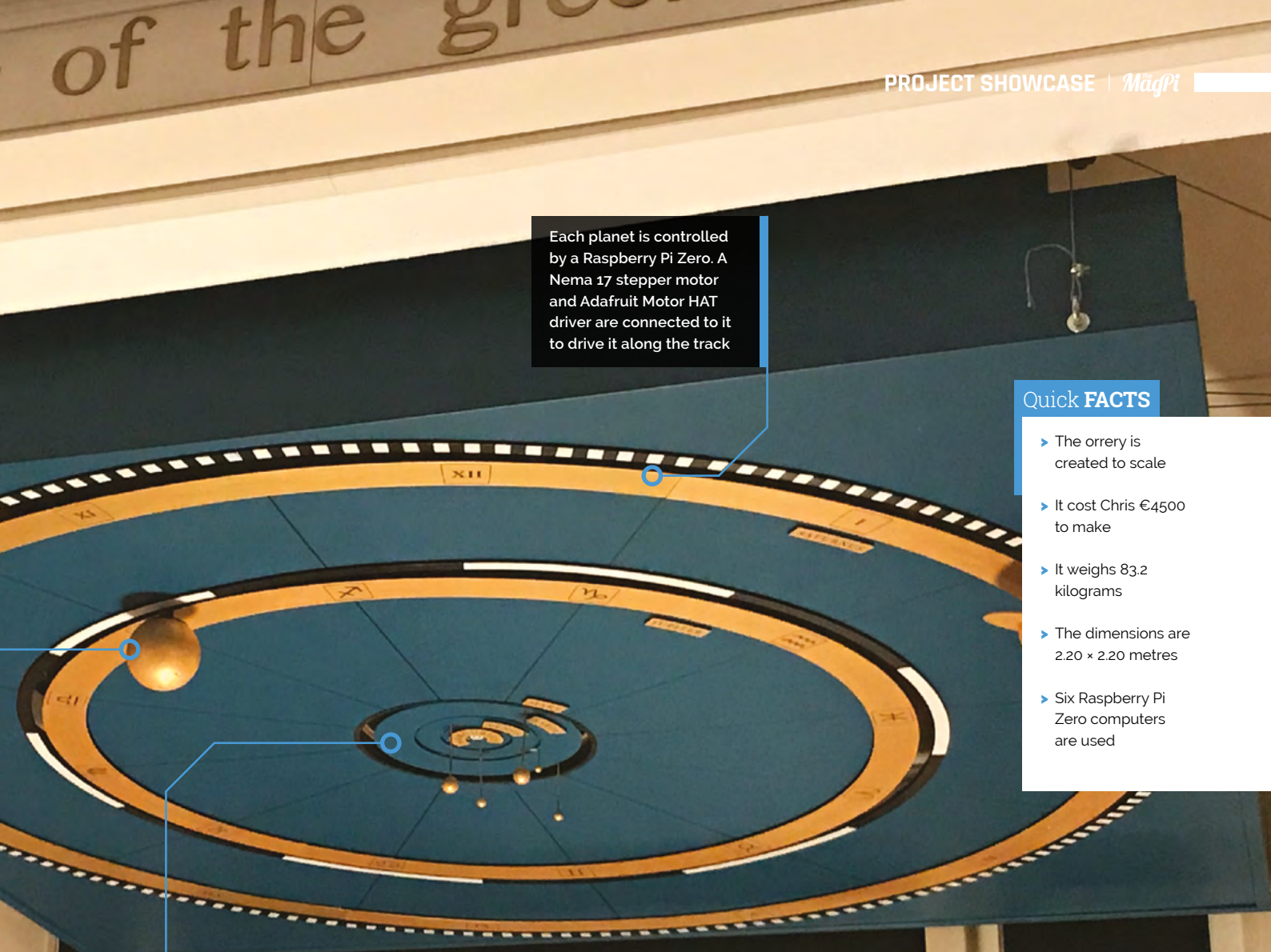


The only departure from scale are Jupiter and Saturn. They should be the size of footballs but Chris made them smaller for artistic reasons

didn't know was how stepper motors worked. They were new to me. But once I bought one Raspberry Pi Zero and a stepper motor and played around, I realised what was possible."

Even so, there were lots of technical challenges along the way. "I got some plywood and started sawing, but a lot of things went wrong," he laughs. "Trying to saw perfect circles by hand is impossible, so I had to go to a store that had a CNC cutting machine, which meant I needed a drawing and DXF vector file. I ended up in areas where I didn't know anything."





Each planet is controlled by a Raspberry Pi Zero. A Nema 17 stepper motor and Adafruit Motor HAT driver are connected to it to drive it along the track

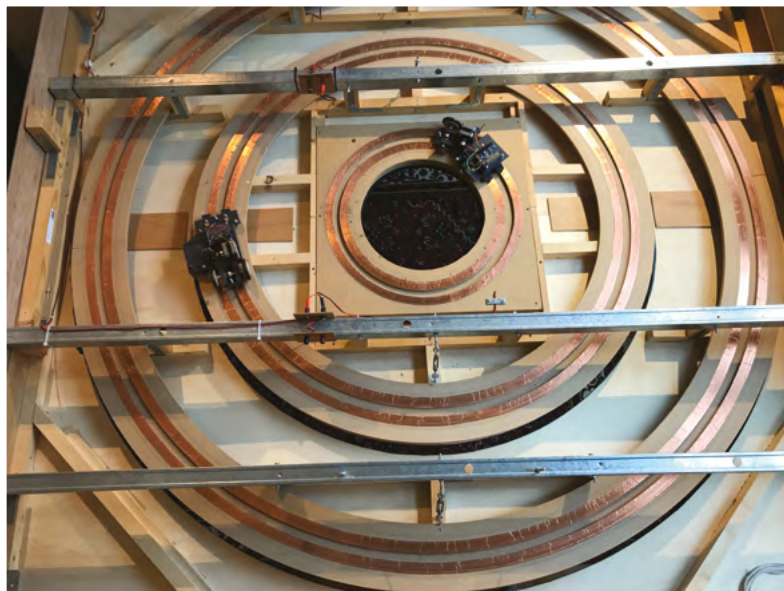
**Quick FACTS**

- > The orrery is created to scale
- > It cost Chris €4500 to make
- > It weighs 83.2 kilograms
- > The dimensions are 2.20 x 2.20 metres
- > Six Raspberry Pi Zero computers are used

The inner planets (Mercury, Venus, and Earth) are on their own system that can be removed from the rest of the orrery

**Raspberry Pi in the sky**

Even so, he persevered and learned, ending up with two ways of moving the planets, each of which is connected to a Raspberry Pi Zero computer. Mars, Jupiter, and Saturn are attached to front-wheel drive, 3D-printed cars which run on tracks on the non-visible side of the project. The inner planets, Mercury, Venus, and Earth, are mounted to dishes. “The inner system is so small, you can’t have tracks there, so I mounted those planets on dishes and even connected Mercury directly to the axle of the stepper motor.”

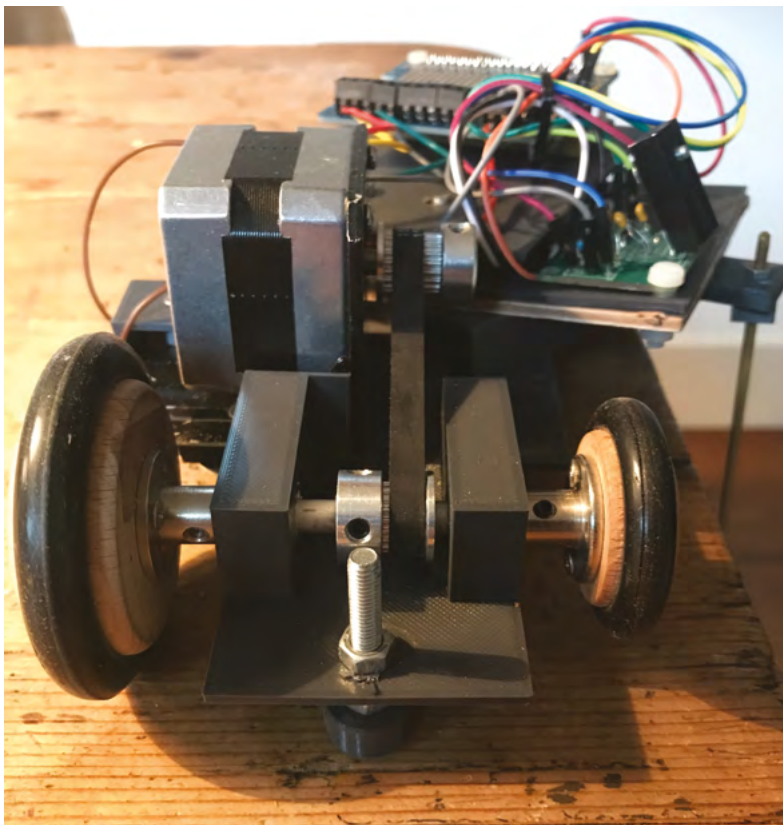


▲ To discover its position, each Raspberry Pi Zero computer detects when it passes a magnet placed on the track. This sets its counter to zero so it can work out how many steps the stepper motor must take to get a planet into position

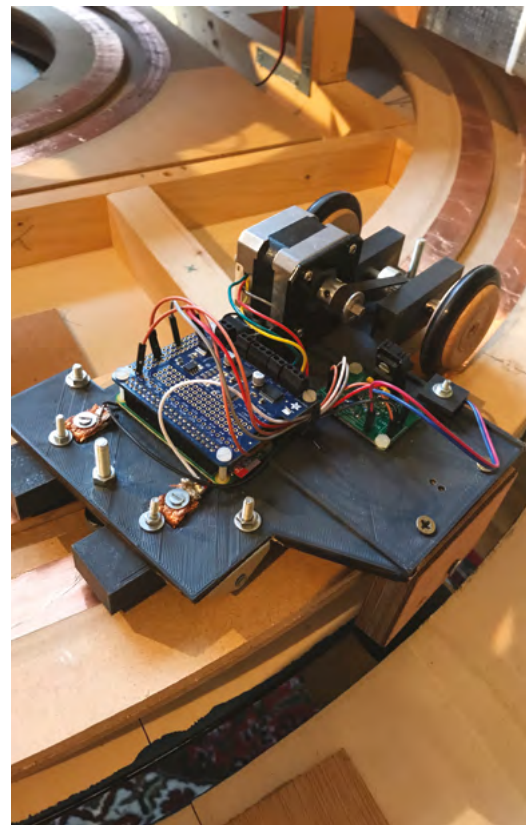


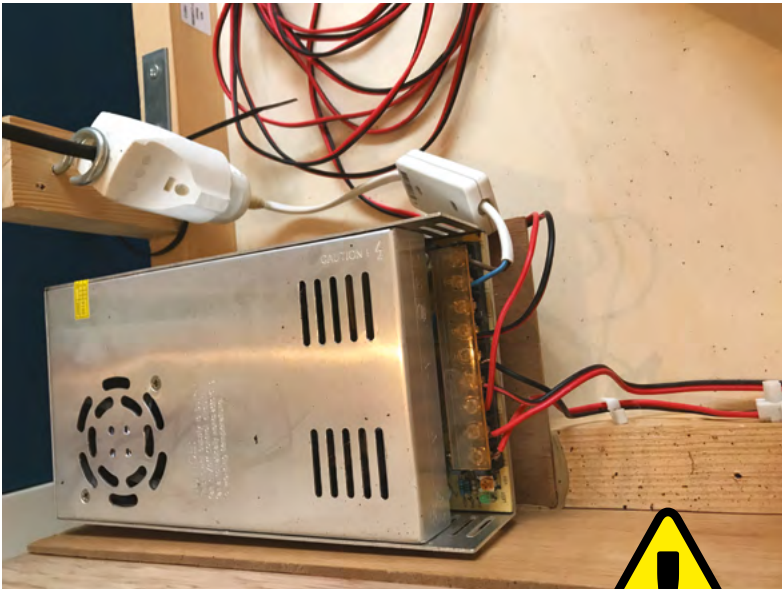
◀ The orrery is 30 centimetres high and suspended from the ceiling. Chris has attached it to a winch which allows it to be lowered for easy maintenance. A winding mechanism from a vacuum cleaner is used to ensure the power cord doesn't get in the way

▼ This car drives Jupiter around its circular track (in reality, orbits are not perfect circles). It gets electricity via two sliding contacts mounted on the back



▲ Here's a close-up view of the front of the Mars car with a Raspberry Pi Zero mounted on top





### Warning! Electrical Safety

Please be careful when working with electrical projects around the home. Especially if they involve mains electricity.

[magpi.cc/  
electricalsafety](http://magpi.cc/electricalsafety)

◀ This is a view of the inner planets attached to their propeller dish. The Sun is drawn on the ceiling, otherwise it'd be 2.85 metres in diameter!

▶ The driver runs on 12 volts and the Raspberry Pi Zero computers on 5 volts. The power supply is firmly attached to the frame

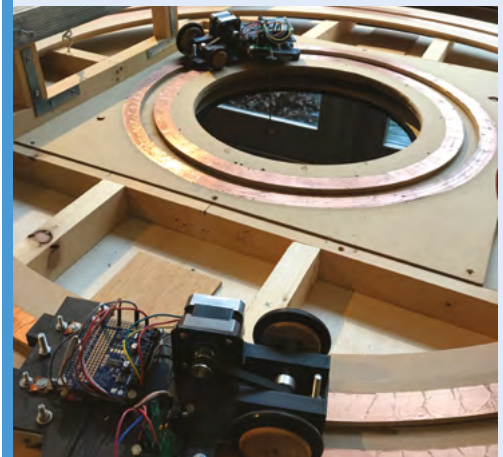
The biggest headache was working out the planetary positions. “I looked into the mathematics of NASA, and the exact positioning of Mercury is a mathematical equation, with more than 40 pages of data. It’s very, very complex,” Chris says. “I had to make it more simple, and I found a beautiful JavaScript library called JSOrtery which is installed on a server. You give it a date and it plots the planets. Raspberry Pi computers are then connected by wireless LAN and they read their position before moving their connected planets to it.”

It’s not 100 percent accurate. “If you want to travel to Mars and you let yourself be guided by my orrery, then you’re definitely going to miss it,” Chris laughs. But as a working showpiece, it’s stunning and, what’s more, it has been made open-source so that anyone can try to make their own. “Maybe it will lead to something – perhaps people will contact me and it’ll involve some travelling and meeting new people,” he says. “If not, I’ve got a beautiful ceiling and that was the whole point.” [M](#)

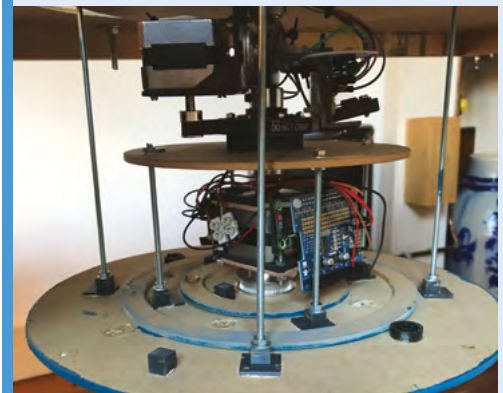
## Recreating Eise Eisinga’s historic orrery



**01** Eise Eisinga spent seven years creating his orrery in the 18th century. Bought by King William I of the Netherlands in 1818, it was very detailed and also kept track of the phases of the moon. Credit: Erik Zachte, Wikipedia



**02** Chris de Moor opted for a simpler system because of the smaller space he had. The outer planets are connected to 3D-printed cars running on tracks, controlled by a Raspberry Pi Zero.



**03** Inner planets Earth and Venus, meanwhile, are connected to a viewing dish that’s mounted to a propeller dish. Mercury is mounted directly on to the stepper motor. It allows for tighter circling.

# Teasmade 2.0

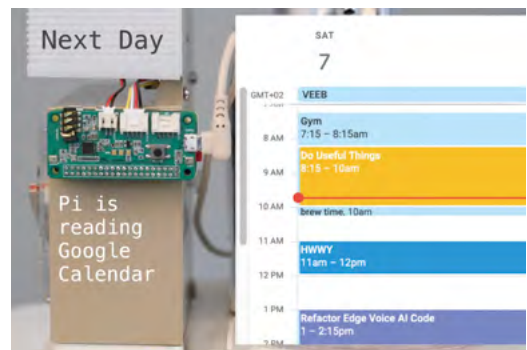
Here's a fresh hack on an absolute classic. Hot beverage anyone?

**Nicola King** admits to being old enough to remember the original



**T**easmades are machines for automatically making tea. They were hugely popular in the 1960s and 1970s, and often placed in bedrooms (for the convenience of having a piping hot cup as soon as you were awoken by the machine's alarm). The Goblin Teasmade, in particular, is something of an icon in its field.

This author fondly remembers her late grandmother's Teasmade that sat proudly in a guest bedroom, waiting for the odd bed-and-breakfast guest that she occasionally took into her home. Although, we did always wonder the



▲ Raspberry Pi receives alerts from Google Calendar so it knows when to start making a brew

point of it when you still had to get up and go to the kitchen to get some milk from the fridge. But, despite our puzzlement, the Teasmade has basked in a form of legendary glory ever since.

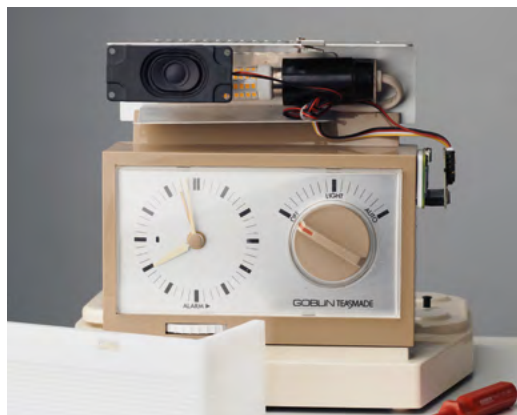
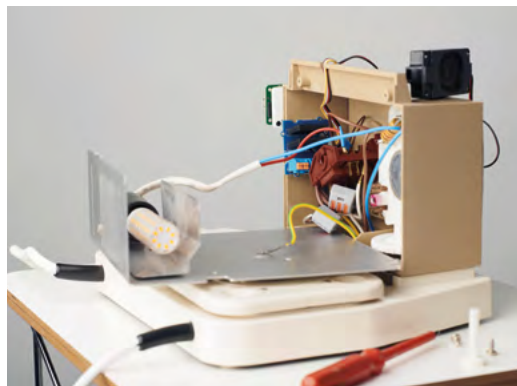
## The coffee stimulus

Hardly surprising then that, decades later, some makers are keen to revive that concept of an automatic hot drink maker, and what better base to use for it than a retro Goblin Teasmade? Martin Spendiff and Vanessa Bradley are two such makers, and this fun update uses a Teasmade along with Raspberry Pi Zero WH to produce their hot drink of choice... coffee.

Their motivation for the project was twofold, as Martin explains: "The Teasmade (inherited) is pretty impressive – it has no microprocessors and therefore has a workflow built with just a few switches and logic. I've long admired the design, so bringing the innards up to date by adding a little Linux machine to the mix was appealing. I don't like to say cyberpunk, but cyberpunk."

He also wanted to incorporate Google Calendar into the venture. "It's nice to have a serious idea dressed up in a novelty application," he tells us. "Getting Google Calendar entries to trigger events has crossed my mind as a useful idea a few times. The idea of automating a cup of coffee was enough motivation to get it over the finish line."

▼ The innards of the Teasmade, fitted with a new Grove Two-Channel Solid-State Relay



▲ A speaker was added inside the light fitting on top of the Teasmade

MAKER

## Martin Spendiff and Vanessa Bradley

Martin is a mathematical modeller who left the UK for Switzerland. He's a fan of FOSS and tech that serves users. Vanessa is new to coding, and a constant source of weird/good ideas.

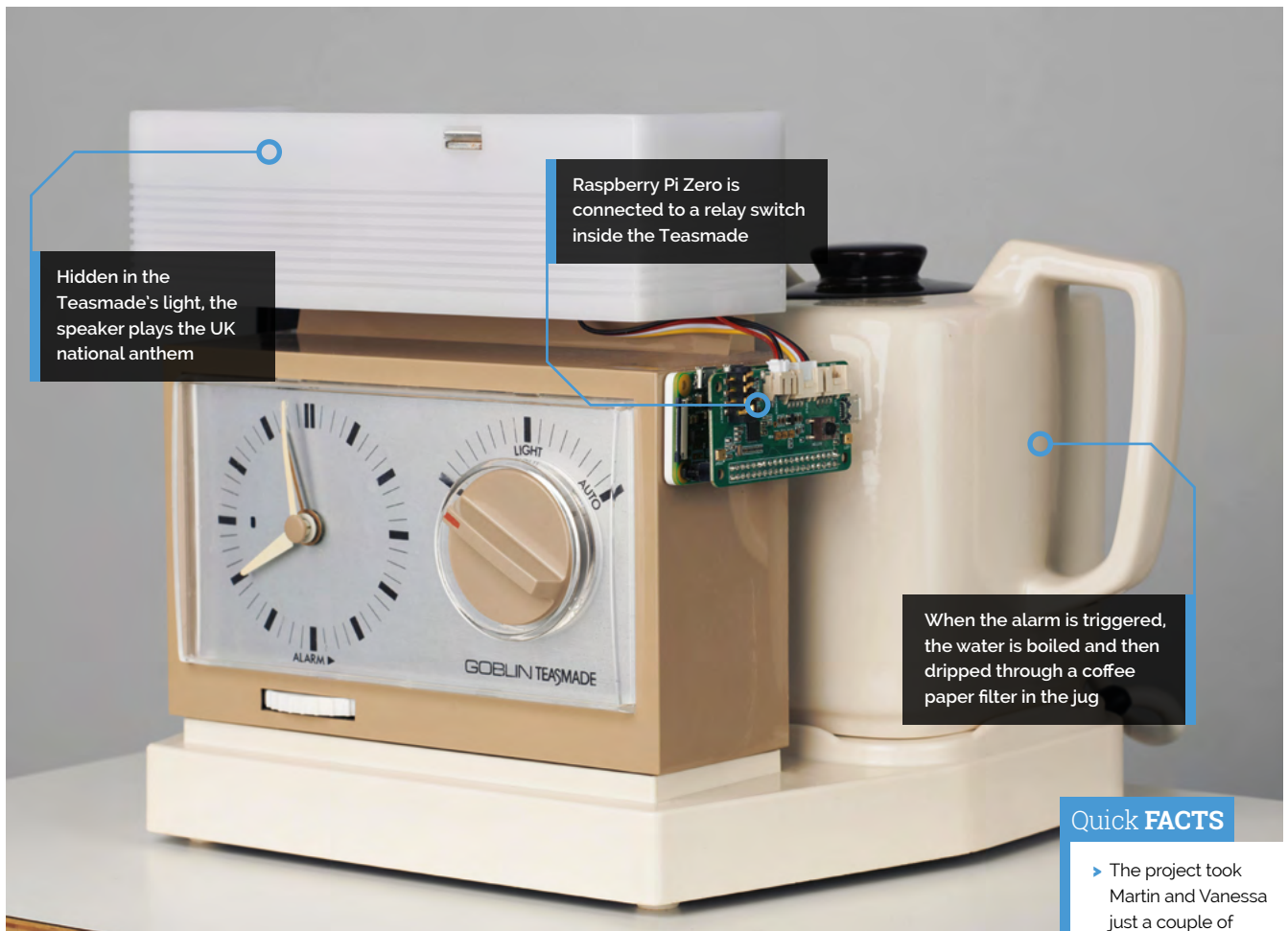
[magpi.cc/teasmade2](http://magpi.cc/teasmade2)



### Warning! Mains electricity

Martin added a relay switch to the innards of the machine. That involves wires that carry mains voltage. Anything with relay switches needs to be done with care.

[magpi.cc/electricalsafety](http://magpi.cc/electricalsafety)



## Right royal cuppa

So, how exactly does the machine produce a regular caffeine hit? On the side of the Teasmade is a Raspberry Pi Zero with a Grove ReSpeaker HAT. “There is also a connection to a little cheap speaker and a relay switch, replacing the alarm switch on the inside,” says Martin. “The script is automatically started using systemd when it turns on. It starts a process that monitors a Google Calendar. Every minute, it runs a query on the calendar, looking for the trigger phrase. If it sees it, it starts the boil cycle.”

The most difficult challenge for the pair was working out how to get the tool that pulls alerts from a Google Calendar (gcalcli) to act as a trigger in the main code. In the end, they used the subprocess module in Python, and now the Teasmade 2.0 cleverly starts brewing their coffee ten minutes before the time it’s required.

What’s more, the speaker that Martin and Vanessa inserted belts out the *God Save the Queen* while refreshments are being prepared. “There is a recurring appointment in our Google Calendar for an 11 am coffee. The sound of the

“ The sound of the tinny national anthem wafting from the kitchen is our signal that it is time to down tools for a break ”

tinny national anthem wafting from the kitchen is our signal that it is time to down tools for a break,” says Martin. This has generated some “bewildered amusement” from their non-British pals: “Friends and family are baffled by it on a number of levels.”

If you’d like to create your own version, Martin has generously made the code for the project available on GitHub, and one motivation for this is the old adage, ‘the more the merrier’. “Generally, the more people that replicate it and chip in, the easier it gets,” notes Martin. “Better coders than me have refined my code on other projects – I’ve no doubt that the same would apply here.”

### Quick FACTS

- ▶ The project took Martin and Vanessa just a couple of days to complete
- ▶ The LEDs flash a patriotic red, white, and blue while the drink is prepared
- ▶ Find the code and instructions on GitHub: [magpi.cc/teasmadegit](https://magpi.cc/teasmadegit)
- ▶ Check out their other great makes here: [magpi.cc/veebyoutube](https://magpi.cc/veebyoutube)
- ▶ Martin recommends YouTuber James Hoffmann’s musings on bedside coffee makers: [magpi.cc/barisieur](https://magpi.cc/barisieur)

# RMS meteor tracker

CCTV monitoring and Raspberry Pi enabled a stargazing duo to capture some incredible scenes, discovers **Rosie Hattersley**



## Mary and Mark McIntyre

Lifelong astronomy enthusiasts Mary and Mark McIntyre are part of the UKMON meteor network and enjoy sharing their astrophotography knowledge with others.

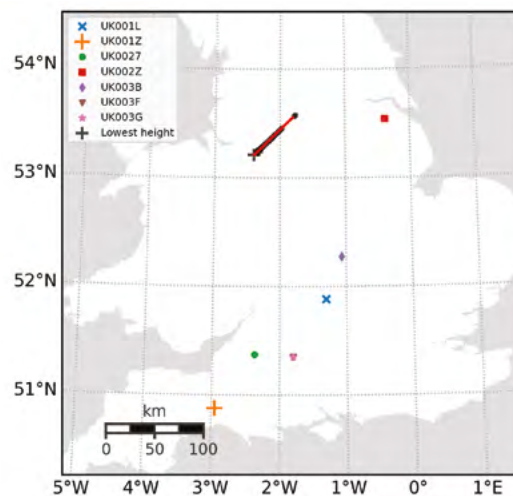
[magpi.cc/marymcintyre](http://magpi.cc/marymcintyre)

**M**ary and Mark McIntyre are so dedicated to astronomy that they had a mini-honeymoon at AstroFarm in France, and timed it so the moonlight wouldn't affect whether they could spot stars. They even moved halfway across the UK in order to set up home close to an important stargazing spot, at which point they decided to replace their existing meteor tracking setup. They have now built an RMS (Raspberry Pi Meteor Software)-based meteor tracker, one of dozens of astronomy trackers that helped pinpoint the whereabouts of a very rare carbonaceous chondrite meteorite which landed in Somerset in February 2020.

Mary and Mark's previous Raspberry Pi projects included a weather station and an all-sky camera which they used with an analogue meteor camera, and for which they adapted code to display findings on their website (see [github.com/markmac99](https://github.com/markmac99)). Expense and maintenance issues with this setup meant they were only too happy to get involved with RMS Raspberry Pi meteor tracking instead. "The RMS project was conceived, and software is written collaboratively by astronomy academics who wanted a lost-cost DIY system using off-the-shelf parts, to generate science-grade data about meteors as they burn up in our atmosphere," says Mary.

This chimed with the interests of the McIntyres, who now run five meteor cameras and help co-ordinate the UKMON (UK Meteor Network). Its team

of more than 100 UK citizen scientists has adapted RMS with a UK-specific toolset and data archive, making it far simpler for stargazers to identify events and objects they spot. "If more than one station captures the same event, then you can calculate velocity, mass, a more accurate orbit trajectory, and whether or not anything survived and fell as a meteorite," Mary explains. This is what happened with last year's Winchcombe fireball meteorite.



▲ Other cameras caught the same Perseid meteor and also the 'ground track' of the meteor as it travelled through the atmosphere and burned up



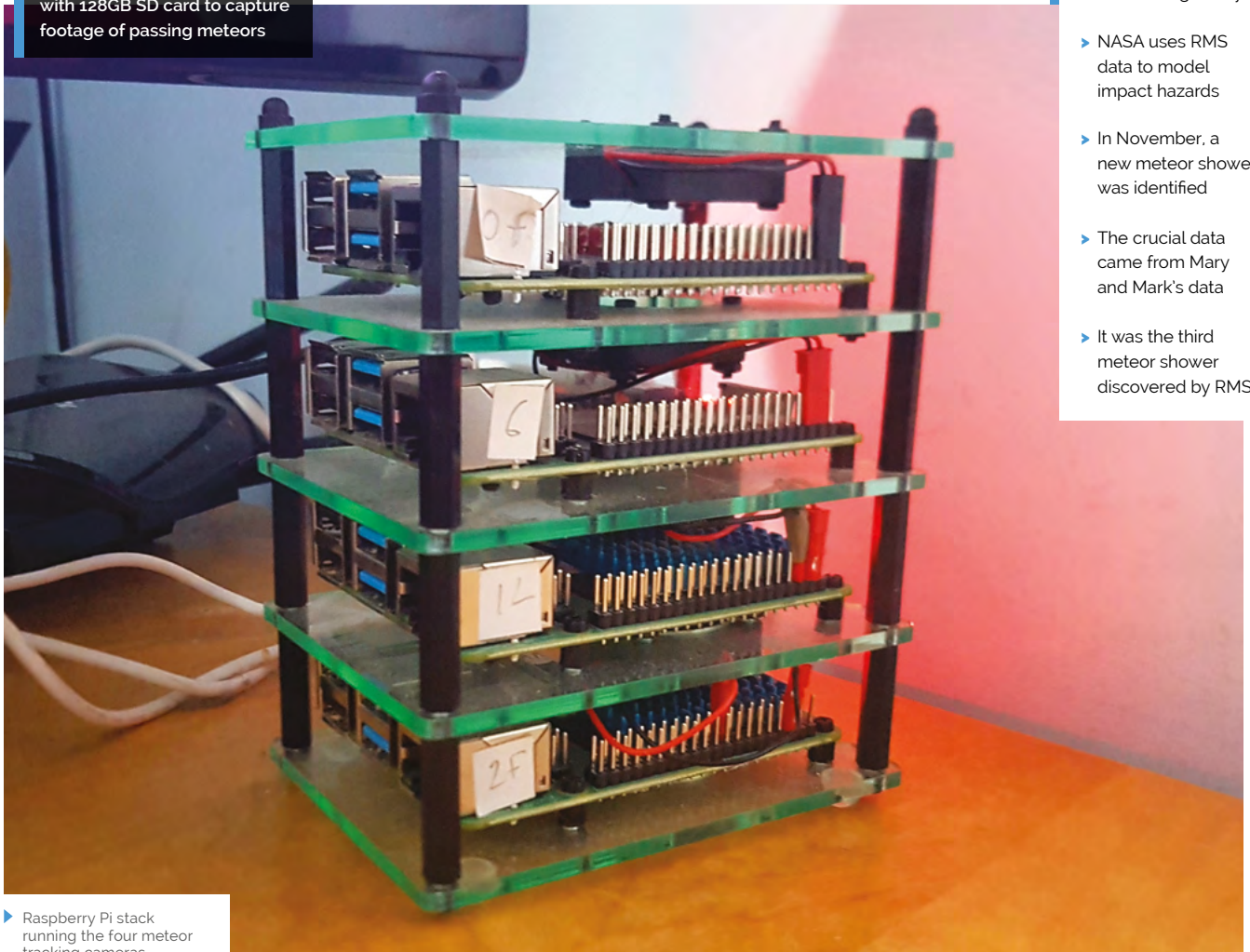
The meteor tracker once detected 20,000 objects an a single night (a spider had crawled over the lens)

Security cameras were chosen to track the night skies due to their reliable performance in low light

The camera is connected via Ethernet to a Raspberry Pi 3 with 128GB SD card to capture footage of passing meteors

### Quick FACTS

- ▶ RMS now has hundreds of members globally
- ▶ NASA uses RMS data to model impact hazards
- ▶ In November, a new meteor shower was identified
- ▶ The crucial data came from Mary and Mark's data
- ▶ It was the third meteor shower discovered by RMS



- ▶ Raspberry Pi stack running the four meteor tracking cameras



▲ A sun dog or parhelion, an atmospheric optical effect caused by ice crystals in high-level cirrus cloud, captured from the McIntyres' home observatory

“As well as meteorites, the RMS cameras can detect sprites – the extremely fast and faint upper atmosphere electric discharges that occur very high above thunderstorms”

### Scanning the skies

The McIntyres' meteor tracker uses a relatively inexpensive CCTV camera – chosen because it can detect objects in low light levels – which is pointing up at the sky and is clad in weatherproof housing. Handily, the camera can be positioned several metres from the couple's home, while its Raspberry Pi is tucked away indoors. Mary's version uses a Raspberry Pi 3, but she recommends the additional power of Raspberry Pi 4 if you're keen to build your

own. “We sometimes detect several hundred meteors per night on every camera, which can lead to heavy load on Raspberry Pi.”

Connectivity is in the form of PoE (Power over Ethernet), but there are other options: “The biggest advantage of Raspberry Pi is that the system can be installed virtually anywhere. Ideally, it should have an internet connection, but it can be run off-grid using batteries and solar power if necessary, provided the operator can



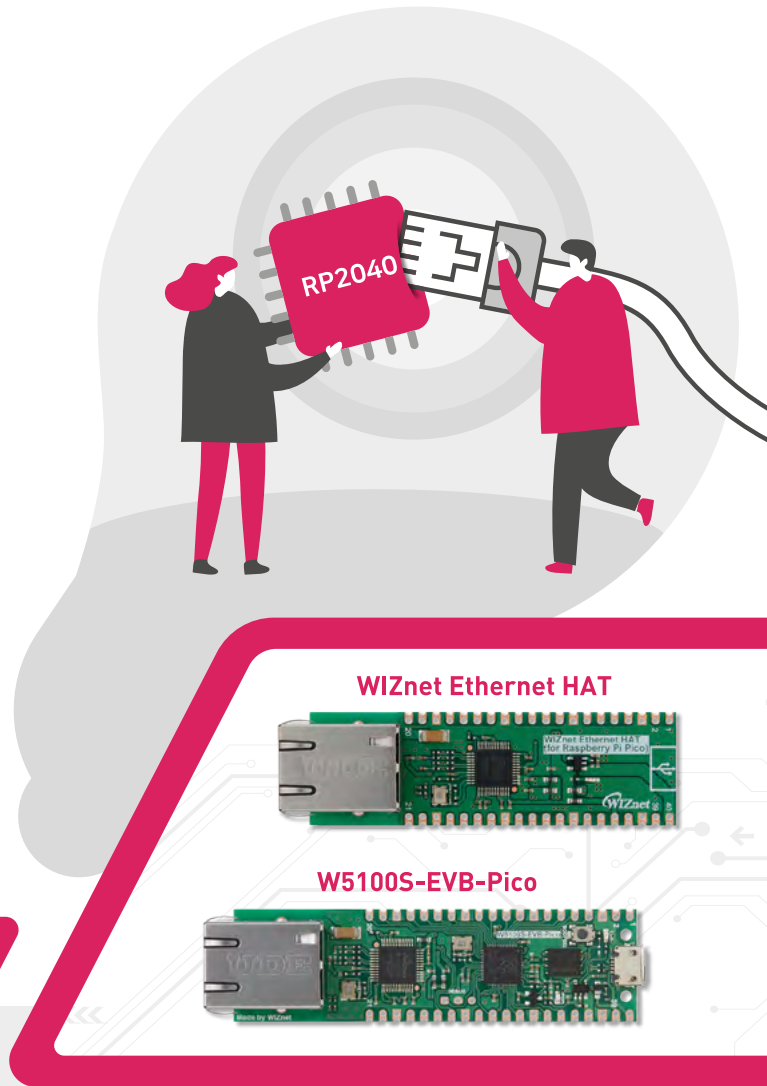
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visit periodically to collect data,” says Mary. Parts to build the meteor tracker were easy to source from The Pi Hut and other component suppliers, with a total cost of around £200, including the camera. “If you have a little experience using Raspberry Pi and Linux, it’s pretty simple to set up,” she says. There’s a pre-built image suitable for UK users on their website ([magpi.cc/rmswiki](https://magpi.cc/rmswiki)).

## Wonders of the universe

The free open-source Raspberry Pi Meteor Software (RMS) records the sky continuously from dusk until dawn, looking for anything that is moving. RMS recognises and discounts aircraft and satellite trails, fireworks, and most moths, bats, and owls. The camera is calibrated in advance with a ‘platepar’ file that identifies the star field in its field of view. Based on this information, it is able to work out the orbit of the material that caused a meteor event.

As well as meteorites, the RMS cameras can detect sprites – the extremely fast and faint upper atmosphere electric discharges that occur very high above thunderstorms. This is helping researchers who study upper atmospheric phenomena.

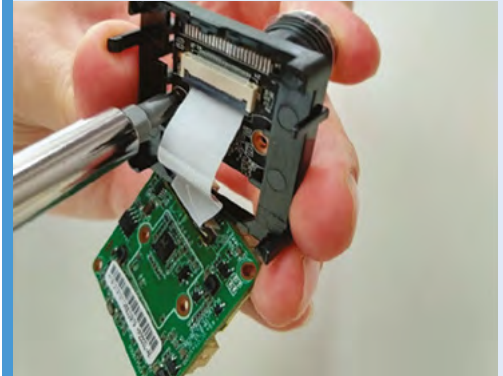
The open-source software is primarily written in Python 3 (and supports Python 2) with some performance aspects coded in C/C++. Downloadable from [magpi.cc/rmsgit](https://magpi.cc/rmsgit), its video capture and stability have recently been improved, while machine learning and detection accuracy are ongoing.

Mary has been impressed at how well Raspberry Pi has worked for their meteor detection setup. It cost around a third as much as a previous meteor system based on Windows. “Raspberry Pi has made it much more affordable, much easier to set up, and much simpler to maintain.” [M](#)

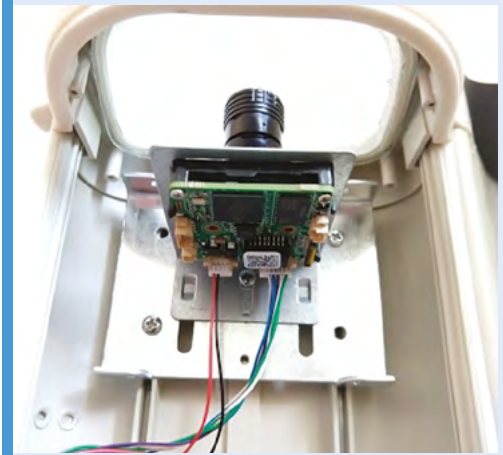
▲ Bright Perseid meteor – magnitude -2.8 (the brighter something is, the lower the number) caught on the McIntyres’ camera UK001L

## Enable night mode

The RMS software can be downloaded from [magpi.cc/rmswiki](https://magpi.cc/rmswiki), while detailed build instructions are at [magpi.cc/rmscamera](https://magpi.cc/rmscamera). You’ll need a Raspberry Pi 3 or 4, IP camera or Raspberry Pi HQ Camera, large-capacity microSD card, and an Ethernet connection.



- 01** Connect the camera via Raspberry Pi’s Ethernet port and a PoE injector, and run the script on Raspberry Pi to configure the camera for night vision.



- 02** Install the camera in a weatherproof housing on the outside of a building with a good view of the night sky.



- 03** After the first night’s run, ‘calibrate’ the camera’s field of view against the stars – see the setup guide. After this, it should be set to run automatically every night.

# Pneumonia Detection

Detecting pneumonia can be a tricky business.

**Rob Zwetsloot** looks at how a Raspberry Pi solution could help improve it



**Arijit**

MAKER

A 15-year-old student with a huge interest in machine learning, being an ambassador for Edge Impulse, and co-organiser of TinyML India.

**P**neumonia is a respiratory condition that results from any number of viral or bacterial infections in people. It can also be fatal, which makes it very dangerous. Diagnosis is usually done via symptoms, and one of the more common ways of confirming it is via an X-ray. Young maker Arijit has been creating a device that scans these X-rays so it can more accurately detect it.

“My project Pneumonia Detection is a complete open-source system that uses a Raspberry Pi accompanied with a Raspberry Pi Camera to run a state-of-the-art embedded machine learning model,” Arijit explains. “[This] allows the device to scan chest X-rays and let the user know the amount of viral or bacterial pneumonia present in the chest of the patient. The entire system kit would cost you less than \$100, including all of the hardware and the software needed, and it can practically run anywhere.”

Over the last two years, there have been more cases of pneumonia, and a great need for a low-cost system that could quickly and accurately detect it.

“There was also a massive number of people above the age of 60 who were affected by pneumonia [which] even caused death due to delay in detection,” Arijit mentions.

## Machine learning and X-rays

For this project, Arijit decided Raspberry Pi was the way forward due to it being easily powered by a mobile battery, as well as the software support.

“The system consists of a Raspberry Pi 4, along with a Raspberry Pi Camera,” he says. “From the software side of things, we have two Docker containers running the balenaCAM and the Edge Impulse machine learning model on top of



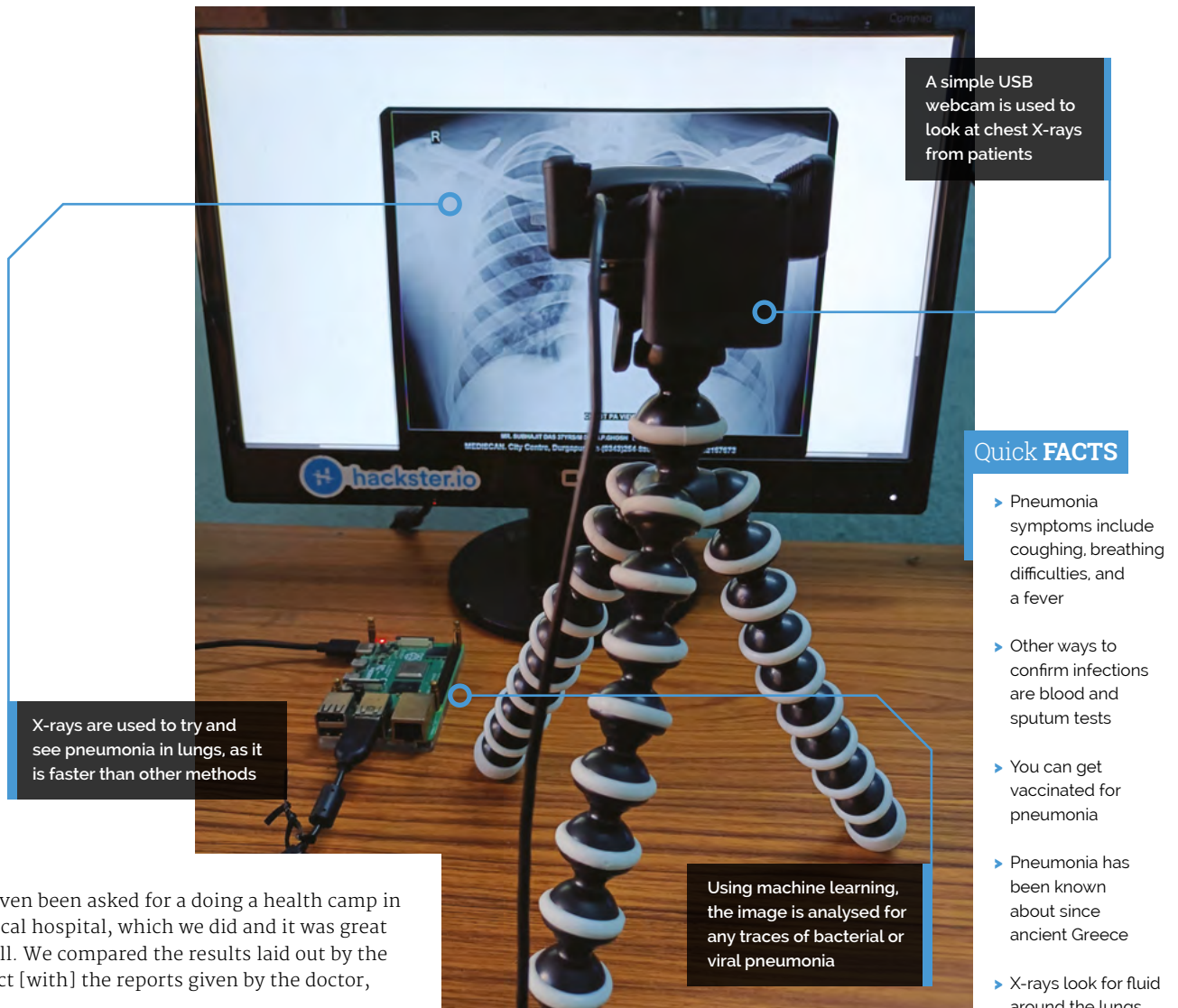
balenaOS running on Raspberry Pi. The user just has to place a chest X-ray or an image of it in front of the camera and open up <http://localhost:4912> in a [browser]. After two-three seconds, the live camera feed will appear in the dashboard and show what type of pneumonia has the person [contracted] with percentages!”

The model was trained with over 3700 images of bacterial and viral pneumonia, which leads to an 80% accuracy in detections. According to a pulmonologist Arijit spoke to, human doctors only have about a 30% accuracy rate when looking at X-rays themselves.

## Positive science

“My Twitter and LinkedIn feed was blasted out on the day I released this project publicly,” Arijit tells us. “People have shown very much interest in this.

▶ As the setup is quite simple, this makes the whole system a lot cheaper than other solutions



A simple USB webcam is used to look at chest X-rays from patients

X-rays are used to try and see pneumonia in lungs, as it is faster than other methods

Using machine learning, the image is analysed for any traces of bacterial or viral pneumonia

### Quick FACTS

- ▶ Pneumonia symptoms include coughing, breathing difficulties, and a fever
- ▶ Other ways to confirm infections are blood and sputum tests
- ▶ You can get vaccinated for pneumonia
- ▶ Pneumonia has been known about since ancient Greece
- ▶ X-rays look for fluid around the lungs

I've even been asked for a doing a health camp in my local hospital, which we did and it was great as well. We compared the results laid out by the project [with] the reports given by the doctor,

“The system consists of a Raspberry Pi 4, along with a Raspberry Pi Camera”

and to my surprise not a single result given by the model was wrong. So, it turns out the ML model has been trained well!”

With more testing and learning, the accuracy of the system will only increase, hopefully resulting in cheaper and more accessible pneumonia detectors.

“The project is completely open-sourced,” Arijit adds. “There are a lot of places wherein you can change and add a new feature to the project. It's now up to the community to contribute and upgrade its features!”



▲ Signs of pneumonia can be detected in X-rays

# GBA Remote Play

Rodrigo Alfonso's Game Boy Advance runs 3D titles made for PlayStation, but all the magic is in the cartridge, as **David Crookes** explains



## MAKER Rodrigo Alfonso

Rodrigo is a teacher and software engineer from Argentina. He is passionate about music, computers, and retro gaming, and he's currently working as a freelance software developer.

[magpi.cc/gbaremote](http://magpi.cc/gbaremote)

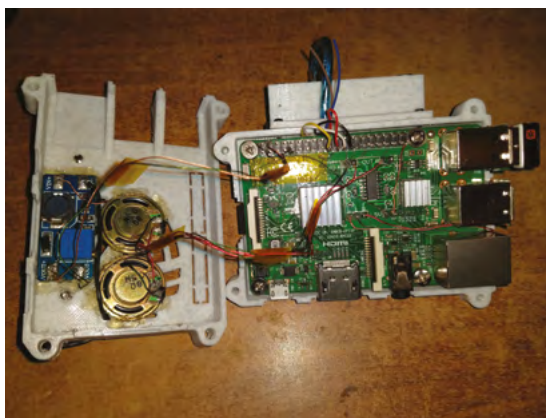
▶ Rodrigo's 3D-printed cartridge includes a Raspberry Pi 3, which he says has a good trade-off between processing power and battery consumption

**M**odding retro consoles is nothing new, but it can leave the original machine feeling a little bruised and battered.

With Rodrigo Alfonso's project, however, no classic console has to suffer harm. Instead, it's possible to take a handheld Game Boy Advance (GBA), run PlayStation games on it, and not so much as take a screwdriver to the device itself.

Rodrigo has achieved this by creating a custom cartridge with a Raspberry Pi 3 computer tucked neatly inside. By installing and running the RetroPie emulator on the cart and engaging in a bit of jiggery pokery with the GBA's Link Port, Rodrigo has been able to stream PSOne games on the Nintendo handheld.

"What inspired me the most was the fact that the whole project seemed impossible to achieve," he says. "But I talked with a friend called Lucas Fryzek who knows a lot about embedded systems and he helped me figure out how to start."



## With great power

At that point, Rodrigo says he didn't even know what a Serial Peripheral Interface (SPI) was, but he soon learned and realised its potential. The idea was to stream video from the cart at 240×160 resolution and send button-press inputs to it through the GBA's Link Port. Nintendo included this interface so that two handheld consoles could be connected together for multiplayer gaming, but it has definitely come in handy here!

"My first step was to solder Raspberry Pi's SPI ports to a GBA Link Cable, then test a multiboot tool to send a ROM [a file containing the game] to the Game Boy Advance," Rodrigo explains. "I then ran a quick benchmark to see how packets could be transferred per second, though after optimising the code, the final transfer rate ended up being considerably higher."

Rodrigo's motivation was to create an impressive "superpowered" cartridge – "something you could take to a party and blow your friends' minds with," he says. He'd played lots of GBA games as a child and he still loves to check out new non-commercial releases for it. "But PlayStation was my first home console and I didn't have too many games for it at the time."

## 3D or not 3D

The project involved lots of trial and error. "I started to learn about bitmap modes on the GBA and frame buffers on the Raspberry Pi side and I tried to send a small image," Rodrigo says. "After some trial and error time, the result was the GBA displaying one frame of Raspberry Pi OS's desktop. Once I had that working, the remaining tasks were

Raspberry Pi 3 is inside a specially made cartridge that can be inserted into an unmodified Game Boy Advance to play games, such as the PlayStation homebrew puzzler Yopaz IceStar

PlayStation games are run via an emulator in RetroPie and a compressed stream of images is sent to the GBA at 2.6Mbps via the console's Link Port

Once per frame, the GBA tells the Raspberry Pi which buttons are pressed. The keys are mapped to a virtual gamepad used by RetroPie

### Quick FACTS

- ▶ Games are streamed from a custom cartridge
- ▶ The Game Boy Advance itself isn't modded
- ▶ The handheld can be overclocked, though
- ▶ It will boot from the GBA Link Cable
- ▶ An audio circuit is also created

“ It's something you could take to a party and blow your friends' minds with ”

creating a virtual gamepad mapped to the GBA keys and improving the transfer rate.”

Rodrigo says there are limits. It's not possible to transfer more than 1.6Mbps bi-directionally, for example, otherwise Raspberry Pi starts to receive “garbage” from the GBA. There's also a one-way limit of 2.6Mbps, or 4.8Mbps if overclocked. Yet a better frame can be achieved if you forgo image quality by lowering the GBA's native resolution from 240×160 to 120×80. Most games run smoothly.

Gamers are not limited to PlayStation games either. You could try SNES and Mega Drive, for instance, but Rodrigo says the whole point was to play 3D games. Ideally, he would have run Nintendo 64 games. “That was the original idea, but it requires more processing power and fine-tuning to get it working well.” He's achieved his main aim, though. “There are several mods out there based on Raspberry Pi [boards] inside Game Boy Advance shells, but this is proper expandability,” he says. **M**



- ◀ A Link Cable needs to be soldered to Raspberry Pi 3's SPI0 pins

- ▼ Most of the original cartridge pins are covered with polyimide silicon tape to prevent games running from it. Instead, data from a program on Raspberry Pi sends a ROM to the GBA via the Link Cable



# Sunrise Lamp

A cheerful lamp that throws NeoPixel beams around the room and encourages sleepyheads to embrace the day caught **Rosie Hattersley's** imagination



MAKER

**Russell Eveleigh**

Teacher Russell was drawn to Raspberry Pi by the magic of such a small and affordable device outperforming the PCs he grew up with.

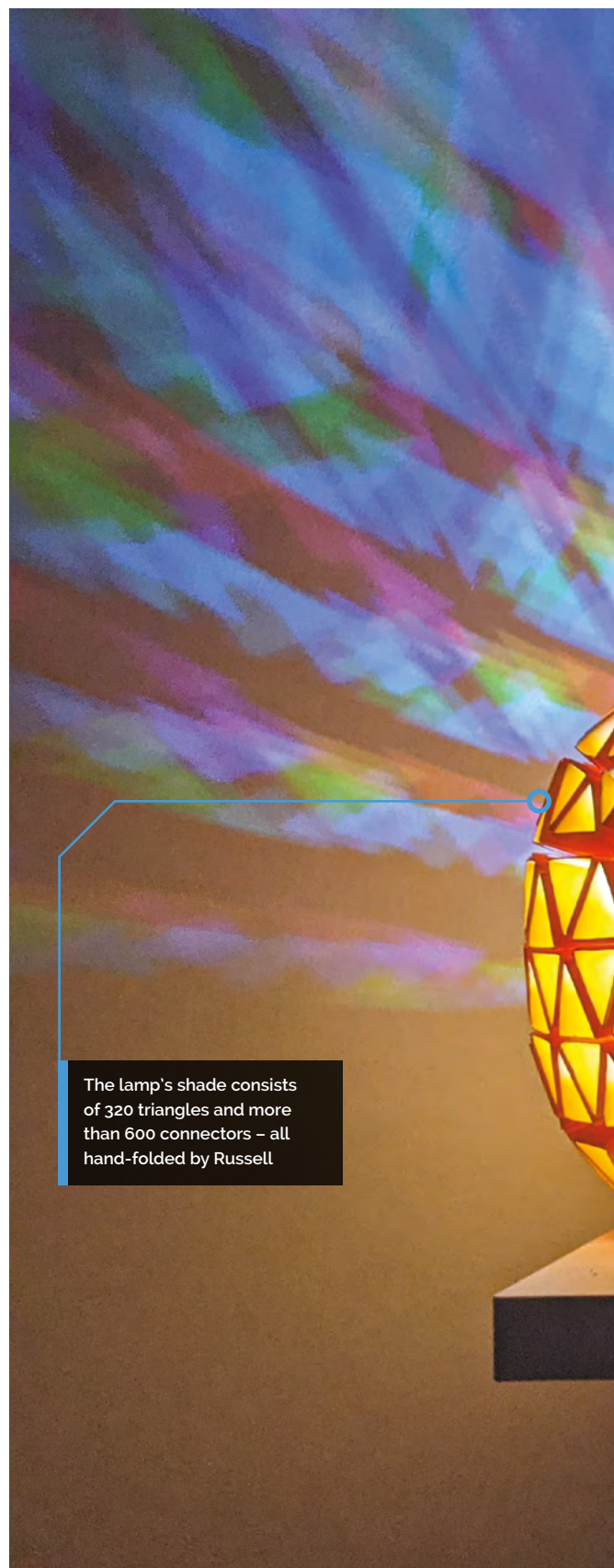
[russelleveigh.medium.com](http://russelleveigh.medium.com)

**T**he gloomier end of the year can be improved with pretty lights and sparkles, at least so goes the thinking behind purveyors of SAD (seasonal affective disorder) lamps, while the festive season also partly owes its timing to attempts to break up the monotony of winter. Teacher Russell Eveleigh’s impressive Sunrise lamp could easily do a turn as a mood-brightening SAD lamp, but was envisaged as an alternative to a Gro clock.

“Gro clocks serve to persuade children to stay in bed until a reasonable hour; in our house, the clocks we had been passed on were simply ignored,” Russell relates. Nonetheless, it was while on paternity leave that Russell began his first forays into Raspberry Pi project creation, using the Raspberry Pi Camera for a time-lapse of his young son sleeping in his Moses basket. “I’m lucky his first word wasn’t LED!” he jokes. More recently, Russell had been looking for an excuse to learn more about addressable LEDs and how they may be controlled via the GPIO pins on Raspberry Pi.

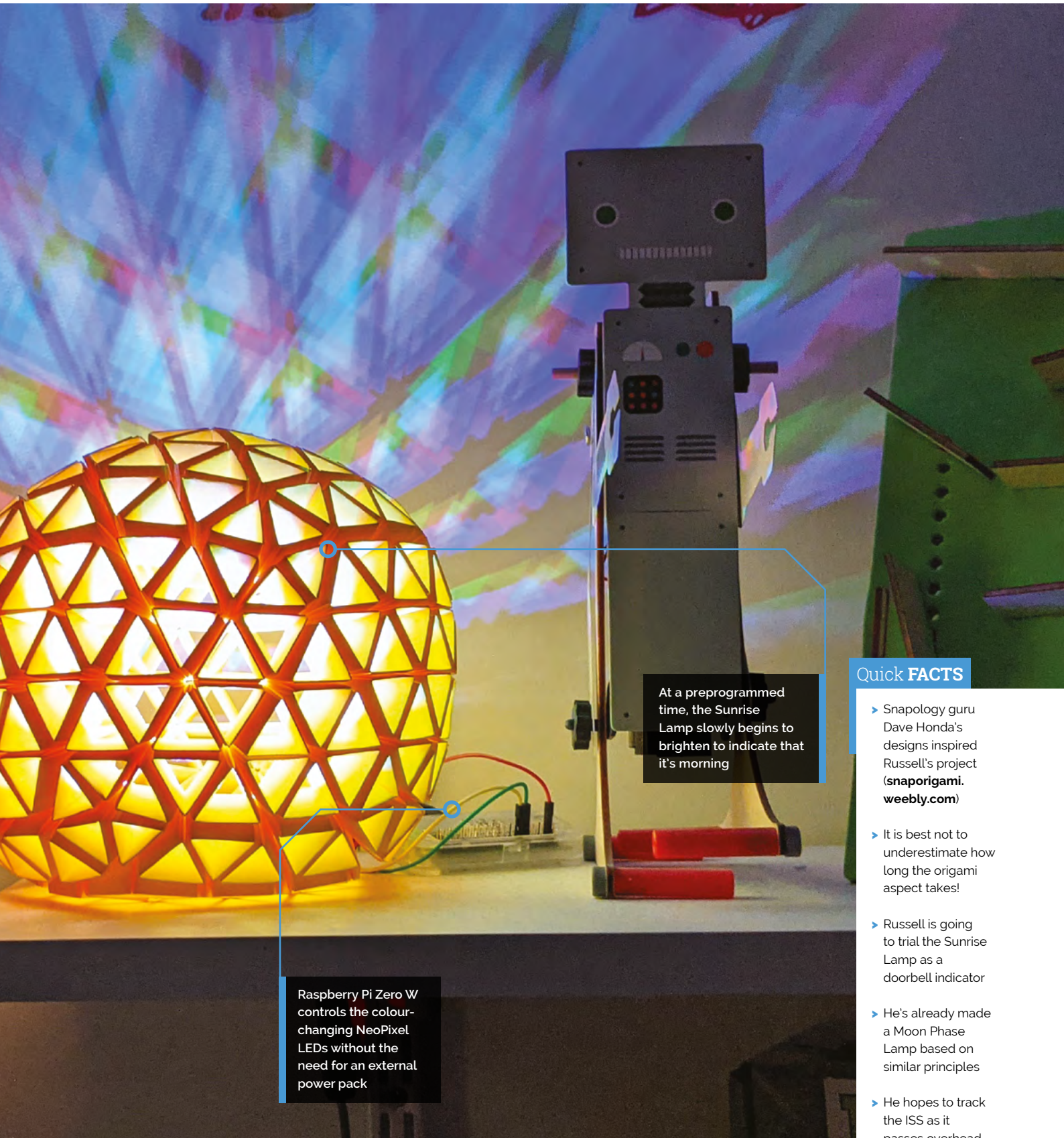
## Snap to it

The Sunrise Lamp resulted from another of Russell’s nascent interests: Snapology, a technique in which origami shapes are created from rigid triangles. Having seen Ed Chew’s award-winning Tetra Lamp made from recycled cartons ([magpi.cc/tetrapaklamp](http://magpi.cc/tetrapaklamp)), Russell became convinced that a programmable light source in the centre of a similar [origami lampshade] “could create some interesting patterns and lead to lie-ins beyond 5 am!” Creating his version became a good way to



The lamp’s shade consists of 320 triangles and more than 600 connectors – all hand-folded by Russell





At a preprogrammed time, the Sunrise Lamp slowly begins to brighten to indicate that it's morning

Raspberry Pi Zero W controls the colour-changing NeoPixel LEDs without the need for an external power pack

### Quick FACTS

- ▶ Snapology guru Dave Honda's designs inspired Russell's project ([snaporigami.weebly.com](http://snaporigami.weebly.com))
- ▶ It is best not to underestimate how long the origami aspect takes!
- ▶ Russell is going to trial the Sunrise Lamp as a doorbell indicator
- ▶ He's already made a Moon Phase Lamp based on similar principles
- ▶ He hopes to track the ISS as it passes overhead



- ▲ A web interface allows the choice of LEDs and the illuminated effect to be changed instantly
- ▶ At night, the Sunrise Lamp functions as a reassuring night light, only reaching full brightness when it's time to wake up



“ There may be some kind of evolutionary link to our ancestors sleeping around camp-fires ”

unwind of an evening, with mindfulness due to the repetition involved in folding 320 triangles and more than 600 connecting pieces for the lamp's origami shade.

During the night, the light dims and the lamp functions as a night light, then at a predetermined time, the Sunrise Lamp slowly begins to brighten to indicate that it's morning and time to get up, he explains.

Armed with Raspberry Pi Zero W, a plastic case, and £7 worth of NeoPixels from The Pi Hut, Russell followed the reseller's detailed instructions for



installing LED libraries ([magpi.cc/usingneopixels](https://magpi.cc/usingneopixels)) and NeoPixel maker Adafruit's guide to installing CircuitPython on Raspberry Pi.

Having established that a modest number of LEDs could be controlled from Raspberry Pi with no need for an additional power source – its 5V pin would suffice – Russell soldered the ring to the GPIO header on his Raspberry Pi and used SSH to log in and control the lamp.

### Changing things up

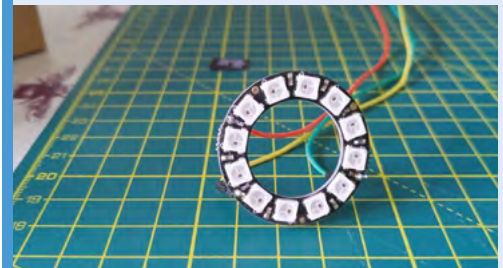
Russell was pleased with his Sunrise Lamp and impressed by the intriguing patterns it creates on his ceiling, depending on whether one or more NeoPixels is active. He later revised the setup (seen in his follow-up Moon Phase Lamp) using Apache and PHP directly on the Raspberry Pi Zero. This meant the web page menu could instantly change the light sequence. Raspberry Pi Pico, or a different microcontroller, could also be used to replicate this project, but in this instance Russell was keen to learn about using Raspberry Pi with a web server.

He was also advised to use red, not blue, lights so as not to interfere with anyone's sleep patterns: [magpi.cc/bluelight](https://magpi.cc/bluelight). "Apparently there may be some kind of evolutionary link to our ancestors sleeping around camp-fires," he muses. [M](#)

▲ Russell created a simpler version of the project using the same ideas for a colour-changing Christmas tree topper

## Embrace the light

To make your own Sunrise Lamp, you'll need a shape such as an icosahedron that allows light through, Raspberry Pi Zero, microSD card, power supply, jumper leads, and a NeoPixel ring.



**01** Use jumpers to attach the NeoPixel ring to the GPIO header on your Raspberry Pi Zero W, and then to the removable base section of the origami shade. Full instructions and code are at [magpi.cc/sunriselamp](https://magpi.cc/sunriselamp).



**02** You'll need around 50 sheets of stiff paper or card from which to cut and fold strips to assemble into a discernible shape. Video instructions for creating origami icosahedra can be found on YouTube: [magpi.cc/icosahedron](https://magpi.cc/icosahedron).



**03** It's simplest to control the Sunrise Lamp from a web dashboard and to log in via SSH.

# Technical Function

What's the best way to test offline computer vision?  
An animatronic eye, of course. **Rob Zwetsloot** takes a look

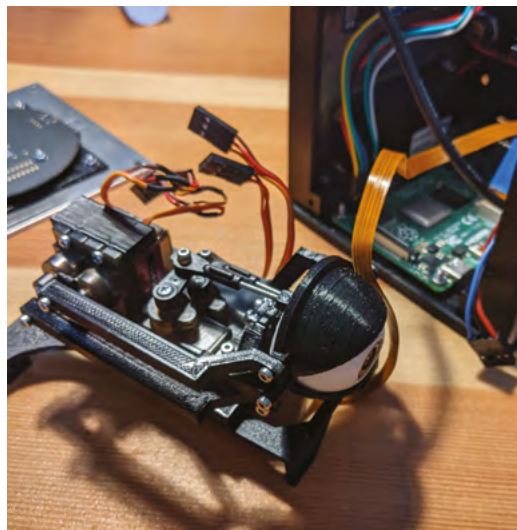


**Sean Glendinning**

A student from Aberdeenshire studying robotics at Heriot-Watt University. He likes anything to do with robotics, including electronics and programming.

It's weird how eyes can be a bit creepy – whether they're animated incorrectly or just sitting on their own. Anyway, here's a very big, single eye that will keep track of you.

"This robot, named 'Technical Function', is... used to test out offline computer vision, this time with the much more powerful Raspberry Pi 4," Sean Glendinning, its creator, explains to us. "It also features a USB microphone array attached to its head, two speakers attached to the sides, and its most striking feature: an animatronic eye where a Raspberry Pi Camera is mounted. I originally wanted to test out offline speech recognition as well, but I haven't had any good results. It also includes a real time clock, an accelerometer to sense orientation, and a power circuit that starts up and shuts down the robot on a button press."



▶ The components are well-packed into the case

## Electric eye

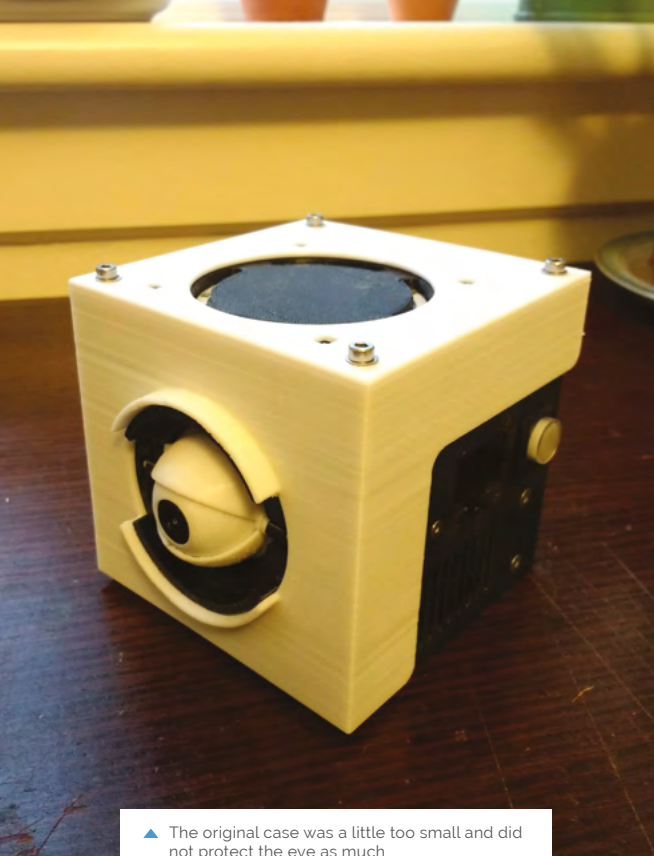
The design is based around a two-eye concept by Will Cogley ([magpi.cc/cogleyeye](http://magpi.cc/cogleyeye)) which Sean cut down to be a single eye, and have space for the camera module as well.

"I then modelled (using Autodesk Inventor) an enclosure for the eye, Raspberry Pi, and the other electronics: including two speakers, amplifier, real time clock, servo controller, custom power circuit, OLED display, microphone, button, and two 5V power connectors (one micro USB and the other a DC power jack)." Sean tells us. "My first design was entirely 3D-printed, with a white shell covering up most of the exposed bolt heads. It was strongly based on the design for my microphone robot I built previously, with space made inside to mount the eye mechanism, replacing the large speaker with two smaller ones."

It's a very compact design, with a lot of components squeezed in.

"There were a number of drawbacks with this design," Sean says. "The biggest one being that the eye was mounted too far forward. If the robot was dropped on its face, the eye would be damaged, and there was no way to move the eye back as the case dimensions were too small. I wanted to try building with sheet metal as a challenge. I designed a case with 3D-printed braces to hold together four pieces of 2mm aluminium sheet metal, cut with the help of my Dad. The braces hold the sides together with an assortment of nuts and bolts. Since the case was slightly bigger than the previous one, the eye mechanism could be mounted further back."

Sean also replaced the power circuit, added an accelerometer, and changed a couple of other small bits to get the eye to where it is now.



▲ The original case was a little too small and did not protect the eye as much

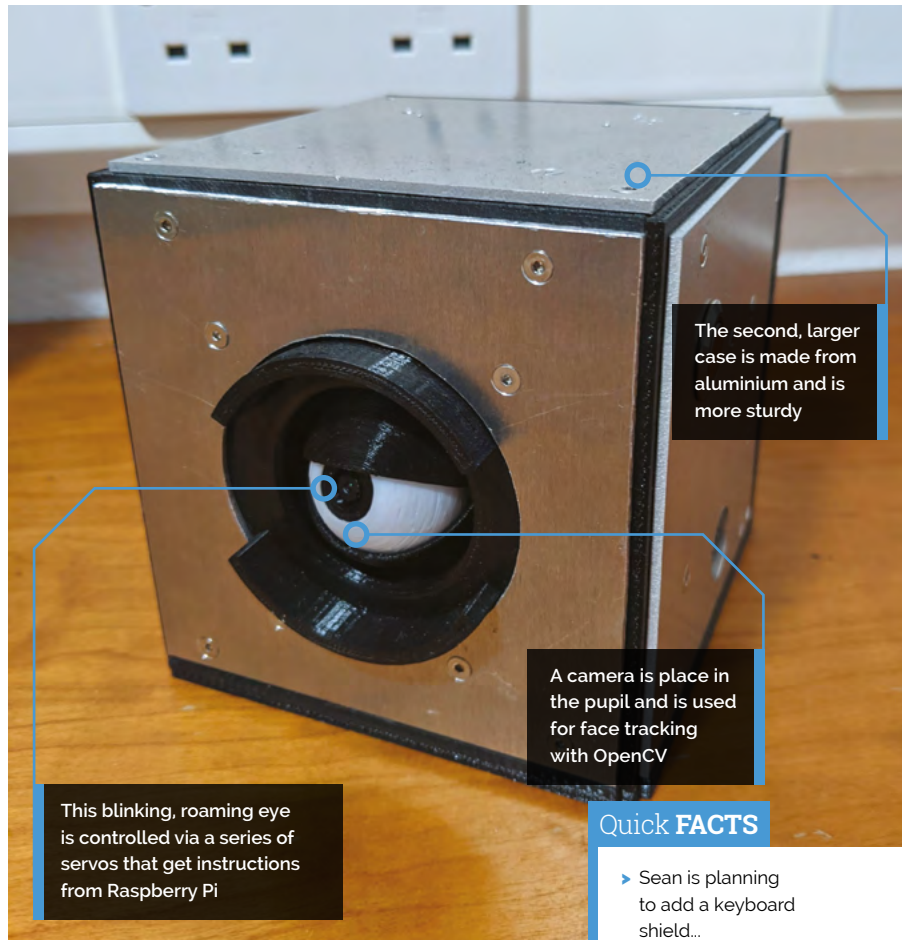
“ I was able to make the eye track people in real time, and say their name if it saw their face ”

### Follow along

As well as servos that control the direction of the eye (pan and tilt), there's also two that control the upper and lower eyelid. These are controlled via Raspberry Pi, which tracks faces using OpenCV.

“Also connected is an audio amplifier that powers the two side-mounted speakers, with the audio signal coming from the 3.5 mm audio jack on Raspberry Pi.” Sean continues. “The microphone array is connected through USB, while two USB ports and the Ethernet port are left exposed for programming. The power circuit connects to the 5V input, the on/off button, and the micro USB input. All that's left is the real time clock module and the accelerometer, which are both connected through I2C, as is the servo driver... using all of this, I was able to make the eye track people in real time, and say their name if it saw their face (it would have to have their face recorded first). It also blinks at random intervals.”

With all that, it works well, although apparently a little too well for some, as Sean explains peoples' reactions: “Very positive! However, I have had people comment on the ‘uncanny valley’ of the single mechanical eye following them around, and blinking at them.”



The second, larger case is made from aluminium and is more sturdy

A camera is placed in the pupil and is used for face tracking with OpenCV

This blinking, roaming eye is controlled via a series of servos that get instructions from Raspberry Pi

### Quick FACTS

- ▶ Sean is planning to add a keyboard shield...
- ▶ ... so people can communicate via text
- ▶ Sean recycled parts from an older robot
- ▶ The microphone is connected via USB
- ▶ Usually only the top lid of a human eye is used to blink



◀ The eye on its own, testing out the movement and tracking

# Rotating television

Anton Suntinger had us in a spin when we saw his amazing rotating television. **David Crookes** gets his head around it



**Anton Suntinger**

Anton is currently studying law in Germany, but he has enjoyed working with electronics since he was a child.

[magpi.cc/su77ungr](https://magpi.cc/su77ungr)

**W**hen Samsung introduced the Sero, it literally turned television on its head. Rather than force viewers to watch in a widescreen format, this 43-inch 4K OLED TV is able to rotate on its stand, giving viewers the choice of horizontal or vertical video – perfect if you want to switch from a TV series such as *The Tick* to enjoying the latest shenanigans on TikTok.

Anton Suntinger was certainly impressed after catching sight of the television in a commercial. Rather than rush out and buy one, though, he looked to create his own version from scratch. Not only would his television show whatever was being played on his Android phone, it would rotate depending on how he was holding his device.

“It started as a kind of feasibility study rather than something practical,” Anton tells us. “But when I was proceeding with the project, I discovered it could be used for a more immersive media experience, reading e-books and enjoying a new perspective for social media. I also wanted to buy a Chromecast dongle anyway and I decided it would be the right time to get started with programming.”



▶ Want to read a brilliant book? Mirror it from an Android phone, turn the device vertically, and the TV will follow suit



▶ A major challenge was to fasten the VESA mount so that it can withstand the emerging torque when swinging a TV

## Steering the project

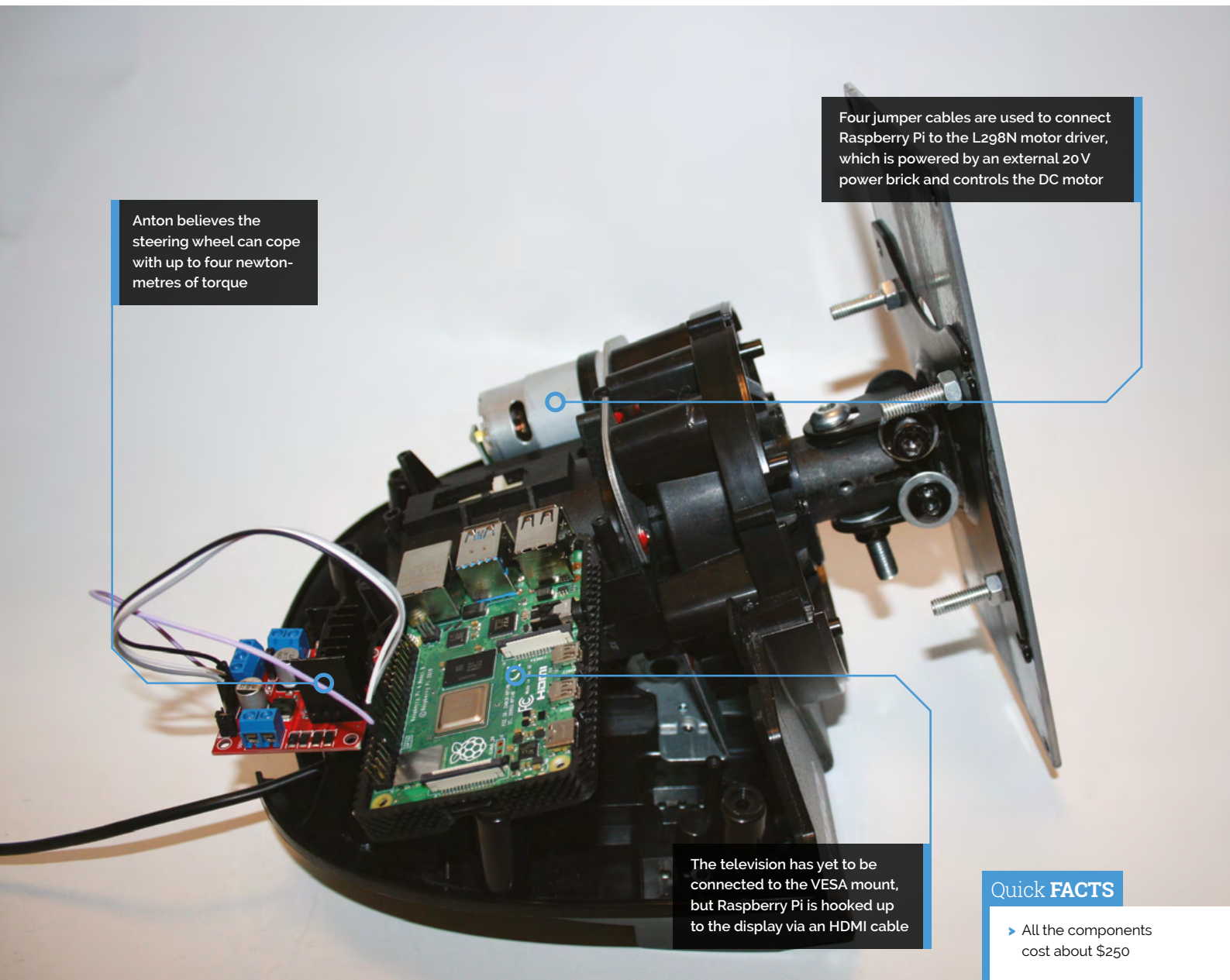
For this project, Anton used a Raspberry Pi 4. “I needed both potent computational and graphical power to drive the screen mirroring,” he explains. “In addition, the GPIO pins and just one other driver board was all that I needed computationally.”

Of course, he also required a way of turning a screen – a 32-inch Sony television in his case. As luck would have it, he owned a Thrustmaster T150 steering wheel used for controlling racing video games. “I love to salvage used tech and give it a new function and, because this wheel was lying around, I didn’t have to design a gearing and mount from the ground up,” Anton says.

His first step was to decide which parts would be useful. “I kept the DC motor and unscrewed the components,” he continues. “The only challenge then was to somehow attach my heavy TV on to it. My eyes wandered around my room and stopped at my old monitor’s VESA mount. I gave it a try and, interestingly enough, it fit perfectly when secured with bidirectional bolts.”

## Round it goes

An L298N motor controller sits between Raspberry Pi and the USB steering wheel. When Raspberry Pi is booted, it runs a script that establishes Bluetooth and a wireless ADB connection with an Android device. At this point, a fork of the open-



Anton believes the steering wheel can cope with up to four newton-metres of torque

Four jumper cables are used to connect Raspberry Pi to the L298N motor driver, which is powered by an external 20 V power brick and controls the DC motor

The television has yet to be connected to the VESA mount, but Raspberry Pi is hooked up to the display via an HDMI cable

#### Quick FACTS

- ▶ All the components cost about \$250
- ▶ The project took three weeks to create
- ▶ It repurposes a gaming steering wheel
- ▶ The steering wheel was not drilled or cut
- ▶ It's operated using an Android phone

## “ I love to salvage used tech and give it a new function ”

source screen-mirroring app Scrcpy (which is available on GitHub) becomes active, and another script discovers the current state of the phone's rotation via an ADB shell.

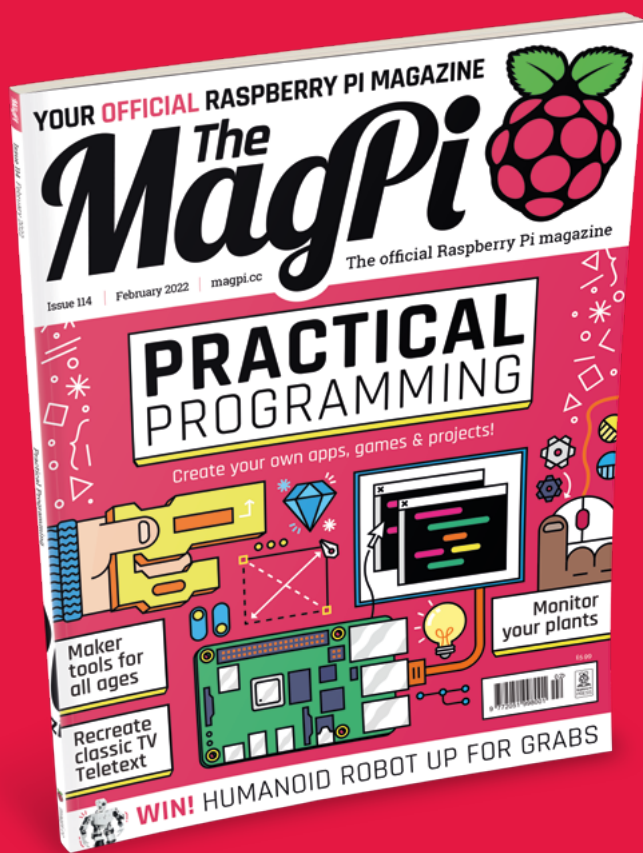
“As soon as the value equals the vertical value, a Python script is triggered which controls the motor via the GPIO outputs,” Anton says. “At the same time, the output of the range is adjusted to either the horizontal mode or the portrait mode using the command-line tool Xrandr.

“When the change in the phone's rotation is registered via ADB, the same Python script is executed with inverted values so the motor's polarity is flipped and triggers the rotation in the other direction. At the same time, it changes the video output of Raspberry Pi. And there's your rotating TV.”

It's certainly impressive and Anton has learned so much from the process. “The biggest challenge – other than reducing the delay which appears when using the ADB wirelessly – was to find a responsive way to get the phone's rotation,” he says. “This project also introduced me to the Android developer options.”

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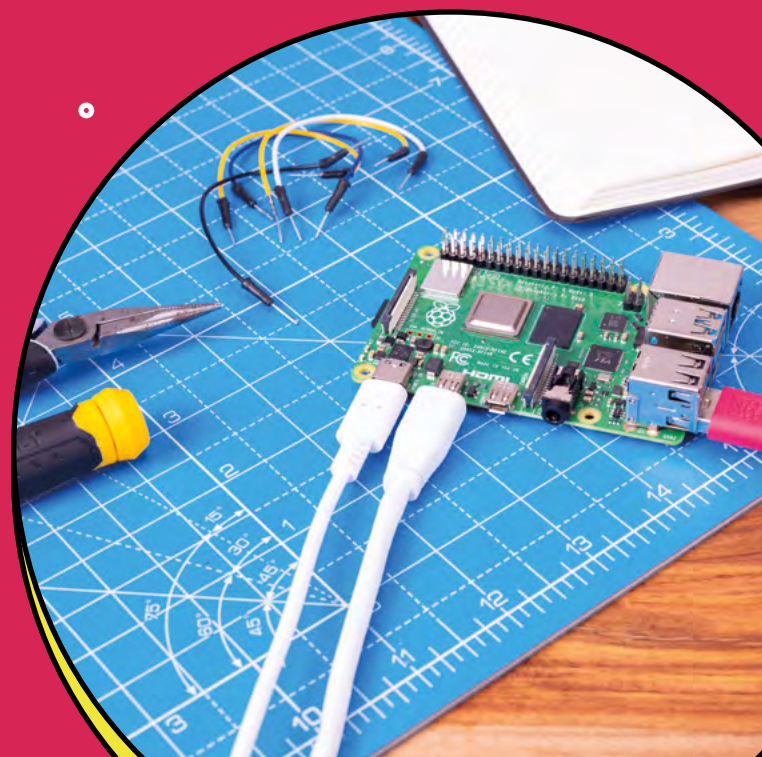
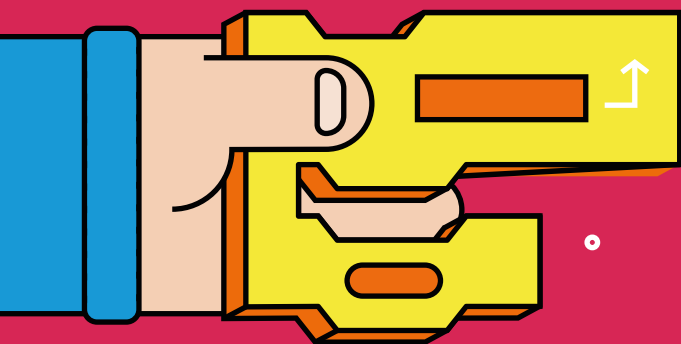


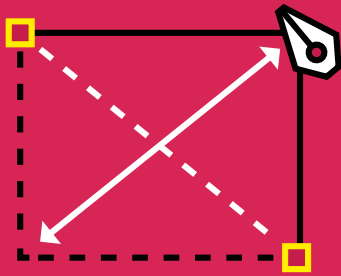


# PRACTICAL PROGRAMMING WITH RASPBERRY PI



Get to grips with coding and start making useful apps, games, and devices. By **Lucy Hattersley**



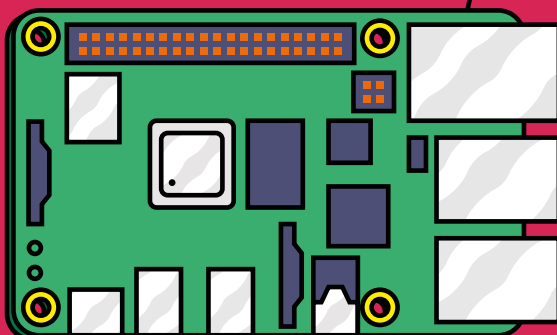
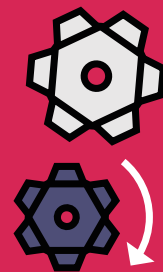


**W**e've had a huge amount of fun learning to code with Raspberry Pi, and for 2022 we're going to make it our mission to make things with code.

If you got a Raspberry Pi recently, then we're pretty sure learning to code is high up on your list. Or, maybe you already have a smattering of code and are looking for inspiration. Either way, this feature is here to help.

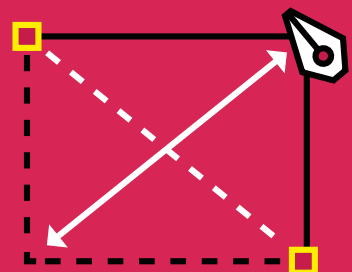
In this article, we're going to look at all the resources we found helpful when learning to code over the years, and explain how you can get coding quickly on Raspberry Pi. We'll cover the key coding concepts and tools, and the resources we found most useful. Finally, we'll brainstorm some great ideas for apps and games. And if you want to do things seriously, we'll show you where to go to get certificates and prove you are a coder.

We're convinced that 2022 is going to be a standout year! So, let's take our code and put it to good use. Let's make practical tools with our programming skills.





# SET UP YOUR ENVIRONMENT



Everything you need to start a coding journey

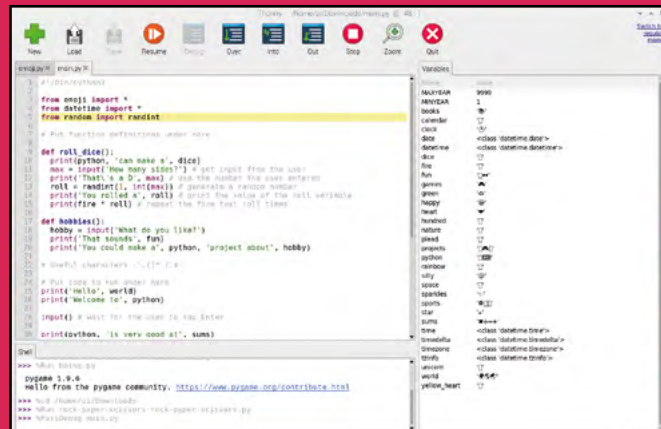


**C**ongratulations! Raspberry Pi OS is the best environment to learn coding you can find. So, you're off to a good start. Raspberry Pi OS is a custom build based on Debian Linux and it is packed with programming environments, useful tools, links to tutorials and projects, and online help.

In this feature, we're going to use the stock Raspberry Pi OS (installed via Imager, [magpi.cc/imager](http://magpi.cc/imager)). If you want help setting up Raspberry Pi and Raspberry Pi OS, take a look at our Get Started with Raspberry Pi feature in *The MagPi* 113 ([magpi.cc/113](http://magpi.cc/113)).

Click on the Raspberry Pi applications menu and choose Programming to reveal a bunch of pre-installed coding software. Most people program

▶ Thonny IDE highlights code in different colours, making it easier to read



## Load up code in Thonny

Raspberry Pi OS comes with a selection of games created alongside the book *Code the Classics* ([magpi.cc/codetheclassics](http://magpi.cc/codetheclassics)). These stylish games are all created in Python and are a good example of what you can make with code. They are found in the accessories menu under Games.

Let's look at the code used to make these games. Open up Thonny Python IDE and click Load. Choose Other Locations and click Computer and you'll find the programs under `usr/share/code-the-classics`. Load



up `boing.py` and you'll see the code for a Pong-style game in the main window. Click Run to run the code, or Debug to step through it. You can get a detailed overview of how each program works by reading *Code The Classics*.

using an IDE (integrated development environment) and Thonny Python IDE is your place to start. In Thonny, you will be coding in Python, which is the best language for beginners; other programming languages are available (more on those in a bit).

The advantage of using an IDE over a text editor lies in its built-in features that help you type, debug, and run code. Your text syntax is colour-coded, making it easier to read and spot errors.

If you want to move beyond Python to other programming languages, or are ready for a more detailed experience, then the IDE of choice is Microsoft's Visual Studio Code (or VS Code, [magpi.cc/vscode](http://magpi.cc/vscode)). Visual Studio Code is packed with advanced features, extensive language support, and extensions are used to provide additional functionality.

Since VS Code arrived on Raspberry Pi OS, we've started using it as our primary coding environment. Microsoft's Jim Bennett has a blog on getting Visual Studio Code up and running on Raspberry Pi ([magpi.cc/vscodeblog](http://magpi.cc/vscodeblog)).



# PICK A CODING LANGUAGE

## Speak the lingo by learning the right language

**T**here are many different programming languages you can choose from, and during your coding journey, you'll typically learn a few different languages. The good news is that most modern programming languages share similar concepts: variables, if-while loops, function definitions, objects, and so on. So, once you've learnt the first language, the second is much easier.

As well as core languages, there are tools of the trade that you will need: SQL databasing, networking, GUI implementation, and so on.

Which languages you should learn is an ever-shifting conversation, with new languages coming along and evolving every year. Having said that, there are a few solid choices that you should keep on your radar. If you're an absolute beginner, then avoid the chatter and go straight to Python.

### Java

Many desktop programs are built in Java. So it's worth knowing, but don't start with it. For all its usefulness, Java is wordy and complex with a lot of complexities that trip up newcomers. The good news is that there is a great community; the bad news is that you'll need it.

Java was the primary language for Android app development and has widespread use throughout the tech industry. So it's certainly a good tool to have in your toolbox.

- + Useful, great library of extensions, good for app development**
- Cranky, convoluted**
- @ [magpi.cc/headfirstjava](http://magpi.cc/headfirstjava)**

### Python

Python is the de-facto standard programming language for learners. And with good reason. Its modern syntax makes code stylish and easy to read and understand; Python is an incredibly powerful language and is used by data scientists and web developers, so it's not just a stepping stone. It's used by Spotify, Facebook and YouTube. You can start small: creating scripts and programs to run on your computer. Python is very popular so there's huge support from websites, courses, and other coders, and it has been adopted throughout the industry.

- + Easy, powerful, packed with tutorials, and useful**
- So good you might stay**
- @ [magpi.cc/pythonintro](http://magpi.cc/pythonintro)**

### C & C++

The venerable grandparent of coding languages. C is a superb language and we think everybody should learn C at some point. Most of

Linux is built in C. Beyond C lies C++, an extension that packs in modern features such as object-oriented programming support. C is (in our opinion) not a great place to start out. But it's certainly not a bad place to visit during

- + Powerful, great for desktop development**
- Complex**
- @ [magpi.cc/cgui](http://magpi.cc/cgui)**

your coding journey, and you may (like many programmers) end up deciding it's where you want to settle down.

### HTML & CSS

HTML (Hypertext Markup Language) and CSS (Cascading Style Sheets) are the two languages at the heart of websites. You don't typically use these tools to create programs. That said, both are important side-skills that you should acquire. Alongside learning to program, it's a good idea to learn how to build websites. You can also combine this with some server skills, by hosting your website using software such as Apache ([magpi.cc/apache](http://magpi.cc/apache)).

- Vital to make websites; important +**
- Not a full programming language -**
- @ [magpi.cc/webdevbasics](http://magpi.cc/webdevbasics)**

### JavaScript

JavaScript is core to the web and is (according to StackOverflow, [insights.stackoverflow.com](http://insights.stackoverflow.com)) the most popular language in use today. While JavaScript is useful for adding power to your website, it's more limited than Python, Java or C. JavaScript is a useful skill to have alongside your HTML and CSS, so take a look alongside learning web skills.

- Adds power to website, useful skill to have +**
- Fairly limited -**
- @ [magpi.cc/introjavascript](http://magpi.cc/introjavascript) / [magpi.cc/odinproject](http://magpi.cc/odinproject)**

# CORE CODING CONCEPTS

The things that dreams are made of

**Y**our computer is set up, your IDE is open, and it's time to learn core coding concepts. The good news is that you don't need to learn that much to get started! It is very easy to fall down a rabbit hole of understanding though. So be careful to learn what you need and get back on track.

Here is a brief overview of the key concepts you will need to learn, read through the lot to get an overview then start looking to learn more about each area. Each concept has a recommended resource for learning more.



## Syntax

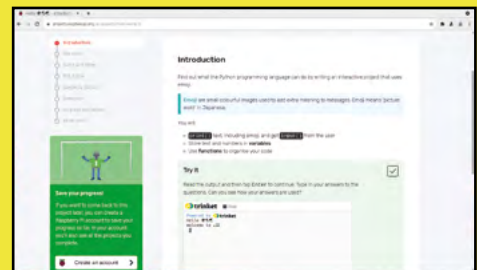
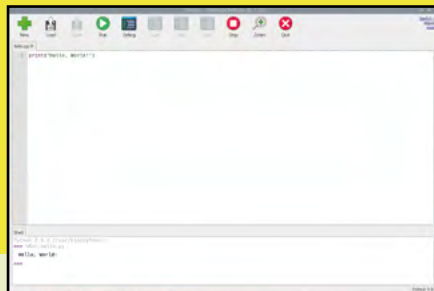
It's traditional to start any programming language by getting it to print out "Hello World!". Open Thonny Python IDE, click New, and enter this line of text the main window:

```
print("Hello, World!")
```

Click Run and Thonny will prompt you to save the file. Call it "hello.py" and it will run. You will see: "Hello, World!" in the Shell.

You're off to a good start. Now you need to know about syntax. What does the **print** command do? And why is it **print** and not **Print**; why is "Hello, World!" in quotes? And what's with those brackets? These are conventions that change from language to language (although many are the same in each language).

Head over to the Python tutorial at W3Schools and complete its Syntax section ([magpi.cc/pythonsyntax](http://magpi.cc/pythonsyntax)). Any encounter with a new language should start with a fresher course on its syntax.



## Variables and data

Once you've practised typing and running programs, the first thing you need to learn about are variables. These are containers for values: numbers and text strings, and so on.

```
foo = 32
bar = "Jill"
```

When you write this, Python creates two variables: **foo** contains the integer 32; **bar** contains a string of characters making up the name "Jill". What's with **foo** and **bar**? You will see these during tutorials (or sometimes you'll see **x** and **y**). These variables can be anything, **foo** and **bar** are rumoured to relate to a slang term, but they're just used as placeholders. Variables can be any word you like, and typically the name relates to the contents, like **first\_name** or **age**. Each language has its own conventions, but Python variables should:

- Only contain lower-case characters
- Use underscores instead of spaces

For a good grounding in variables, check out the Raspberry Pi Foundation's Introduction to Python ([magpi.cc/pythonintro](http://magpi.cc/pythonintro)).

## Data structure

Now that you are making variables and getting to grips with basic syntax, you'll start thinking of variables as the data that make up your program. You'll begin bunching data together into different groups. These lists of data collate a bunch of variables into a single space, which is itself a variable.

By far the most common is a straightforward list, which is a bunch of (typically) similar items. So, you might have three strings called Jack, John, and Jill and a list variable called **people**. Python has six different data types, but you only need to learn lists, sets, and dictionaries.

- **LISTS.** A basic sequence of any type of items (strings, integers, etc) that you can add and remove items to at any point. This is known as "mutable". Lists are common and are easy to spot in Python because they are inside square brackets and items are separated by commas, e.g.:

```
names = ["Jack", "John", "Jill"]
```

- **TUPLES.** Same as lists but once created you don't add and remove items to them. Tuples are written in Python with round brackets:

```
names = ("Jack", "John", "Jill")
```

- **SETS.** These are a bit rarer and harder to comprehend. Sets store multiple different

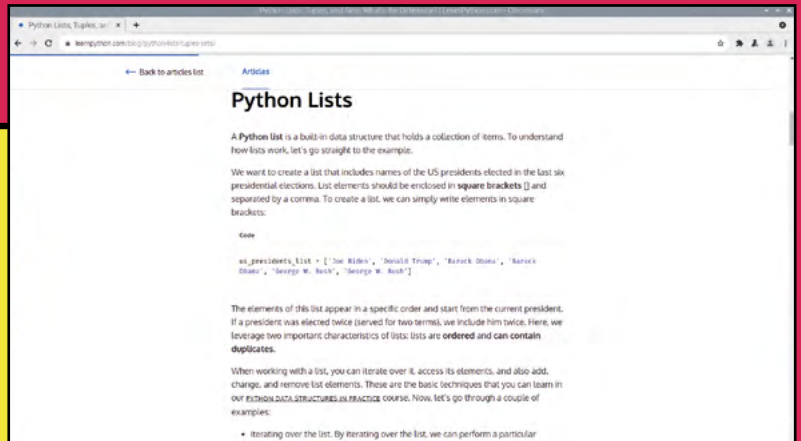
items into a single unordered list. Each item has to be different, so you couldn't have two Jills in your list for example. Spotted by the use of curly braces:

```
names = {"Jack", "John", "Jill"}
```

- **DICTIONARIES.** Harder to get your head around yet useful. Dictionaries store values in key:value pairs. Each item has a key and a value. Typically you use this to get the value by providing the keys. Spotted by the use of curly braces and colons separating the key/value pairs. In this example, our names are the key, and the values are the person's age:

```
names = {"Jack": 32, "Jill": 29, "John": 45"}
```

Getting your head around the various data structures can be challenging. It is best to learn lists, tuples, and sets and leave dictionaries for later. Learn Python has a good page to help you get started ([magpi.cc/learnpythonlists](http://magpi.cc/learnpythonlists)).



## TIP! PEP 8

PEP 8 is the Style Guide for Python code. If you are ever wondering if a variable should be capitalised or how many spaces to use, consult the style guide. Bookmark this!

> [magpi.cc/pep8](http://magpi.cc/pep8)

## Flow

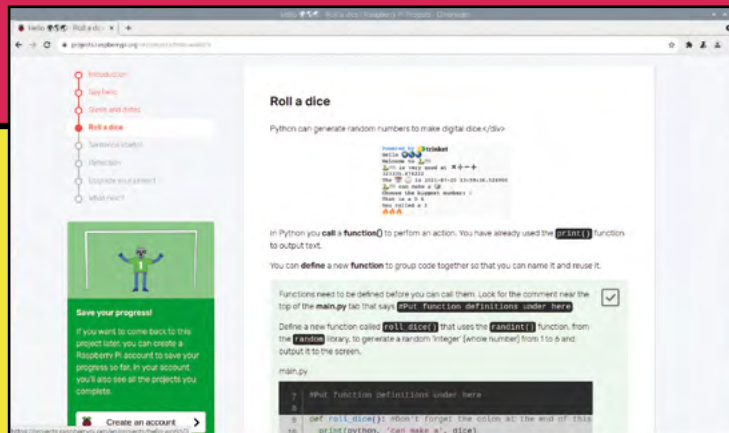
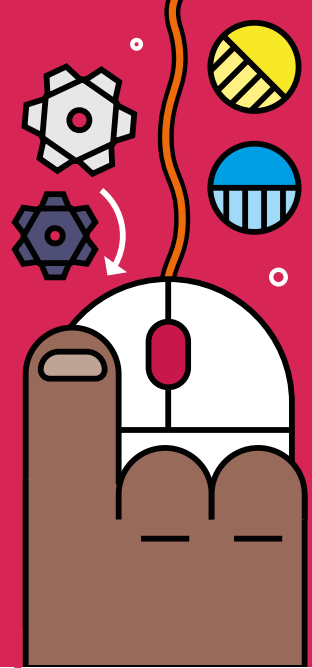
After variables and lists, it's time to start learning about program flow. This is the first big departure for a language like Python from a markup language like HTML. Flow enables you to make decisions in a program using conditional statements (in Python these are **if**, **elif**, and **else**).

You can perform the same action multiple times, known as "looping", using **for** and **while** statements.

To learn these, we recommend you head to the Raspberry Pi Foundation's Introduction to Python ([magpi.cc/pythonintro](http://magpi.cc/pythonintro)).



# CORE CODING CONCEPTS



## Functions

Now that you can make variables and control flow, it's time to learn about functions. Programming languages come with all kinds of functions, such as `print()` and `type()`. In Python, you can spot them as single words followed by brackets. A list of Python's built-in functions can be found here: [magpi.cc/pythonfunctions](http://magpi.cc/pythonfunctions).

The real power of functions is to create your own using a piece of code called a "function definition", which you can spot as `def` in Python code. Function definitions are like copy-and-paste for code. Instead of writing out identical code several times, you create it once, inside a function definition and then use the function in your program.

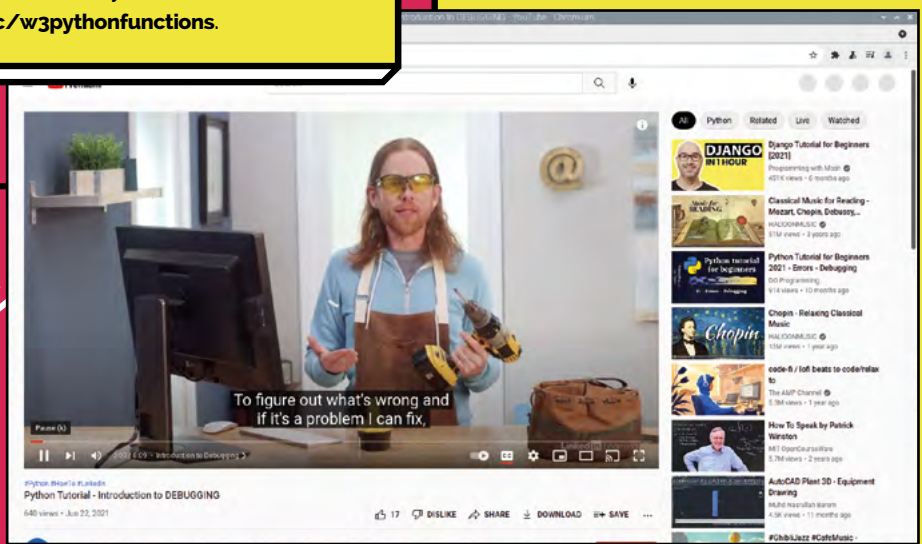
Functions are a vital part of programming and it's great to roll your own. W3Schools has a good tutorial on Python Functions [magpi.cc/w3pythonfunctions](http://magpi.cc/w3pythonfunctions).

“ We created a guide to object-orientated programming in *The MagPi* issue 54 ”

## Debugging

This is one thing you'll have no shortage of practice in. Every program you write will need debugging at some point. Because it is something you will spend so much time doing, it's worth learning how to do it better.

Sasha Vodnik has created a great video tutorial on debugging on LinkedIn Learning ([magpi.cc/debugging](http://magpi.cc/debugging)) as part of Programming Foundations: Beyond the Fundamentals. After that, freeCodeCamp has detailed documentation on improving your debugging skills ([magpi.cc/debuggingskills](http://magpi.cc/debuggingskills)).



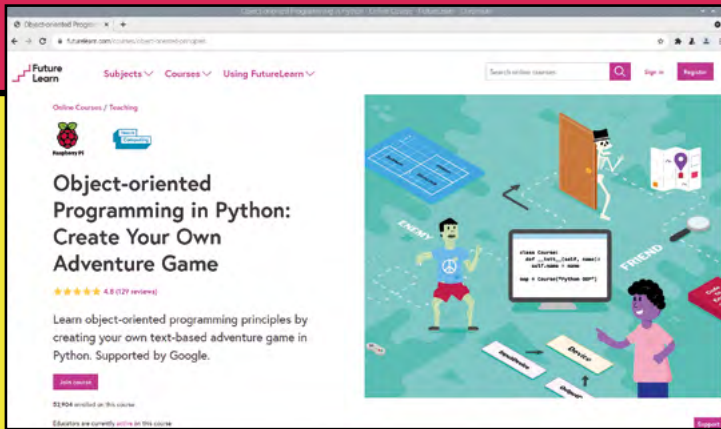
## TIP! TABS OR SPACES

A key aspect of code is indentation. These are the spaces at the start of a line. In Python, you indent with blocks of four spaces and never use the tab key.

> [magpi.cc/pythonindentation](http://magpi.cc/pythonindentation)







## Object-orientated programming

Once you have got to grips with variables and functions, you can start to bring it all together with object-orientated programming (OOP). This is a complex coding concept that groups variables and functions together into "classes" and uses them to create objects. You then access the functions, now referred to as "methods" using dot notation. Confused? You probably will be. At least at first.

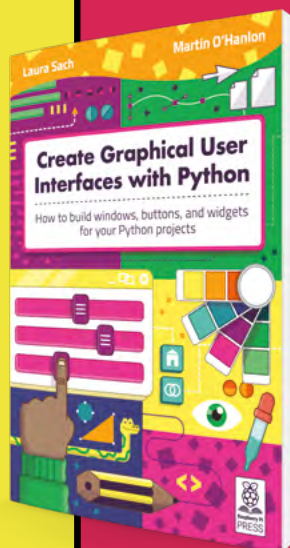
Learning OOP is vital, although it's a big subject and be careful not to fall too deep down a rabbit hole. You only need the basics: how to import modules and use dot notation to access methods. This will enable you to use other folks' code in your programs, and access important APIs (application programming interfaces).

We created a guide to object-orientated programming in *The MagPi* issue 54 ([magpi.cc/54](http://magpi.cc/54)). For a more hands-on course, check out the Raspberry Pi Foundation and FutureLearn's course: 'Object-orientated Programming in Python: Create Your Own Adventure Game' ([magpi.cc/futurelearnoop](http://magpi.cc/futurelearnoop)).

## GUI

Even after learning all these skills, you will still mainly be working in text documents and the command line. This is a powerful place for a programmer to be, but the command line is not where your average non-coder lives.

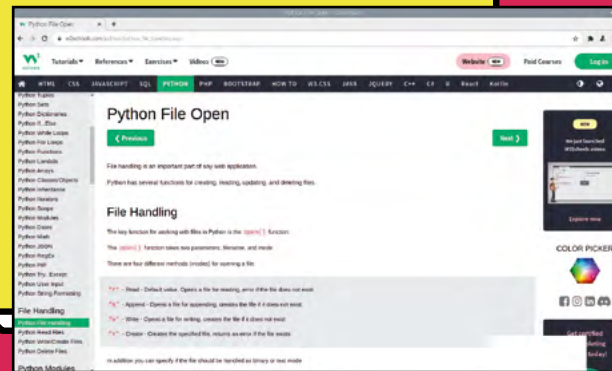
To make working programs, you'll need to implement GUIs (graphical user interfaces). Don't worry, other people have done all the heavy lifting and there are several APIs for different operating systems. We've got your back here with our book *Create Graphical User Interfaces with Python* ([magpi.cc/gui](http://magpi.cc/gui)).



## File handling

At some point, you'll need to address saving data. Python manages all this data automatically, but when the program closes, everything is cleaned up and thrown away.

In order to save a program, and come back to it later, you'll need to learn about file handling. You'll need to save data in files. Also, many programs rely on handling data found in other files (text documents and images and so on). W3Schools has a good course on File Handling ([magpi.cc/pythonfilehandling](http://magpi.cc/pythonfilehandling)).



## TRAINING WEBSITES

Here are some websites that carry full coding courses

FutureLearn

> [magpi.cc/futurelearn](http://magpi.cc/futurelearn)

freeCodeCamp

> [magpi.cc/freecodecamp](http://magpi.cc/freecodecamp)

Raspberry Pi Projects

> [magpi.cc/projects](http://magpi.cc/projects)

Codecademy

> [magpi.cc/codecademy](http://magpi.cc/codecademy)

W3Schools

> [magpi.cc/w3schools](http://magpi.cc/w3schools)

Khan Academy

> [magpi.cc/khan](http://magpi.cc/khan)

MIT OpenSource

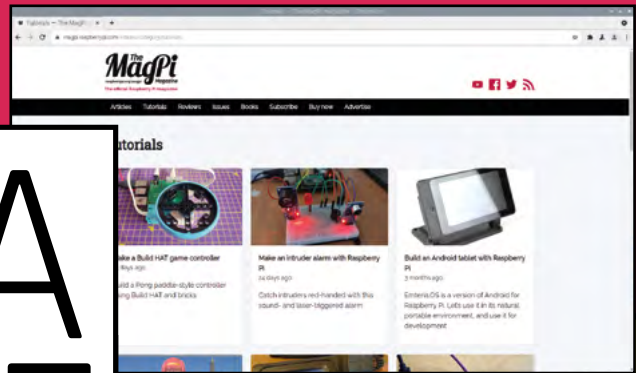
> [magpi.cc/mitopen](http://magpi.cc/mitopen)

Coursera

> [magpi.cc/coursera](http://magpi.cc/coursera)

Udemy

> [magpi.cc/udemy](http://magpi.cc/udemy)



# PICK A PROJECT

## Start programming with purpose



**T**he best way to learn and improve your coding abilities is to start a project. You can learn a lot from fixing problems in projects and building something from the ground up. Plus, it's simply more fun to build something you're personally interested in.

What you pick is up to you. It depends on what you are interested in and there are lots of lots of ideas out there. We advise you to pick up a pen and start writing down ideas, after you get past the first few your later ideas will start to become interesting.

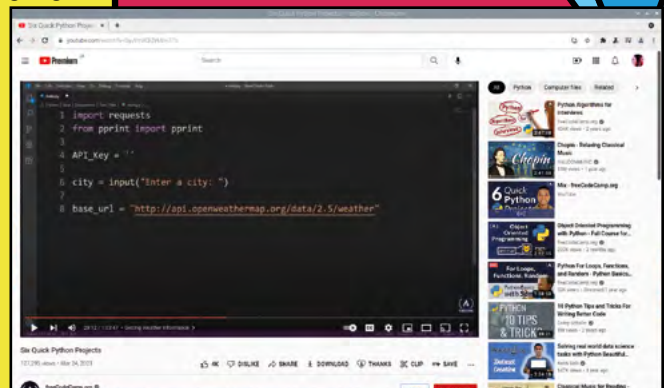
Here are some areas to help you get started...

### Build a full-stack website

Everybody uses the web and many of us have had some experience of building websites. So, this is a great place to start.

Of course, because you're now programming as well as web designing, you can take things much further and build a server setup and host your website. The freeCodeCamp course Responsive Web Design is a good place to boost your HTML & CSS skills ([magpi.cc/responsiveweb](http://magpi.cc/responsiveweb)). Udemy's Web Dev Bootcamp ([magpi.cc/webdevbootcamp](http://magpi.cc/webdevbootcamp)) takes things a step further with web applications and database integration.

Build a web server or even a personal web browser. Building a web scraping program is a fun coding project that teaches you how to crawl websites. And you can also create websites that integrate APIs, such as a weather site that outputs the weather in a specific location. freeCodeCamp has a video with six such web projects to help you get started ([magpi.cc/6quickpython](http://magpi.cc/6quickpython)).



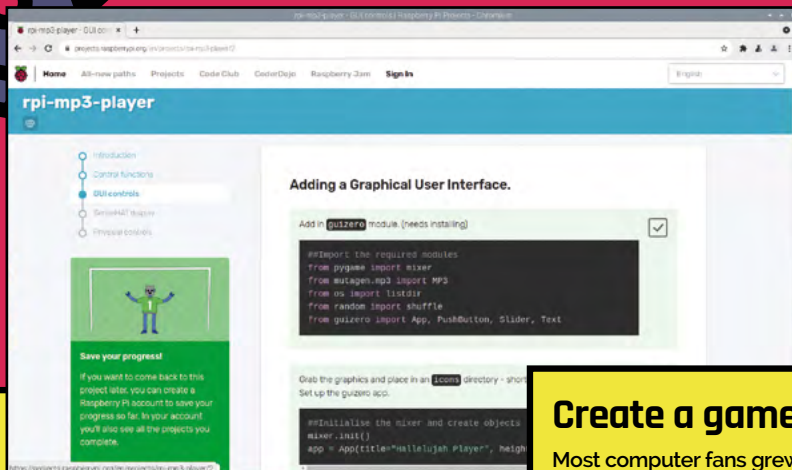
### Make something physical

This is one area where we have plenty of suggestions. Every month inside this magazine you'll find projects and tutorials that combine the electronic hardware of Raspberry Pi with the real world. Raspberry Pi is ideal for making real-world items.

Head to our website and click on Tutorials ([magpi.cc/tutorials](http://magpi.cc/tutorials)). At this moment, there are guides for building an Android tablet, an intruder alarm, a digital do-not-disturb sign, and a Pomodoro timer. Plus, hundreds more ideas. How about picking up the latest copy of the *Raspberry Pi Handbook 2022* ([magpi.cc/handbook2022](http://magpi.cc/handbook2022))? It has over 200 pages packed with projects for you to try out at home.

If you want help getting started with electronics, check out Mark Vanstone's Get Started with Electronics guide ([magpi.cc/electronics](http://magpi.cc/electronics)), which is packed with information on prototyping circuits with breadboards, and adding batteries, buttons, switches, speakers, and all manner of widgets to your project.





## Build an application

Making websites is fun, but many folks learn programming to make standalone applications, either for the desktop or as apps for mobile devices.

Both are eminently possible with Raspberry Pi. So much so, that the real challenge is picking a program project to develop. In the process of learning to code, you'll build many command-line applications, but integrating a GUI will help you transition to making a full program ([magpi.cc/gui](http://magpi.cc/gui)). Along the way *Create Graphical User Interfaces with Python* teaches you how to create a simple paint drawing application and an animated GIF creator.

Beyond the guizero library, you will find many useful Python libraries. Guizero is built on top of Tkinter ([magpi.cc/tkinter](http://magpi.cc/tkinter)), and for the 20% you can't achieve in guizero, turn to Tkinter. Beyond that, there's PyQt5 ([magpi.cc/pyqt5](http://magpi.cc/pyqt5)) which provides further bindings for features such as location, NFC, and Bluetooth and extends development up to platforms including mobile apps.

The big thing is picking an idea. Get a pen and paper and keep brainstorming until you find something that appeals. You could create a music player, news content aggregator, expense tracker, to-do list app, imager editor, or just about anything you want.

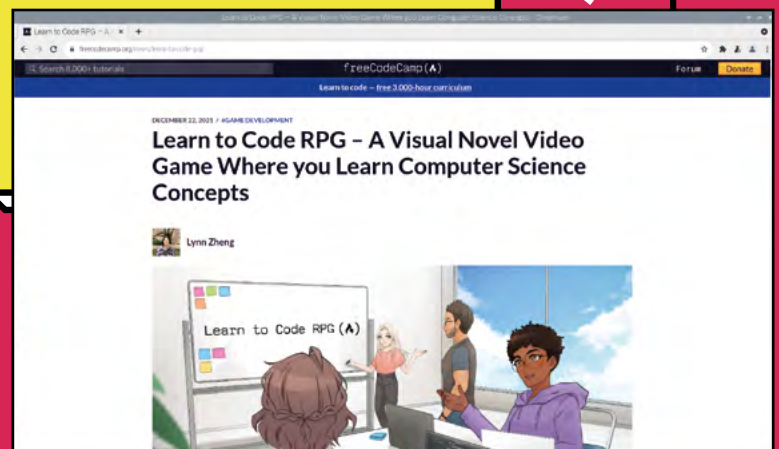
“ Making a game is a good way to practise coding skills with more freedom of expression “

## Create a game

Most computer fans grew up with video games in some form or another, and making a game is a good way to practise coding skills with more freedom of expression. The indie video game market has never been more vibrant, so a good story could catch the public eye.

If you have a memory of 1980s video gaming, then *Code the Classics* is the place to start ([magpi.cc/codetheclassics](http://magpi.cc/codetheclassics)). It features recreations of classic-style video games, like Pong and Pac-Man, but coded with Pygame Zero ([magpi.cc/pygamezero](http://magpi.cc/pygamezero)). Our sister title Wireframe ([wfmag.cc](http://wfmag.cc)) has a monthly Source Code section that features video game development.

Learn to Code RPG is a new open-source game that features 600+ computer science quiz questions. If you want to make a similar RPG of your own then take a look at Mark Vanstone's Make an Adventure Game with Ren'Py ([magpi.cc/makeadventure](http://magpi.cc/makeadventure)) or KG Orphanides' Make Your Own Video Games feature in *The MagPi* magazine issue #73 ([magpi.cc/73](http://magpi.cc/73)), which takes you through the process of creating games and distributing them. [M](#)



## PROVE YOUR SKILLS

Want to show what you've got? Check out these code affirming websites

HackerRank  
> [magpi.cc/hackerrank](http://magpi.cc/hackerrank)

Codewars  
> [magpi.cc/codewars](http://magpi.cc/codewars)

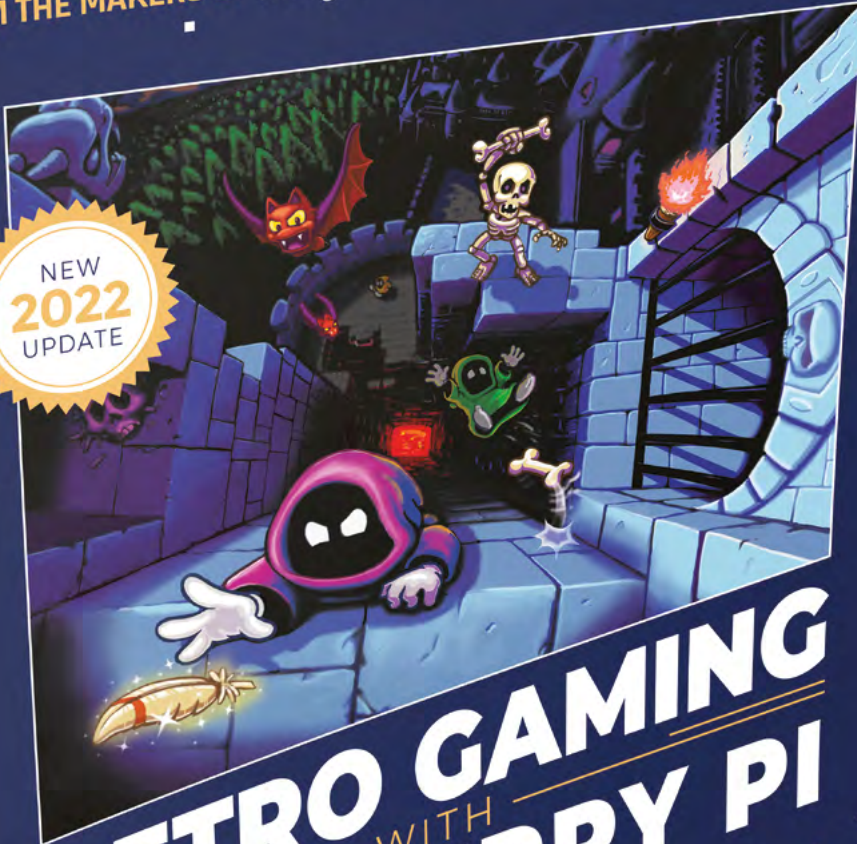
LinkedIn Learning  
> [magpi.cc/linkedinlearning](http://magpi.cc/linkedinlearning)

edX  
> [magpi.cc/edx](http://magpi.cc/edx)

FutureLearn  
> [magpi.cc/futurelearn](http://magpi.cc/futurelearn)

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NEW  
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**PLAY  
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# RETRO GAMING WITH RASPBERRY PI 2ND EDITION

**164 PAGES** OF  
VIDEO GAME PROJECTS



# RETRO GAMING

WITH

# RASPBERRY PI

2<sup>ND</sup> EDITION

***Retro Gaming with Raspberry Pi*** shows you how to set up a Raspberry Pi to play classic games. Build your own games console or full-size arcade cabinet, install emulation software and download classic arcade games with our step-by-step guides. Want to make games? Learn how to code your own with Python and Pygame Zero.

- ***Set up Raspberry Pi for retro gaming***
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- ***Learn to code your own retro-style games***
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BUY ONLINE: [magpi.cc/store](https://magpi.cc/store)

# Create your own teletext service



Feeling retro? Turn any Raspberry Pi into a teletext broadcast service, make your own pages, and even generate content from the web

WRITER

**PJ Evans**

PJ is a writer, developer and tinkerer who enjoys retro tech. He will beat Bamboozle one day.

@mrpjevans

## You'll Need

- ▶ TV with teletext decoder and composite input
- ▶ Composite cable
- ▶ Raspberry Pi Zero 2 W

**T**he web? A bit overrated if you ask us. What was wrong with the beautiful teletext pages that came into our homes in the 1980s?

The latest news, pop gossip, holiday bargains, and of course Digitiser. Did you think teletext was gone forever? Well, not only have a small group of dedicated archivists been saving and transcribing old teletext signals, but they have produced Raspberry Pi software that can generate the signals required to deliver those pages to your TV. Teletext is back! Here, we'll show you how to get a teletext service running and even create your own pages.

## 01 Get your kit together

We're basing this project on our Raspberry Pi Zero 2 W build from issue 113 ([magpi.cc/113](http://magpi.cc/113)) to which we added composite video output last month. The computing requirement of the project is quite low, so a Zero-class device is perfect and



- ▶ That 'noise' at the top of the screen? That's the encoded teletext signal that the TV turns into information pages

cheap too. That said, this tutorial will work with any Raspberry Pi with a composite video signal out. You'll also need a TV with a built-in teletext decoder. These are hard to find new but are plentiful second hand. You can normally see from the remote control whether it has the capability. Older CRT televisions will also give a truly retro feel to the project.

## 02 Choose your operating system

Teletext works by adding encoded data to the top few lines of the PAL video signal, which is why we cannot use HDMI for this project. The software we are going to use creates this encoded information, which the TV will detect as a teletext signal. This is done at the frame buffer level, which means a graphical user interface, such as Raspberry Pi Desktop, is not required. So, it's up to you. You can install either full Raspberry Pi OS or the Lite version, which is preferable if you're going to be displaying teletext all the time.

## 03 Preparation

Once your OS is installed, open a command line, or SSH into your Raspberry Pi and before continuing, make sure everything is up-to-date with `sudo apt -y update && sudo apt -y upgrade`. If you are using Bullseye, the latest major release of Raspberry Pi OS, then Raspberry Pi requires a little configuration change. Open the main configuration file as follows:

```
sudo nano /boot/config.txt
```



Near the bottom of the file, look for a line that reads:

```
dtoverlay=vc4-kms-v3d
```

Comment it out so it looks like this:

```
#dtoverlay=vc4-kms-v3d
```

Now save and exit (**CTRL+X** followed by **Y**). Reboot before continuing.

## 04 Check video output

Make sure your composite output is working from boot. Disconnect any HDMI cable you have been using, and make sure you have a working display. If not, run `sudo raspi-config` and enable composite output in Display Options > Composite. Also, for the teletext software to work, the TV has to be able to 'see' the encoded data at the top of the screen. If you have configured overscan

compensation in `raspi-config` then it will not be able to do so. Double-check Display Options > Underscan is set to 'No'. You may need to reboot.

## 05 Install VBIT2

Time for the magic part. The software that generates the teletext signal for us is called VBIT2 by Peter Kwan, with the help of `raspi-teletext` by Alistair Buxton. Thankfully, the community has made the installation of this collection of software a piece of digital cake. To install VBIT2, `raspi-teletext`, and all its dependencies, run this from the command line:

```
curl https://raw.githubusercontent.com/peterkvt80/vbit2/master/getvbit2 | bash
```

This will also install a configuration utility, similar to `raspi-config`, that will help you get set up quickly and easily. After downloading everything it needs, it will go straight into the configuration menu.

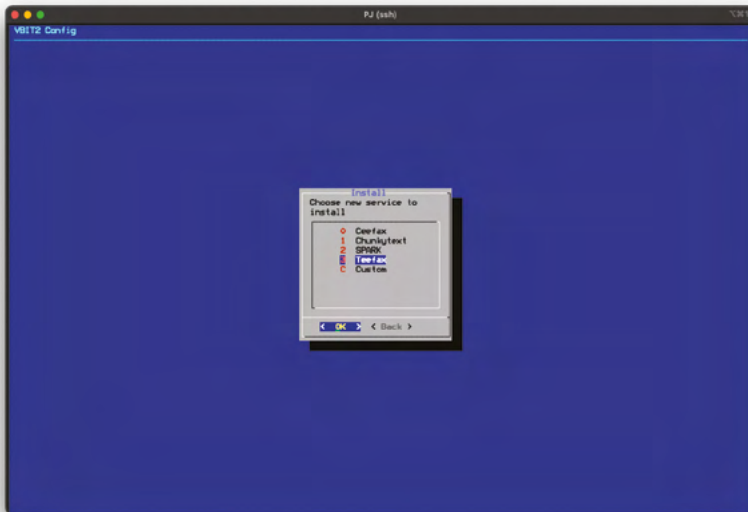
## Top Tip

Get interactive

VBIT2 comes with a powerful interface for updating pages in real-time. See [magpi.cc/vbitzci](https://magpi.cc/vbitzci) for more information.



▲ Creating 'blockart' is a popular pastime amongst teletext fans



▲ VBIT2 comes packaged with a few different services, including Teefax, a community-led collection of pages

## 06 Configuration

You should now see a rather lonely 'Install service' menu item. That's because VBIT2 cannot run until it's got some content to work with. Tap **ENTER** to select and then review the choices. Out-of-the-box, VBIT2 offers a selection of teletext services. Some are community projects; others are archives of commercial services such as Ceefax, the BBC teletext service. We chose 'Teefax'. If you get an error at this point, try another option and then select 'Update services'. When you return to the main menu, a few new items will have appeared. Select 'Options' and then both items to make sure you keep up to date and start the service on boot.

## 07 Start and test

VBIT2 is now ready to start. From the configuration menu, select 'Start VBIT2' and then exit the utility. At this point, you should be dropped back to the command prompt. Try pressing the teletext button on your remote control. Hopefully, you'll get a colourful home page (page 100). If it didn't work, check whether you



can see the encoded lines at the top of the screen. If so, you'll need to change the underscan options in `raspi-config` (see Step 4) and try again. If all is well, enjoy moving from page to page by entering prompted page numbers.

## 08 Try a different service

As mentioned earlier, you can switch between services to vary your output. At any time, run `vbit-config` from the command line and change the way VBIT2 behaves. You can also 'Update services' which will check for newer collections of pages and updates to existing ones. Some are art collections, while others are collections of popular pages from the past (such as the writings of Mr Biffo and the Bamboozle quiz games). Others are snapshots of an entire service in a moment of time. Some even dynamically update from news feeds. Just 'Select service' to change what is being broadcast in real time.

## 09 Add some music

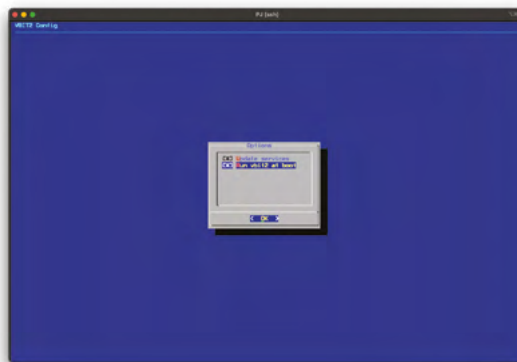
Giles Booth ([magpi.cc/blogmywiki](http://magpi.cc/blogmywiki)) was looking to recreate the late-night feel of Ceefax pages cycling on TV with groovy background music. If you've got sound capability on your Raspberry Pi computer, let's add some tunes. From the command line, run the following:

```
sudo apt install mpc mpd
mpc add http://icecast.radiofrance.fr/fip-midfi.mp3
mpc play 1
```

Now add audio cabling from your Raspberry Pi to your TV's A/V input for relaxing sounds to accompany your teletext. You can choose any music you like of course. Be warned, the music will restart on boot.

## 10 Add Twitter!

Tweets as teletext pages. What's not to like? Mark Pentler has developed an additional service for VBIT2 that will generate pages from your Twitter feed. This Python script will run in the



◀ If you're wanting to create an installation for display, make sure you start VBIT2 on boot

background and generate teletext pages using the TTI format supported by VBIT2. It requires a bit of setup, including creating API keys for your Twitter account. Luckily, it's all very well detailed on the project's GitHub page ([magpi.cc/teletexttwitter](http://magpi.cc/teletexttwitter)). Mark himself describes the project as 'useless', but we think it's a great bit of fun.

## 11 Create your own service

So, you've trawled Ceefax as it was on the 14 August 1987, played a few games, and found out that the amazing holiday offer has now expired. Never mind, why not start creating your own teletext service? VBIT2 uses the TTI format for storing pages. This is a simple text format, but there's a lot of commands. To make your own service, you'll need to create a git repo that VBIT2 can clone and install. Have a look at the `~/teletext-services/` directory and [magpi.cc/vbit2](http://magpi.cc/vbit2) for more information.

## 12 What's next?

This is one of those projects which is done because it can be. That said, Teletext's blocky format can be very eye-catching with its bright primary colours, and it could well serve as an attractive retro display for a shop window or makerspace. The art community is thriving and the ability of VBIT2 to live-update pages via a network interface means it can be hooked up to anything on the internet and turned into a cool display. Plus, there's always the benefit of upcycling an old, unloved CRT box. So, what will you do with it? [!!!](#)

## Top Tips

Block party!

Check out [teletextart.co.uk](http://teletextart.co.uk) for lots of info on creating teletext art and their regular competitions.

PAL Only

This project only works with TVs that understand the PAL (UK) video signal.

# Explore the sensory world: Make a plant monitor



**Phil King**

Long-time contributor to *The MagPi*, Phil is a freelance writer and editor with a focus on technology.

@philkingeditor

## You'll Need

- Moisture sensor [magpi.cc/moisturesensor](http://magpi.cc/moisturesensor)
- Liquid level sensor [magpi.cc/liquidlevel](http://magpi.cc/liquidlevel)
- MCP3008 ADC [magpi.cc/mcp3008](http://magpi.cc/mcp3008)
- Jumper wires

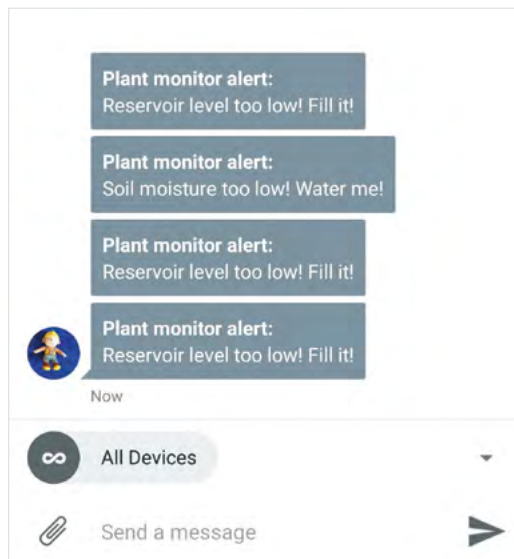
- Pushbullet notifications can be sent to a smartphone or the Chrome browser on another computer

Check the moisture level of your plant's soil and send an alert if it's too dry

In this series, we are exploring some of the most commonly available sensors and their use cases. Previously, we have built a couple of alarms – one for fire and gas safety, the other for detecting intruders – and a basic weather station.

In the latter, we made use of an ADC to read the analogue output of a UV sensor. This time we'll be using an ADC to check the value from a moisture sensor placed in a plant pot. We'll also add a liquid level sensor to check the water level in a reservoir (saucer) holding the plant pot.

If the soil or water reservoir is dry, the monitor will send us a Pushbullet alert telling us to water the plant to keep it healthy.



## 01 Connect the ADC

Since the two sensors we'll be using for the plant monitor both output their readings as an analogue signal, we'll need to convert that to a digital value using an ADC (analogue-to-digital converter) chip. As before, we're using the MCP3008 ADC, which has eight input channels.

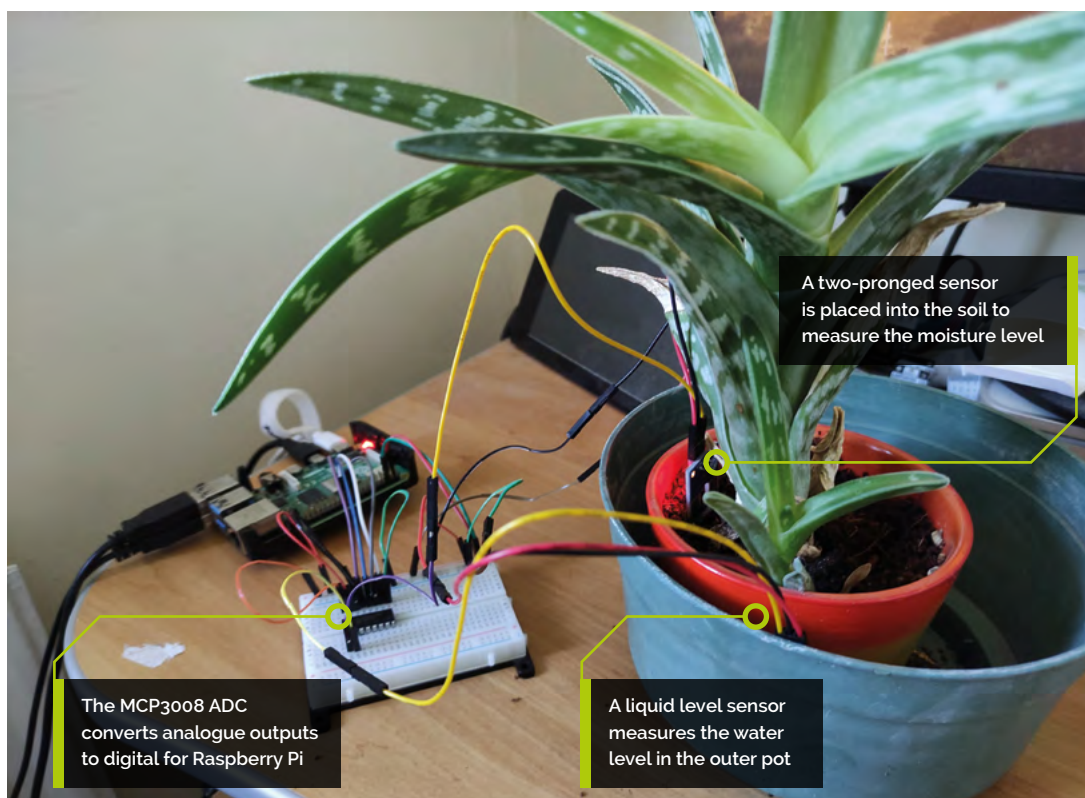
As the ADC chip makes use of the SPI interface, we'll need to enable SPI in the Raspberry Pi Configuration tool. It's also best to enable full SPI support in Python 3. To do so, open a Terminal window and enter:

```
sudo apt-get install python3-spidev
```

Now, with the power to Raspberry Pi turned off, it's time to connect our ADC – you may already have it set up from the last instalment in this series. Place the MCP3008 in the middle of the breadboard, straddling its central groove. Make sure it's the correct way round, as shown in the **Figure 1** wiring diagram, with the top of writing on top of the ADC nearest Raspberry Pi.

Now connect the jumper wires as in **Figure 1**. Two go to the '+' breadboard power rail, connected to a 3V3 pin; two others are connected to a GND pin via the '-' rail. The four middle legs of the ADC are connected to the SPI interface on Raspberry Pi: GPIO pins 8 (CE0), 10 (MOSI), 9 (MISO), and 11 (SCLK).

Double-check they are all connected to the correct pins otherwise it won't work properly and you may even damage the ADC chip or your Raspberry Pi.



## Top Tip

### Digital sensor

We've used a moisture sensor with an analogue output, but some offer a digital output, such as this: [magpi.cc/soilsensor](https://magpi.cc/soilsensor).

“ Double-check they are all connected to the correct pins otherwise it won't work properly ”

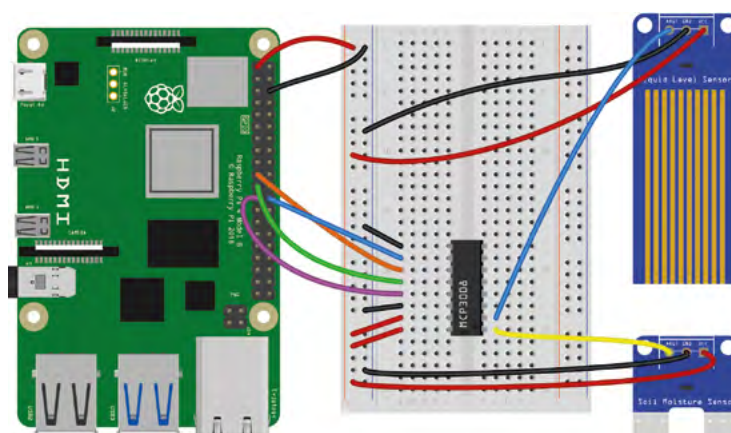
## 02 Connect the moisture sensor

With the ADC wired up correctly to Raspberry Pi, we can now add our moisture sensor to the setup. We're using one from the Waveshare Sensors Pack available in the UK from The Pi Hut ([magpi.cc/wavesensors](https://magpi.cc/wavesensors)). The sensor is available separately, too, and there are also alternative soil moisture sensors you could use.

As in **Figure 1**, we connect the sensor's VCC pin to 3.3V via the breadboard power rail, and its GND pin to GND on Raspberry Pi via the breadboard ground rail.

Since we want to place the sensor in a plant pot, we're using long female-to-female jumper wires (as supplied in the Waveshare Sensors Pack) to extend the distance from our Raspberry Pi and breadboard.

Finally, we connect the sensor's AOUT (analogue out) pin to the MCP3008's channel 0 pin, as shown in **Figure 1**. You could wire it to any of the eight channels on that side, but we're using this one in our code.



## 03 Moisture level test

Let's create a simple program to test the sensor. In the `moisture_test.py` listing, we're using the GPIO Zero library as it has a handy `MCP3008` class, which we import at the top. We assign the moisture variable to the MCP3008's channel 0 to read the connected sensor's analogue output.

In a `while True:` loop, we multiply the digitally converted sensor output (which ranges from 0 to 1) by the 3300 maximum voltage (in microvolts) to get an accurate reading. In our `print` statement, the `%-3.2f` format parameter sets each output to a minimum three digits including two decimal

▲ **Figure 1** The wiring diagram for the plant monitor, including the liquid level sensor, soil moisture sensor, and ADC

## Top Tip

### Add a display

To see at a glance how your plant is doing, you could add a mini LCD display to your Raspberry Pi to show the sensor readings.

places. You can alter this to your preference. We add the `end = "\r"` parameter so that the message is always printed on the same line.

If the sensor is not placed in anything, the reading should be very low (ours was 1.61 mV). To test it, try holding it in your hand and the reading should rise to around 200 mV or more, depending on how damp your fingers are – they are acting as a conductor between the sensor's two prongs so that the current passes through from one to the other. The damper the material, the more conductive it is. This also applies to the soil in a plant pot.

If you dampen your fingers and try the test again, you should see the reading rise to over 800 mV. Be very careful not to get any of the electronics wet, though.

## 04 Plant pot moisture

Now we know that the moisture sensor is working correctly, let's try placing it in a plant pot. We put ours in fairly dry soil to take a reference

## moisture\_test.py

> Language: Python 3

```
001. from gpiozero import MCP3008
002.
003. moisture = MCP3008(0)
004.
005. while True:
006.     print("Moisture: %-3.2f mV   " % (
        3300 * moisture.value), end = "\r")
```

## liquid\_test.py

> Language: Python 3

```
001. from gpiozero import MCP3008
002.
003. liquid = MCP3008(1)
004.
005. while True:
006.     print("Liquid level: %-3.2f mV   " % (
        3300 * liquid.value), end = "\r")
```

reading. We will then be able to use this to trigger an alert when the soil becomes too dry and the plant needs watering.

Running the `moisture_test.py` program again, we found that the dry soil gave a reading well under 100 mV. When we watered the plant, it rose to over 1400 mV.

## 05 Liquid level sensor

If you have your plant pot placed in a saucer containing a reservoir of water, you can also add a liquid level sensor to check the water level. This is an optional step, and probably a bit of overkill as the moisture sensor should suffice.

Our liquid level sensor is from the Waveshare Sensors Pack and also sold separately. It works in much the same way as the moisture sensor, with the water conducting a current between its metal strips. The higher the water level, the higher the voltage output: from around 0 V at 0 cm to 1.88 V at 4.8 cm. So we can use it to trigger an alert when the water level drops to near zero.

Wire it up as in **Figure 1**, with the AOUT pin connected to the channel 1 pin of the ADC. Test it out with the `liquid_test.py` code and immerse it at different levels in the water to see the voltage change. Again, be careful not to get water on your electronic connections or Raspberry Pi.

“ We put ours in fairly dry soil to take a reference reading ”

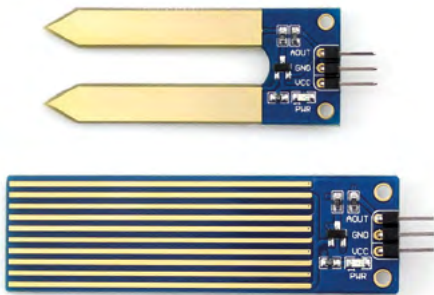
## 06 Push notifications

We will write a program to read the two sensors and trigger an alert when either the moisture or liquid level is too low.

While we could sound an alert with a buzzer, as for the alarms in parts 1 and 2 or this series, we thought it would be more useful to send a push notification to a phone or computer. For this, we're using Pushbullet, which offers a free service tier.

Go to [pushbullet.com](https://pushbullet.com) and sign up for an account. Then go to Settings > Account on the website and click Create Access Token. Copy this down, as you'll need to add it into the code.

We will also need to install the Python 3 library for Pushbullet. After making sure your Raspberry Pi is up to date, open a Terminal and enter: `sudo pip3 install pushbullet.py`.



▲ The two sensors we're using: moisture (top) and liquid level (bottom)

## 07 Plant monitor code

In our final code, `plant_monitor.py`, we import the `pushbullet` library and assign the `pb` variable to our Pushbullet account – you will need to replace `Your Access Token` with the Pushbullet access token you obtained in the previous step.

You will also need the name of the Pushbullet-connected device that you want to send the push notification to. Your device names can be found either on the Pushbullet website, in Settings > Devices, or by using the line `print(pb.devices)`, as shown near the top of the code.

In the `alert` function, we set the `device` variable to the name of the desired device to send the notification to. We then send a push notification with the text 'Plant monitor:' followed by the `message` string determined by the conditional statement in the `while True:` loop. We add a `sleep` of 60 seconds (or more if you want) so that multiple notifications aren't sent straight after each other.

In the `while True:` loop, we check whether the readings for moisture and liquid level (in mV) and set thresholds of 500 and 1000 respectively (alter them to your preference) under which an alert is triggered with the relevant message.

## Taking it further

We now have a working plant monitor that alerts us when it needs watering. You take it a step further by creating a system to water the plant automatically when the soil becomes too dry. For this, you could use a solenoid valve to open and close off the water supply, or a water pump. You'll also need a relay board to control the solenoid or pump, since it will likely have a higher voltage and current than Raspberry Pi can output. [\[4\]](#)

## plant\_monitor.py

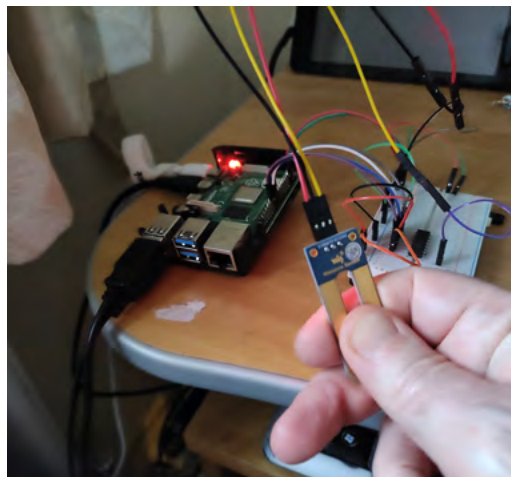
DOWNLOAD THE FULL CODE:



[magpi.cc/github](https://magpi.cc/github)

> Language: Python 3

```
001. from gpiozero import MCP3008
002. from time import sleep
003. from pushbullet import Pushbullet
004.
005. pb = Pushbullet("Your Access Token")
006. print(pb.devices)
007.
008. message = ""
009. moisture = MCP3008(0)
010. liquid = MCP3008(1)
011.
012. def alert():
013.     device = pb.get_device('Your Device')
014.     push = device.push_note("Plant monitor alert: ", message)
015.     sleep(60)
016.
017. while True:
018.     moisture_mv = 3300 * moisture.value
019.     liquid_mv = 3300 * liquid.value
020.     print("Moisture: %-3.2f mV    " % moisture_mv,
021.           "Liquid level: %-3.2f mV    " % liquid_mv, end = "\r")
022.
023.     if moisture_mv < 500:
024.         message = "Soil moisture too low! Water me!"
025.         alert()
026.     elif liquid_mv < 1000:
027.         message = "Reservoir level too low! Fill it!"
028.         alert()
```



▲ Testing the moisture sensor by holding it in the hand; current is conducted from one prong to the other

## Top Tip

Watch it grow

Connect a Camera Module to your Raspberry Pi and take a photo of the plant every ten minutes, then combine them into a time-lapse video of it growing.

# Build your own MIDI synthesizer



WRITER

**K.G. Orphanides**

K.G. now has enough GM/GS MIDI devices to create an entire dungeon synth orchestra.

@KGOOrphanides

Turn Raspberry Pi into a stand-alone retro MIDI synth unit with authentic General MIDI voices

In *The MagPi* issue 111 ([magpi.cc/111](http://magpi.cc/111)), we set up external MIDI interfaces like the Roland MT-32 and SC-55 with Raspberry Pi to play classic game soundtracks and compose music.

However, original hardware has become scarce and its interest to collectors has kept prices high. Fortunately, thanks to Dale Whinham's `mt32-pi`, you can turn Raspberry Pi 3, 4, or Zero 2 W into an accurate standalone emulated synth. We're going to use its support for SC-55 quality General MIDI and Roland GS audio, as this doesn't present the legal complications of MT-32 emulation, which requires that you own ROM images that are not currently available to buy.

## 01 Budgeting

The cheapest version of this DIY MIDI synth project only requires a Raspberry Pi Zero 2 W and its usual set of cables. But you'll also need one or, more likely, two USB MIDI adapters to connect it. We recommend using branded adapters such as a Roland UM-One Mk 2 (£40), but we've also successfully implemented this project with a £7 generic USB MIDI adapter bought on eBay. These are a budget-friendly choice, but we've heard reports of such cables not

always working as they should. For most setups, you'll also need at least one female-to-female MIDI cable or adapter, for another £4 or so.

## 02 Prepare `mt32-pi`

Format a microSD card as FAT32 using Raspberry Pi Imager. Download the latest version of `mt32-pi` from [magpi.cc/mt32releases](http://magpi.cc/mt32releases) – at the time of writing, that's `mt32-pi-0.11.0.zip`. Unzip the file, and copy the zip file's contents into the root of your freshly formatted SD card.

If you open `config.txt`, you'll find a number of options to help you optimise `mt32-pi` for different versions of Raspberry Pi. We'll be leaving all this at the default settings. FluidSynth polyphony has, in the latest version, been adapted to make it run smoothly on the Zero 2 W, but if you experience any performance issues, you can enable an appropriate overclock here.

## 03 Basic mode

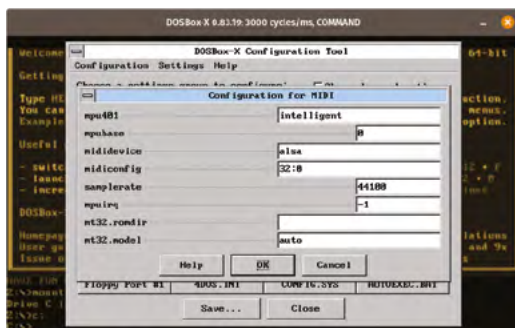
Now edit `mt32-pi.cfg`. The `output_device` setting should already be `pwm`, which uses Raspberry Pi's headphone jack, so all we need to do is configure `mt32-pi` to use the softsynth. Search for 'default\_synth' and change the setting to read:

```
default_synth = soundfont
```

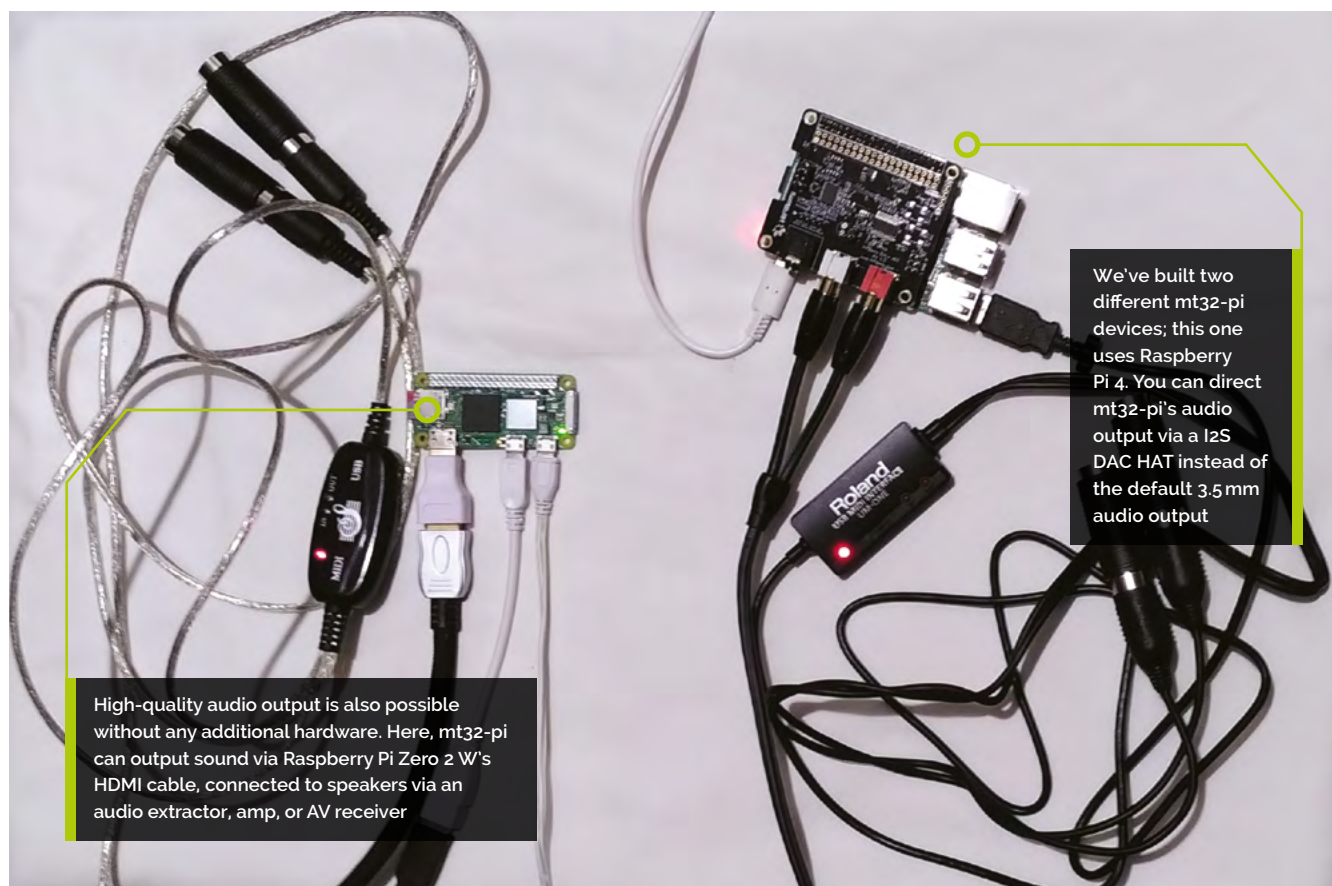
If you're using Raspberry Pi Zero 2 W, which has no 3.5 mm port, set the following option to output sound via an HDMI connection.

```
output_device = hdmi
```

If you connect this to a monitor or TV with built-in speakers, you'll get high-quality MIDI audio.



► DOSBox-X allows you to output MIDI to an external synth with a few configuration changes



High-quality audio output is also possible without any additional hardware. Here, mt32-pi can output sound via Raspberry Pi Zero 2 W's HDMI cable, connected to speakers via an audio extractor, amp, or AV receiver

We've built two different mt32-pi devices; this one uses Raspberry Pi 4. You can direct mt32-pi's audio output via a I2S DAC HAT instead of the default 3.5 mm audio output

Note that no visual information will appear. A better option is an AV receiver or HDMI-bearing hi-fi amp with a decent set of speakers connected to it, or an HDMI audio extractor with a 3.5 mm or stereo RCA output.

## 04 Detect a DAC

mt32-pi uses Raspberry Pi's headphone port by default, but this isn't a recipe for optimal audio quality. The software supports DAC HATs, but you'll need a bit more information to use one. Connect your HAT to Raspberry Pi and pop in a microSD card with a fresh install of Raspberry Pi OS. Boot the system with the DAC connected. We're going to find its address. In a Terminal:

```
sudo raspi-config
```

Set Interfacing Options > I2C > Yes to enable > Finish.

```
sudo apt install i2c-tools
i2cdetect -y 1
```

Note the position of the UU symbol – ours was in column 4, row 40, giving us the address 4d.

Having got this information, we're going to add it to mt32-pi.

## 05 Configure mt32-pi.cfg for your DAC

Edit **mt32-pi.cfg** in your microSD card's root directory again. We're going to change a few settings and add support for our DAC. If you're using a HiFiBerry DAC+ ADC, change the following:

```
default_synth = soundfont
output_device = i2s
i2c_dac_address = 4d
i2c_dac_init = pcm51xx
```

We want to use a General MIDI soundfont via FluidSynth, as we have no MT-32 ROMs. We want to initialise and output via our HAT. And we need the **i2c\_dac\_address** to match whatever result you got from **i2cdetect** in the last step.

Other settings here allow you to enable and disable features such as network MIDI support, an FTP server for easier version updates, and support for LCD displays and physical controls.

## You'll Need

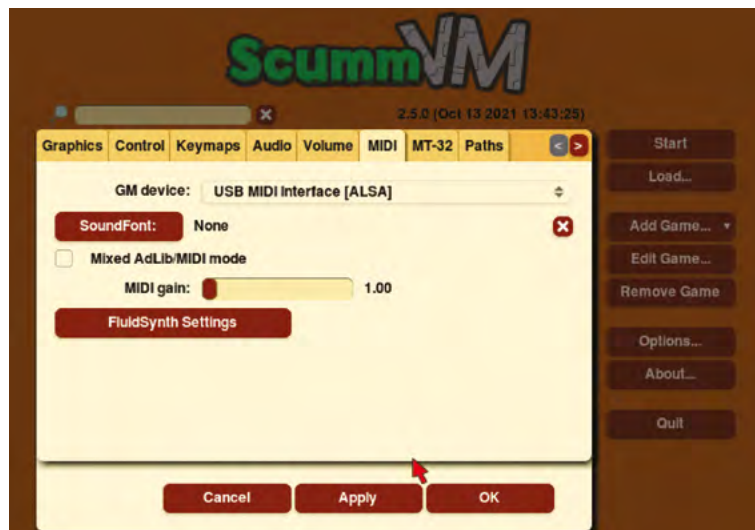
- USB MIDI cable(s) [magpi.cc/umone](http://magpi.cc/umone)
- Female-female MIDI adapter
- I2S DAC HAT (optional). A HiFiBerry DAC+ ADC in our example [magpi.cc/dac2hd](http://magpi.cc/dac2hd)
- HDMI audio extractor (optional)
- HDMI audio to 3.5 mm adapter
- mt32-pi [magpi.cc/mt32pi](http://magpi.cc/mt32pi)



▶ Both name-brand hardware like this Roland UM-One mk2 and generic USB MIDI adapters worked for us, but the former guarantee functionality

▶ Both our USB MIDI adapters have male connectors, so we'll join them with a female-to-female MIDI adapter. Adapter cables and breakout boxes also work

▼ ScummVM makes it easy to direct MIDI output via a USB-connected MIDI synth



## 06 Specialist DACs

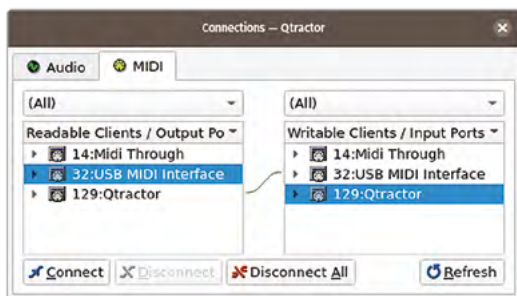
A list of known-functional DACs for mt32-pi can be found at [magpi.cc/mt32wiki](https://magpi.cc/mt32wiki). Another option is a custom hardware HAT ([magpi.cc/mt32custom](https://magpi.cc/mt32custom)) specifically designed for MIDI use, such as clumsyMIDI and mt32-pi-midi-hat. These include features such as MIDI ports, tiny OLED displays and physical buttons. These sometimes turn up on Tindie, but you're more likely to have to assemble them yourself from open specifications. mt32-pi also supports MIDI ports connected via GPIO, standalone OLED displays, buttons, and rotary encoders.

## 07 First connections

Save your changes, eject the card, and insert it into Raspberry Pi. Everything's configured, but we need to provide Raspberry Pi with power and a physical MIDI interface. This is where things get a bit tricky. mt32-pi isn't a USB MIDI device, so you can't just plug it into a computer and start blasting MIDI tunes.

To add the MIDI connectivity required by mt32-pi, plug in a USB MIDI adapter such as a Roland UM-One mk2. For sound output, connect Raspberry Pi's headphone port (or Raspberry Pi Zero 2 W's HDMI port, or any DAC you may be using) to powered speakers or an AV receiver as appropriate.





▲ Qtractor uses JACK's MIDI connector to direct output from the DAW to your USB MIDI interface

## 08 A forest of cables

You'll need to play a slightly old-fashioned game of interface and cable assembly to make the computer you want to use with mt32-pi MIDI-capable. You'll need something like one of:

- A second USB MIDI interface with either female-to-female MIDI adapters or a breakout box. This works well on modern PCs, including Raspberry Pi
- A dedicated MIDI HAT for your mt32-pi
- A (probably vintage) computer with a MIDI interface card such as an MPU-401 or integrated MIDI ports
- A similar setup with a gameport-equipped sound card and a MIDI breakout adapter, with female-to-female MIDI adapters if required

Other options are also available, including a network MIDI mode (see [magpi.cc/mt32midi](http://magpi.cc/mt32midi)).

## 09 Modern PC configuration

Connect a second USB MIDI adapter to your PC – a Raspberry Pi 4 or 400 is ideal for the software we'll be running. Use a female-to-female MIDI adapter to connect the MIDI IN jack on the cable plugged into your PC to the MIDI out jack on the cable plugged into the mt32-pi. On some adapters, such as the UM-One, these are respectively labelled 'connect to MIDI OUT' and 'connect to MIDI IN'. Your PC should recognise the adapter as a USB MIDI device, so now you just need to try it out.

## 10 ScummVM

Download the latest version of ScummVM from [magpi.cc/scummvm](http://magpi.cc/scummvm) or grab it from your OS's repo. Select Options on the main interface.

In the MIDI tab, select your USB MIDI adapter from the GM Device drop-down. Most Linux systems, including Raspberry Pi, show this as USB MIDI Interface [ALSA]. In the MT-32 tab, select your MIDI interface again and tick Roland GS device.

Leave the Audio tab's Preferred device as <default> to have Sound Blaster audio through your usual sound card as well as MIDI output from mt32-pi. If you want to send a game's Ad-Lib or Sound Blaster compatible MIDI audio via mt32-pi, use the Edit Game menu to change this to your USB Midi adapter on a per-game basis. Disabling General MIDI support in the MIDI tab can be used to force MT-32 emulation.

## 11 DOSBox-X

Install DOSBox-X on your PC – follow the instructions at [magpi.cc/dosemulation](http://magpi.cc/dosemulation) to build it on Raspberry Pi. We're going to assume you're using a Raspberry Pi or other Linux PC for this. For Windows or macOS installations, see the documentation at [magpi.cc/dosboxx](http://magpi.cc/dosboxx). Start DOSBox-X and, at the prompt, type:

```
mixer /listmidi alsas
```

Copy the results listed for your USB MIDI interface – 32:0 in our example. Open the Configuration tool from the Main menu and select MIDI. For mididevice, enter alsas; for midiconfig, enter the address you noted down in the previous step. Click OK, then Save, and Save & Restart.

## 12 Synth breakout

The mt32-pi is also a useful tool for musicians who work with retro synth sounds. Because it's a standalone external device, it's easy to just plug in with minimal configuration, and you don't have to worry about the additional resource overheads of running FluidSynth on the same system that you're composing on.

The ability to connect digital outputs and high-quality DAC hats is a benefit, as the analogue output quality on 30-year-old original hardware can leave something to be desired.

DAWs such as Qtractor and Rosegarden use JACK to detect your USB interface and either automatically configure themselves to use it, or allow you to use JACK's MIDI connections interface to attach the DAW's output to your MIDI interface. 

## Top Tip

### Shop by ear

The Video Game Music Preservation Foundation wiki ([vgmpf.com](http://vgmpf.com)) can help you find games with fantastic GM soundtracks.

# Build a LEGO® remote-controlled car

Use LEGO and the Raspberry Pi Build HAT to build a robot car, then program it so you can control it with a Bluetooth connection from your Android phone. Then add some LEDs to dazzle your friends



MAKER

## Richard Hayler

Richard is an engineer who's easily distracted by comics, music, rugby, and LEGO. His quest to combine them into a single activity is ongoing.

[raspberrypi.org](http://raspberrypi.org)



MAKER

## Marc Scott

Marc is a former computer science teacher, and manages informal learning content for the Raspberry Pi Foundation.

[raspberrypi.org](http://raspberrypi.org)

In this tutorial, you will build a wheeled car using LEGO components. Its movement will be determined by two separately driven wheels placed on either side of the car, allowing it to move forwards, backwards, and turn. You can optionally add LEDs to the car to act as brake lights, indicators, or headlights.

You'll need a Build HAT, two Technic™ motors, and an assortment of LEGO, including two wheels (we used a selection from the LEGO Education SPIKE™ Prime kit)

This tutorial is from the Raspberry Pi Foundation and you can find a more detailed guide online at [magpi.cc/legocar](http://magpi.cc/legocar).

## 01 Set up the Build HAT

Before you begin, you'll need to have set up your Raspberry Pi computer and attached your Build HAT. See our Get Started with Raspberry Pi Build HAT in *The MagPi* magazine issue 112 ([magpi.cc/112](http://magpi.cc/112)).

## 02 Set up the LEGO SPIKE motors

It is easier to test and develop your program before you build your robot. This reduces the risk of ruining your wonderful model when a motor unexpectedly sends the robot in the wrong direction and it careens off your desk (although, of course, the good thing about using LEGO is that you can always rebuild).

The Raspberry Pi Build HAT and its Python library allow you to control LEGO Technic motors directly from your Raspberry Pi computer. Plug two motors into ports A and B on the Raspberry Pi Build HAT. Connect your battery pack to the barrel jack on the Build HAT and turn it on.

Open Thonny on your Raspberry Pi from the Programming menu.

Enter the code from `bt_car_test.py` (overleaf) to spin both motors at 50% of their maximum speed for 10 seconds. (They'll run one at a time, not together.)

Run your program and check the motors turn. Your current program should move the motors in opposite directions because the motors will be mounted on opposite sides of the car's chassis. So anti-clockwise rotation on the left-hand wheel will move the robot forward, whereas a clockwise rotation is needed on the right-hand side.

Now that you have tested the motors, you can create functions to make the motors stop and drive forward.

Remove the two lines of code (lines 6 and 7) that make the motors run for ten seconds, and add the `stop()` and `forward()` functions from `bt_car_test2.py`.

The `forward()` function works differently from the run functions of the LEGO motors so that both motors will run together this time.

Type the rest of the lines from `bt_car_test2.py`. Run the code and test that your motors work.

## 03 Testing Blue Dot

To remotely pilot your car, you're going to use the Blue Dot library and Android app. You should only have to pair your Raspberry Pi and mobile device once. After that, they should connect easily each time.

Open a Terminal window. At the prompt, enter:

```
sudo pip3 install bluedot
```

You should see your Terminal return that the latest version of Blue Dot is installed.

Click on the Bluetooth icon in the top right-hand corner of the desktop and make sure that Bluetooth is turned On and that the device is Discoverable.

Depending on the version of Android you are running, the steps to follow on your device may vary slightly but should be close to: Choose Pair new device, and then select your Raspberry Pi device from the devices shown. Then choose Pair from the dialog box. On the Raspberry Pi, you should be prompted to accept the pairing request.

Clicking on OK should show a successful pairing of the Raspberry Pi and the Android device. Sometimes you might be asked to confirm a code before you are allowed to pair the devices.

## 04 Testing Blue Dot

Create a new Python file on your Raspberry Pi and enter the code from `bluedot_test.py`. Run the program and then, on your Android device, open the Blue Dot app. The first screen will show you a list of Bluetooth devices that have been paired with your device.

Click on 'raspberrypi' from the menu and you should see a big blue dot on your screen. Tap it.

In order for Blue Dot to connect to your Raspberry Pi, a server needs to be running on the Raspberry Pi. This means that a `BlueDot` object (`dot = BlueDot()`) must have already been created in your Python program and be waiting for connections.

Make sure that you are running your program before trying to connect with Blue Dot and that it has no errors.

On the Raspberry Pi, you should see that your program has accepted the Bluetooth connection and has successfully responded to you pressing the blue dot.

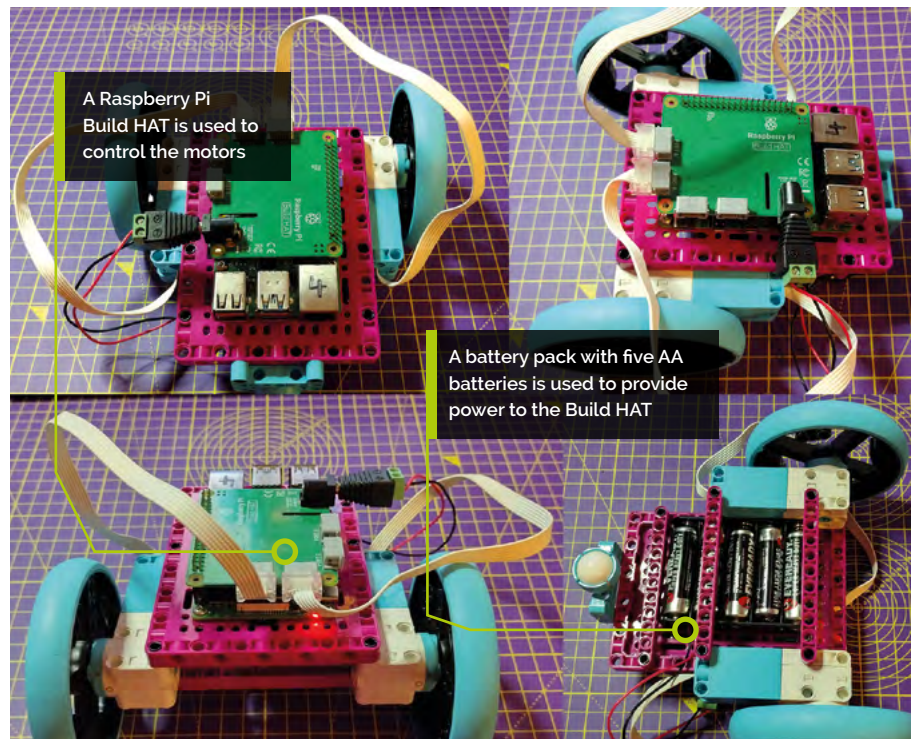
## 05 Control your motors with Blue Dot

The Blue Dot app and Python library can be used to control your LEGO Technic motors, from your device.

Our final `bt_car.py` code listing is based on `bt_car_test2.py`. Add the import statement to line 2:

```
from bluedot import BlueDot
```

You should also replace the `sleep` import on line 3 with the following:



A Raspberry Pi Build HAT is used to control the motors

A battery pack with five AA batteries is used to provide power to the Build HAT

```
from signal import pause
```

Remove the `for` loop at the end of the code and add a function that uses Blue Dot to call the `forward` function to the bottom of your script.

Add the `move` function (as shown in `bt_car.py`). It has a single parameter, which has been called `pos`. This will be automatically passed to the function, depending on where the Blue Dot is touched. Add the `dot.when_pressed` and `dot.when_released` calls to the bottom of your code. These will make the car move forward and stop. The final `pause()` call makes sure the program doesn't just end at the bottom of the script.

Run your code. On the Blue Dot app on your device, press the blue dot near the top and the motors should turn. When you take your finger off the blue dot, the motors should stop.

At the moment, the motors will only turn the wheels in the forward direction. By using the `pos` parameter, you can make them turn in all directions. Add the `dot.when_moved = move` function so that the motors will move the car backwards, left, and right. Your final code should look like `bt_car.py`.

Run your code again, and test it with the Blue Dot app. Pressing on the right, left, and bottom of the blue dot should now move the motors in different directions.

You can add a single line to your code so that Blue Dot responds not only to presses, but also to when your finger moves over the blue dot.

## You'll Need

- Raspberry Pi
- Raspberry Pi Build HAT  
[magpi.cc/buildhat](http://magpi.cc/buildhat)
- 2 × LEGO Technic motors
- Some LEGO elements to build a wheeled vehicle
- An Android mobile phone or tablet
- 5 × AA batteries and a holder pack with a barrel jack

## Top Tip

### GitHub files

You can view the source code for this project on the Raspberry Pi Foundation's GitHub page [magpi.cc/legocargit](http://magpi.cc/legocargit).



Mark Calleja

Mark is a Learning Manager and hosts the Digital Making at Home weekly stream for Raspberry Pi Foundation.

[raspberrypi.org](http://raspberrypi.org)

MAKER

## Top Tip

### Bluetooth

The name Bluetooth was proposed in 1997 by Jim Kardach of Intel. At the time of this proposal, he was reading Frans G Bengtsson's historical novel *The Long Ships* about Vikings and the 10th century Danish king Harald Bluetooth. Bluetooth was King Harald's nickname, and he united the Danish tribes into a single kingdom, just as Bluetooth unites communication protocols.

## bt\_car\_test.py

> Language: Python

```
001. from buildhat import Motor
002. from time import sleep
003.
004. motor_left = Motor('A')
005. motor_right = Motor('B')
006. motor_left.run_for_seconds(seconds=10,
    speed=50)
007. motor_right.run_for_seconds(seconds=10,
    speed=-50)
```

## bt\_car\_test2.py

> Language: Python

```
001. from buildhat import Motor
002. from time import sleep
003.
004. motor_left = Motor('A')
005. motor_right = Motor('B')
006.
007. def stop():
008.     motor_left.stop()
009.     motor_right.stop()
010.
011. def forward():
012.     motor_left.start(50)
013.     motor_right.start(-50)
014.
015. def back():
016.     motor_left.start(-50)
017.     motor_right.start(50)
018.
019. def left():
020.     motor_left.start(50)
021.     motor_right.start(50)
022.
023. def right():
024.     motor_left.start(-50)
025.     motor_right.start(-50)
026.
027. for i in range(2):
028.     forward()
029.     sleep(1)
030.     back()
031.     sleep(1)
032.     right()
033.     sleep(1)
034.     left()
035.     sleep(1)
036.     stop()
```

Run your program and experiment with pressing the blue dot on your Android device, and moving your finger around to different positions. The motors should spin in different directions, and stop when you lift your finger off the blue dot.

To read the full documentation for Blue Dot, go to [magpi.cc/bluedotdocs](http://magpi.cc/bluedotdocs).

## 06 Assemble your robot

Now you have the motor code working, it is time to construct and test your robot.

The basic design needs to have a mounted Raspberry Pi and Build HAT with two motors (and wheels) mounted parallel to each other, and a caster or balance point at the front. There also needs to be a secured battery pack with a barrel connector.

Raspberry Pi and Build HAT can be secured to LEGO Maker Plate using M2 machine screws and nuts. There are lots of ways to connect or mount a Raspberry Pi computer to LEGO elements.

The easiest way is to use the Maker Plate that comes with the LEGO Education SPIKE Prime Expansion Set (45680). You can also use the cable clip LEGO elements from a LEGO Education kit, or design and make a laser-cut or 3D-printed adapter.

You can power the Raspberry Pi and Build HAT using a battery connected to a barrel jack. A minimum of five AA batteries or a 9V battery will be required. Once your robot is assembled, you should test it using Bluetooth with your Android device. Power up your Raspberry Pi, and then run your **bt\_car.py** program. Test that your car works when using Bluetooth and the Blue Dot app from your Android device.

You may need to make changes to your code depending on which side of the car, and which way around, your motors are connected.

## 07 Going headless

Now you need to make Raspberry Pi run headless. This means running your code without needing to have a monitor, keyboard, or mouse connected.

First of all, make sure your Raspberry Pi is connected to a wireless LAN network.

Now, you can use a program called cron to make your Python script run every time the Raspberry Pi is booted.

Open a Terminal by pressing **CTRL+ALT+T** on your keyboard.

Type `crontab -e` into the terminal window. If this is the first time you have ever used crontab, then it will ask you which editor you would like to use.

Unless you are experienced with vim, choose:

```
1. /bin/nano
```

Nano will open up and show the default template file.

Use the cursor keys to scroll to the bottom of the file. You can then add this single line, which will wait for 30 seconds and then run your `bt_car.py` file.


```
# m h dom mon dow   command
@reboot sleep 30 && python3 /home/pi/bt_car.py
```

Reboot your Raspberry Pi, wait for 30 seconds, and then use your Blue Dot app on your Android device to connect to your car and control it.

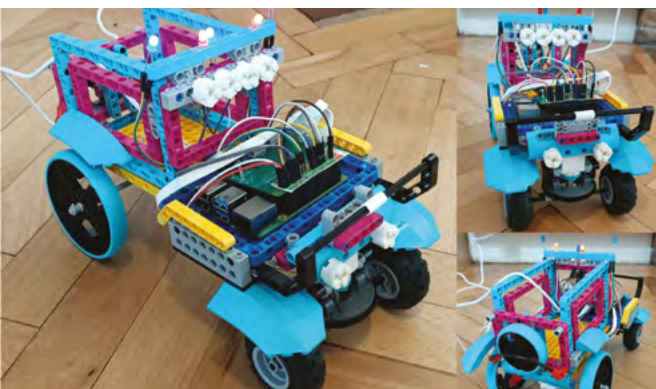
## 08 What next?

Take a look at the online guide at [magpi.cc/legocar](http://magpi.cc/legocar) to find more detailed instructions, including how to add LED lights to your RC car (to act as blinkers/indicator lights).

If you would like to enhance your Bluetooth car, then you could think about adding more electronic components: Add extra LEDs as flashing police 'pursuit' lights, or headlights when the car drives. Many vehicles make a sound when they are reversing, so you could add a buzzer to your project.

You could even use an ultrasonic distance sensor (UDS), which detects when the car approaches an obstacle, and automatically stops it from crashing! 

▼ The following photos show some different designs for how your LEGO car could be built, which incorporate the Raspberry Pi, Build HAT, and battery pack.



DOWNLOAD  
THE FULL CODE:



[magpi.cc/legocargit](http://magpi.cc/legocargit)

## bluedot\_test.py

> Language: Python

```
001. from bluedot import BlueDot
002. dot = BlueDot()
003.
004. print('Waiting...')
005. dot.wait_for_press()
006. print("It worked!")
```

## bt\_car.py

> Language: Python

```
001. from buildhat import Motor
002. from bluedot import BlueDot
003. from signal import pause
004. from gpiozero import LED
005.
006. motor_left = Motor('A')
007. motor_right = Motor('B')
008. dot = BlueDot()
009. led_left = LED(20)
010. led_right = LED(21)
011.
012. def stop():
013.     motor_left.stop()
014.     motor_right.stop()
015.     led_right.on()
016.     led_left.on()
017.
018. def forward():
019.     motor_left.start(-100)
020.     motor_right.start(100)
021.     led_right.off()
022.     led_left.off()
023.
024. def backward():
025.     motor_left.start(100)
026.     motor_right.start(-100)
027.     led_right.on(0.2)
028.     led_left.on(0.2)
029.
030. def right():
031.     motor_left.start(-100)
032.     motor_right.start(-100)
033.     led_right.blink(0.2)
034.     led_left.off()
035.
036. def left():
037.     motor_left.start(100)
038.     motor_right.start(100)
039.     led_right.off()
040.     led_left.blink(0.2)
041.
042. def move(pos):
043.     if pos.top:
044.         forward()
045.     elif pos.bottom:
046.         backward()
047.     elif pos.left:
048.         left()
049.     elif pos.right:
050.         right()
051.
052. dot.when_pressed = move
053. dot.when_released = stop
054. dot.when_moved = move
055.
056. pause()
```

# Make your own retro platformer

Code your homage to *Rainbow Islands* in Python – a vertical scrolling platformer where enemies meet incredibly colourful deaths



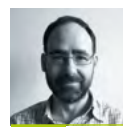
## Wireframe

This tutorial first appeared in *Wireframe*, our sister magazine that lifts the lid on the world of video games. Every issue includes tutorials and in-depth interviews, along with news and reviews of the latest indie and triple-A games.

To find out more, visit their website at [wfmag.cc](http://wfmag.cc).

Check out their subscription offers at [wfmag.cc/subscribe](http://wfmag.cc/subscribe).

► This is what happens when the player jumps just after leaving a platform: they jump in the air like a cartoon character. Hence its name, 'coyote time'.



### AUTHOR JORDI SANTONJA

Jordi currently works as a software engineer in Norway for a company that develops systems to design infrastructure: roads, railways, utilities... He originally comes from Spain and, in his spare time, codes video games.

Platform games have long been about dexterity: running, jumping, and avoiding enemies and pits. The genre's roots go back to Nintendo's *Donkey Kong*, released in 1981, and gradually evolved from single fixed screens to scrolling levels, and then to 3D.

*Rainbow Islands: The Story of Bubble Bobble 2*, developed for arcades by Taito in 1987, stood out from other platformers thanks to its vertical level design and unique attacks. The player makes their way from the bottom to the top of narrow stages, and can cast rainbows which can be used as both temporary platforms and an attack that destroys enemies. The rainbows kill the enemies if they collide with them when created, or, when destroyed, if they fall down over them. A rainbow is destroyed when the player character jumps over it, or after a certain time from its creation.



We're going to code our own take on *Rainbow Islands* in Python and Pygame Zero, with the help of Shapely for the collision detection. Head to [wfmag.cc/shapely](http://wfmag.cc/shapely), where you'll find out how to download and install it.

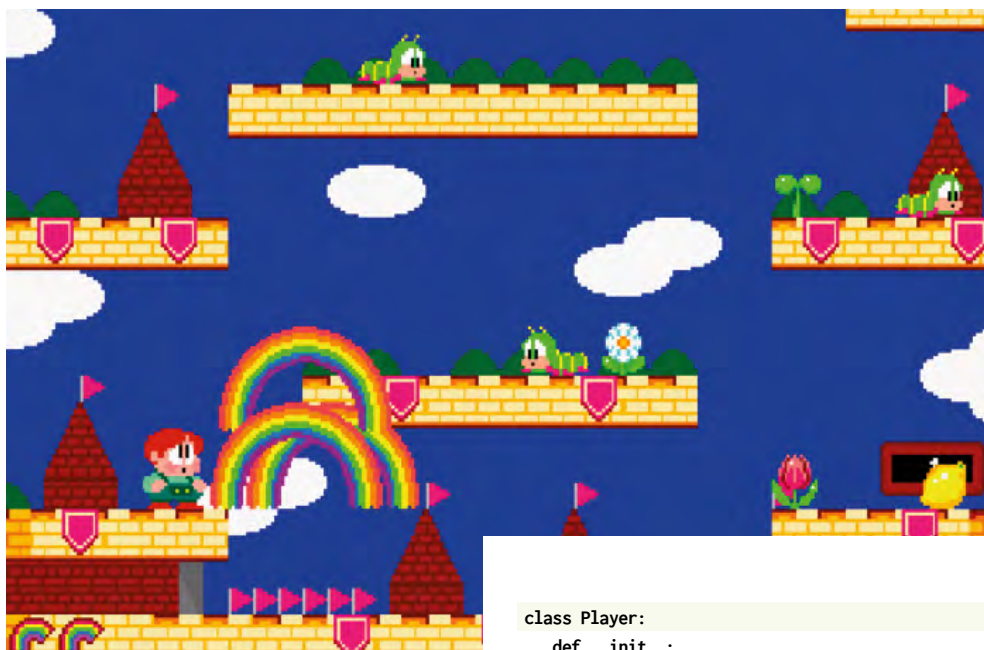
## DRAW PLATFORMS

Let's start coding some of the game's main mechanics. We'll first test the player's interactions with platforms: jumping, falling, and walking around. We need some platforms to check all this, and to draw them we use the program **Listing01\_DrawPlatforms.py**. We can draw lines with the mouse, **RETURN** starts a new line, and the **SPACE** bar prints the resulting lines to the Python console.

In the game, the player's character can jump up through a platform without colliding with it, but when they're dropping down they'll land on top of the platform. This way, the player can advance upwards by jumping from platform to platform. To achieve this, the platforms consist of a single open polyline from left to right, which doesn't intersect itself and has no loops.

## PLAYER PROTOTYPE

The first lines of **Listing02\_PrototypePlayer.py** contain the platforms, called **surfaces** in the code, copied from the result of the previous program. The rest of this listing is quite complicated and long, but it contains the main foundation of the full game. After the platforms come some player



◀ *Rainbow Islands: The Story of Bubble Bobble 2* - the 1987 classic we're using as the basis for our Python project.

parameters: size, acceleration, jump speed, terminal speed, and lateral speed. You can change them at will to see how they affect the character's movement.

Next, the **Player** class is defined. The **update** function contains its main behaviour, where the collision with the platforms is handled. The collision is computed only when the player is falling down, that is, when **speedY**  $\geq$  0. An object with a speed greater than zero goes down. When the speed is less than zero it goes upwards, and it doesn't collide with anything. The collision is computed using Shapely's **intersection** function between two Shapely geometries: the platform line and the player bounding box. Both are defined as Shapely **LineString**. The intersection result consists of one or more points. In order to avoid missed intersections when the player is falling down at a high speed, the player's bounding box size is expanded down by the speed value. The highest point of the intersection is assigned to the player's position. This way, when the player's character intersects a platform, it will remain at the top.

After the collision detection, the new position is computed from the old position and speed, limit checks are performed, and finally, input management from the keyboard is done with the three functions: **jump**, **left**, and **right**.

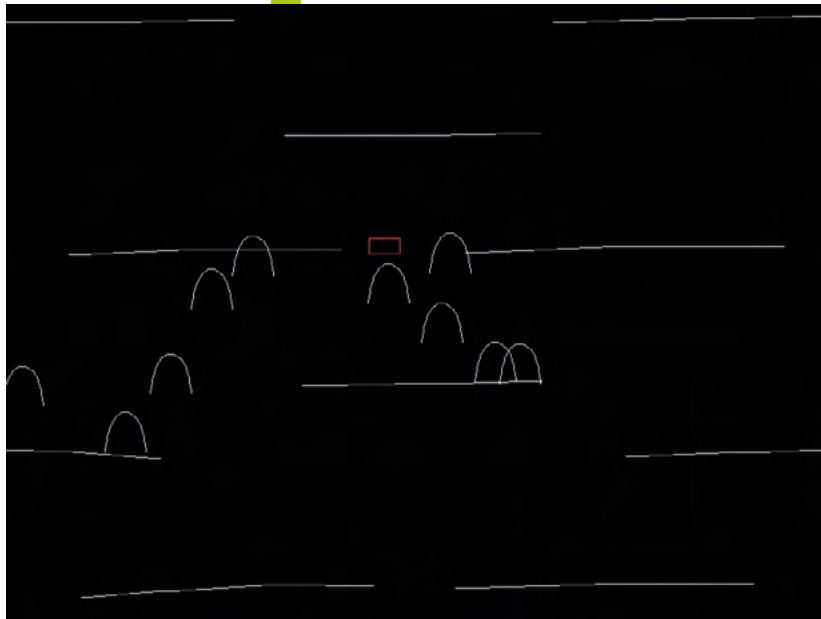
The pseudo-code for this prototype can be described as follows:

```
surfaces = [point lists]
player parameters
```

```
class Player:
    def __init__:
        centre = initial position
        lineString = box around centre
    def draw:
        draw lineString lines
    def update(surfaces):
        if speedY >= 0:
            for all surfaces:
                intersection surface / box
                if intersection:
                    centre.Y = intersection highest
point
    centre.Y += speedY
    translate(lineString)
    def jump:
        if not jumping:
            speedY = -playerJumpSpeed
            jumping = True
    def left:
        centre.X -= playerLateralSpeed
    def right:
        centre.X += playerLateralSpeed
player = Player()
def draw():
    screen.clear()
    for all surfaces:
        draw surface
    player.draw()
def update():
    if keyboard.left:
        player.left()
    elif keyboard.right:
        player.right()
    if keyboard.up:
        player.jump()
    player.update(surfaces) →
```

## PROTOTYPES

When you have an idea for a new mechanic, one of the best ways to check its feasibility and fun factor is to build a prototype. A prototype must be fast to code, and needs no fancy graphics: some boxes and lines will do. But it needs to show the mechanic as best as it can be implemented, so if it's successful, it can be translated directly to the final game with finished graphics. I recommend taking a quick and dirty approach to prototyping – build it in the engine or programming language you're most comfortable with. If the prototype's successful, it can be translated into proper code in the final platform.



^ The code 'Listing08\_PrototypeShootRainbows\_Polygon.py' is used to test the creation of rainbows and the correct placement of the player on the rainbows. Please try it, tweak the code, and play around to test the results.

## GAME PARAMETERS

To test the possible values of the parameters of the game, we can code them into variables that can be easily changed, either in the code or in a file. Be it the speed of the player character, the height of its jumps, or the size of the rainbows, it can be changed any time to immediately test its effects on the gameplay. The goal is to iterate rapidly through the possibilities to find the most satisfying and fun values.

## VERTICAL SCROLLING

To tackle the scrolling, we need some platforms. To make them, we'll adapt the drawing platforms listing to get **Listing03\_DrawPlatformsVertical.py**, where pressing the arrow keys 'Up' and 'Down' displaces the whole screen vertically. Then we adapt the player's prototype code to allow the vertical scrolling in **Listing04\_PrototypeVerticalMovement.py**, which defines the new variable `screenPosition`, which stores the vertical viewing position. All the operations are performed as before, with the intersections done in the world coordinates. In the **draw** functions, `screenPosition` is subtracted from all objects' vertical position to draw them in the right place on the screen after scrolling. `screenPosition` is updated in `screenPositionUpdate` from the vertical position of the player.

Another tweak has been introduced here. If you've played around with the first prototype, you may have noticed that if you press 'Jump' after you fall from a platform, your character jumps. To avoid this double jump, a check has been introduced when the character is in mid-air:

```
if not self.jumping and self.speedY >= 4:
    self.jumping = True
```

This sets the character as jumping when the vertical speed downwards is higher than 4, thus avoiding a double jump. This still allows

**“Now we have a basic prototype for all the main elements of our platformer”**

the jump in mid-air just after falling from a platform. This is a useful technique in platform games called 'coyote time'. The next step is to rename the '4' to something more meaningful, `coyoteTimeVerticalSpeed`, and test different values.

## ENEMIES

Let's prototype the enemies now. In **Listing05\_PrototypeEnemies1.py** and **Listing06\_PrototypeEnemies2.py**, we code two basic enemy behaviours: back and forth on a platform, and falling down from the border of a platform.

The first enemy moves over a platform without leaving it. That behaviour is achieved by using a line to intersect the platform. The line is placed in front of the enemy to find the vertical position of the platform and place the enemy accordingly. If the line doesn't intersect the platform, it means the enemy has passed the border, so it must reverse its trajectory to go back to the platform.

The second enemy moves over a platform, but when it reaches the platform's border, it falls down. The collision box is similar to the player's character one, so we could reuse the code here.

## SHOOT RAINBOWS

Next, prototype the rainbows. We reuse the code from **Listing04\_PrototypeVerticalMovement.py** to create the new file **Listing07\_PrototypeShootRainbows.py**. Here, every time the player presses the **SPACE** bar, a new rainbow is created. As the rainbow is placed in front of the player, a new variable is defined: `directionX`, which can store two values, +1 and -1, facing right and facing left. The new rainbow is then added to the current platforms as an

arc, so the player can walk and jump on it. But in the first prototype, we find that the player's box gets into the arc when walking on top.

To fix this, we must compute a **Polygon/LineString** intersection, that draws a **LineString** completely inside the **Polygon**. Then we get the highest point of the resulting **LineString** to place the player's character. Now the player correctly rests on top of the arcs without intersecting it. The file **Listing08\_PrototypeShootRainbows\_Polygon.py** contains the changes.

Another change is the size of the bounding box to detect intersections. When you jump from a platform to the one above, you'll suddenly



appear on top of the platform, which is a jarring behaviour. We can reduce the size of the bounding box to avoid this.

## COLLECTABLES

We have enemies and rainbows. What happens when an enemy is killed by a rainbow? An item is released that can be collected by the player.

**Listing09\_PrototypeShootCollectables.py** prototypes how these items fly from the enemy and land on a platform.

Here, when the player presses the **SPACE** bar, a new flying item is created at the character's position. Then it starts to fly in a random direction, computed with a pair of **randint** – one for horizontal speed and the other for vertical speed – and it flies until it lands on a platform. The collision detection is similar to the player character collision detection.

The **Collectables** class contains two lists, **collectablesFlying** and **collectables**, that store all the collectables, and defines the function **addCollectable** to add a new flying collectable. When a flying collectable lands on a platform, it's deleted from the **collectablesFlying** list and added to the **collectables** list.

## DESTROY RAINBOWS

The **Listing10\_PrototypeDestroyRainbows.py** program prototypes both ways to destroy a rainbow: when it reaches its time limit and when the player jumps over it.

In this code, the rainbows are independent entities, stored in the class **AllRainbows**. This class keeps two lists: **rainbows** and **fallingRainbows**. When the player shoots a rainbow, it's appended to the **rainbows** list, and when the player's character jumps over a rainbow, or its time of life **rainbowTimeLife** has ended, it's removed from the **rainbows** list and appended to **fallingRainbows**. When the falling rainbow exits the screen, it's removed from the list.

When the player's character lands on a rainbow, its speed is compared against **playerVerticalSpeedToDestroyRainbow** and, if bigger, **allRainbows.rainbowFall** is called to destroy the current rainbow and to add a new falling rainbow. Another tweak to the player's behaviour is also introduced here: the variable jump. When the player presses the **SPACE** bar longer, the character jumps higher, and with a short press, the character jumps shorter. This has been achieved by calling **stopJump** when the **SPACE** bar is released.

## GRAPHICS

Now we have a basic prototype for all the main elements of our platformer: the player's character, the platform, enemies, collectables, and rainbows as weapons. With some adjustments, it's possible to start putting it all together to get the final game. It's also the time where we can start creating the graphics. My preferred software is GIMP ([gimp.org](http://gimp.org)), but you can use any other software capable of creating graphic files with transparency – PNGs in our case. Please replace the provided graphics with your own – I'm not an artist!

## PLATFORMS

With the help of GIMP, we've designed a set of platforms to be placed on the screen. The list of platform file names is stored in the file **Listing11\_PlatformNames.py** under the name **platformNames**. Now we must draw a line over each to define the top line where objects can land. We draw the lines with the program **Listing12\_DrawPlatformLine.py**, and, after pressing the **SPACE** bar, the result is stored in the file **Listing13\_PlatformLines.py** under the variable **platformLines**.

Next, we create the level by placing the platforms in their final positions with the program **Listing14\_PlacePlatforms.py**. Here, we use the mouse to move and place every platform, the ➔



▲ **Listing12\_DrawPlatformLine.py** helps us to define the platform surface where the game objects will rest.

▼ After creating the map, **Listing19\_PlaceEnemies.py** allows us to place the enemies on the platforms.



## COYOTE TIME

If the jumping from platforms is pixel-perfect, sometimes it can feel unfair to miss the platform by a pixel and fall to the void without the possibility to jump. To avoid this, some platformers implement a 'coyote time', where the player can still jump after having left the platform and being mid-air, in a similar way the cartoons realise they are in mid-air and start falling.

✓ Can you reach the top of the stage? And more importantly, can you create a more challenging map?

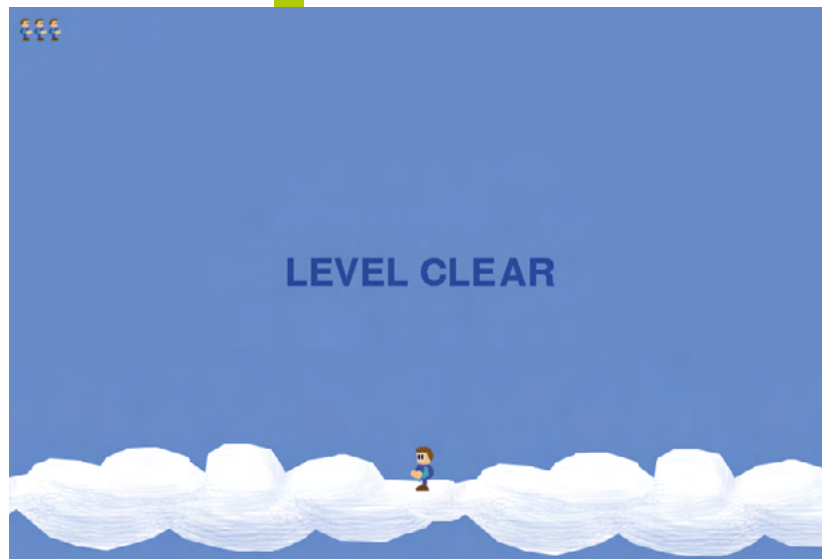
arrow keys to select platforms and to scroll the screen, and the **SPACE** bar to print on the Python console the final distribution of the platforms. Every entry of this list contains the index of the platform and the global position on the screen. This list is copied into the variable `platforms` in the file `Listing15_Platforms.py`.

The code in `Listing16_TestPlatforms.py` combines the player and the rainbows from `Listing10_PrototypeDestroyRainbows.py` and the newly created platforms, stored in the new class `AllPlatforms`. Here, we discover that the previous jump height is not enough to reach the next platform, so we increase `playerJumpSpeed` from 12 to 14.

At the moment, our background is plain black. As we've drawn some clouds as platforms, it feels appropriate to have the background fade from black to blue as the player goes up. The colour is computed in the function `backgroundColourUpdate` and stored in `backgroundColour`. This code also draws the platform collision lines to check that everything works as intended.

## PLAYER

Now it's time to test the player and rainbow graphics with the program `Listing17_TestPlayerGraphics.py`. Here, we've defined the variable `drawLines` to enable or disable drawing the collision lines. In the final game it must be `False`, but for debugging and testing, it's convenient to activate it. The player can shoot up



to three rainbows at a time. To test it, the variable `numberOfRainbows` has been introduced, and set to 3. Later, it must start with 1 and be incremented every time a specific item is collected. To allow a small delay in the creation of the rainbows, each rainbow is created with a `creationTime`, and it becomes active and visible when the time arrives.

All the player image names are stored in the variable `playerImageNames`, and then loaded into actors at the list `actors` in the class `Player`. Then, in the `draw` function, the right image is selected from the current state of the player.

## ENEMIES

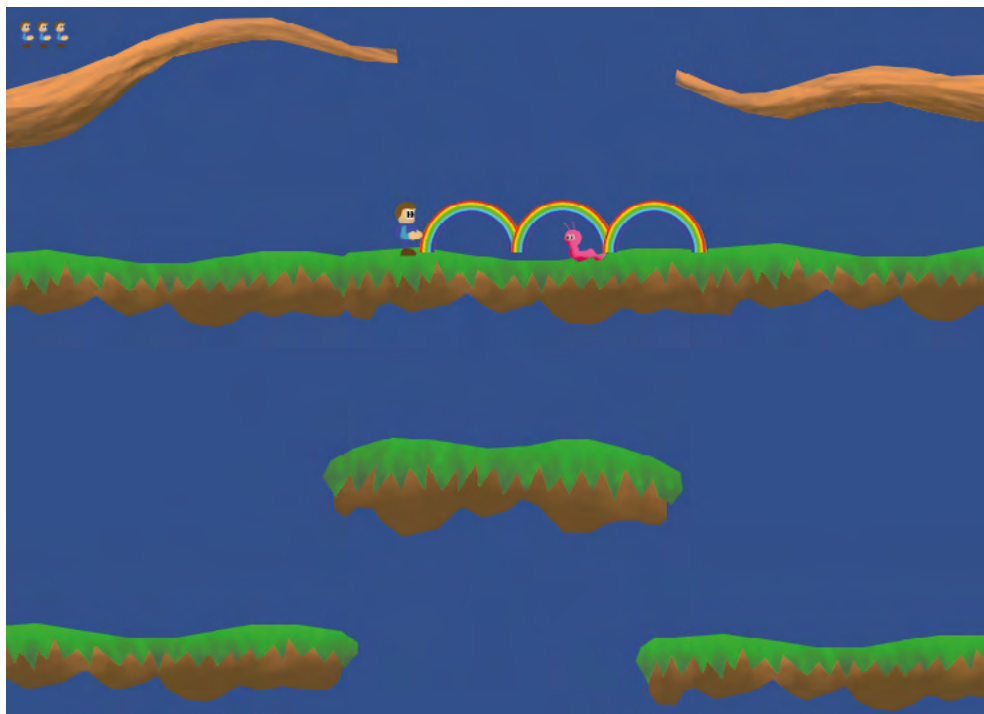
Let's place the enemies on the level map. I've created three types of enemies: one that crawls on the same platform, another that crawls on platforms but falls from its borders, and a third that flies. The image file names are stored in the file `Listing18_EnemyNames`. It's a list of lists: every element of `enemyNames` is an enemy, containing the list of all the graphic files that define that enemy. The first element in every list is the enemy facing right, the second one is facing left; and if an enemy has more graphics, all odd positions face right and all even positions face left.

To place the enemies on the map, the program `Listing19_PlaceEnemies.py` is used. With the arrow keys 'Left' and 'Right', we can select the enemy type and its direction: facing left or right. With 'Up' and 'Down', we move the map, and with the **SPACE** bar, the list of enemies and positions is printed on the Python console. We copy this result on the file `Listing20_Enemies.py`, in the variable named `enemies`. Every element of this list stores four values: the enemy index, its direction +1 or -1, and the two screen coordinates X and Y.

## FULL GAME

Now it's time to put all these elements together. `Listing21_FullGame.py` gathers all the previous pieces of code to connect them and create a full level. We now have a huge chunk of code where it can be difficult to find anything. To fix that, we need to split the code into manageable chunks.

Code files named `Listing22` to `Listing29` have been extracted from `Listing21_FullGame.py`, and called from `Listing30_FinalGame.py`. Some adjustments have been made to pass around parameters and objects, as the global variables defined in `Listing21_FullGame.py` aren't accessible from the extracted modules. `Listing23_IntersectionRectangles.py` is a



◀ It's not pretty, but it's still the basis of a platform game similar to *Rainbow Islands*.

simple rectangle intersection calculation. Its function `RectanglesIntersect` returns `True` or `False` when the two input rectangles overlap (or don't). A rectangle is defined by its central point and its half size. This function performs a faster intersection than with `LineStrings` or `Polygons`.

`Listing24_Rainbows.py` has all the rainbow-related operations.

The class `AllRainbows` keeps two lists: `rainbows` and `fallingRainbows`.

A rainbow will only intersect an enemy at the exact time of its creation, when `timeFromCreation == 0`. A rainbow won't destroy anything at any other time, but enemies or the player will be affected if they interact with it. Elements in `fallingRainbows` can, however, destroy enemies if they intersect – this is computed with the `RectanglesIntersect` function.

The code in `Listing26_Collectables.py` manages the collectable items with two main lists in the `Collectables` class: `collectablesFlying` and `collectables`. When an enemy dies, it releases a collectable by adding a new element to the `collectablesFlying` list at the same enemy position but with a random speed. When the flying collectable lands on a platform, an element from the `collectableNames` list is selected randomly. One of the elements is a small rainbow

– when collected by the player, this adds to the number of rainbows they can cast at once.

`Listing27_Player.py` contains all the player's character stuff. When an enemy collides with the player, the number of lives is decremented, the player's moved to its starting position, the number of rainbows restarts at 1, and all the enemies

are restored. When the number of lives reaches 0, the game ends.

`Listing30_FinalGame.py` imports all the previous modules,

creates the game classes, and calls them at `draw` and `update`. It manages the keyboard input, and also manages the `levelClear` variable: when the player character reaches the top of the platform map, it's set to `True` and the level ends.

## NEXT STEPS

In this guide, we've learned how to code a platform game from scratch, starting with prototypes to test the mechanics in a complete level. The work is far from done, though.

From here, you can develop the project further: add more enemies, draw new graphics, add sounds and music, more levels, bosses, and so on. Or, even better, prototype your own type of platformer featuring a completely new game mechanic. It could be fantastic! 🗨

**“In this guide, we've learned how to code a platform game from scratch”**

## FINITE-STATE MACHINES

If your player system has more than two states, you must consider using a finite-state machine to control all the states and transitions between them. This way, it's much easier to know what to do when the user presses 'Jump' and the protagonist is in the air falling after a hit by an enemy, for example.

# MAKER TOOLS FOR ALL AGES

Essential kit for building at home

**I**f you have a Raspberry Pi, you've already taken a step into making. While programming is a great way to have fun and learn with Raspberry Pi, you can also use it to control things in real life.

You'll need to get some tools and materials for the job though. Not everything is suitable for all age groups though, which can cause a little brain wracking when you're trying to come up with things to do.

Fear not, we have the solution for you. Over the next several pages, we'll lay out the kind of tools safe for younger and older makers alike. Get ready to build up a storm.



## YOUR MAKER SPACE

Where should you be building?

### 01 Find your space

Different projects demand different kinds of spaces. Not everyone has access to a shed or garage, but you might have a desk or table. Get cutting mats and wooden boards to work on if you don't want to damage the surface you're using, and make sure anything else you don't want to damage is moved away.

### 02 Safety-conscious

You need to make sure that any space you choose is safe to use, for both you and everything else. You'll likely be working with tools that can get hot or are sharp, so keep flammable objects away, wear goggles where necessary, and wear thick gloves if you need to. Cut away from yourself as well, and make sure any tools are out of reach of kids and furry kids.



### 03 Storage thoughts

This can trip up a few new makers – where will you keep your tools or projects in progress? Plastic storage drawers are cheap and sturdy for tools and such, or you could put them in a toolbox. For smaller projects, you can easily fit them into a drawer, but with larger ones you need to consider how they'll affect everyone else near your maker space.



#### Warning! Soldering

Soldering irons get very hot, and stay hot for a long time after they're unplugged. Read up on soldering before connecting the wires.

[magpi.cc/soldering](http://magpi.cc/soldering)



#### Warning! Power tools

Power tools require some guidance and training in proper use, as well as safety equipment.

[magpi.cc/drillsafety](http://magpi.cc/drillsafety)



#### Warning! Blades

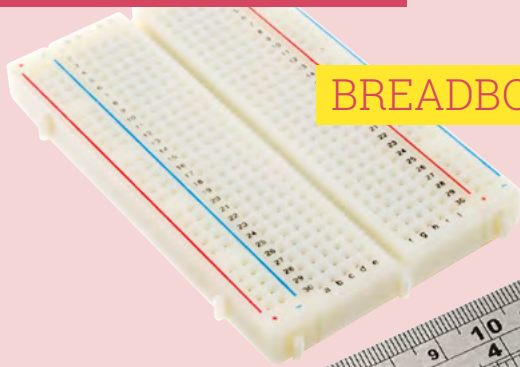
You can easily cut yourself on sharp blades. Cut away from yourself and store them safely.

Image: CC BY 2.0 btwashburn

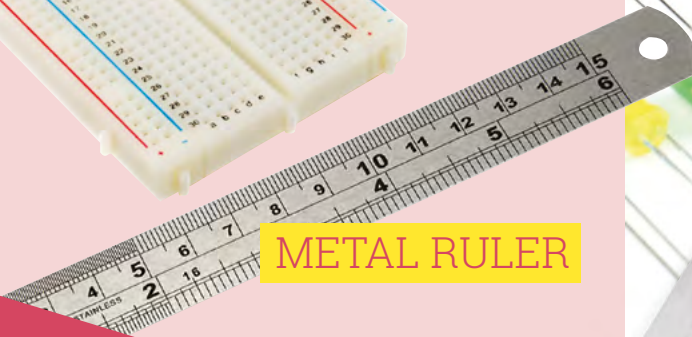
# TOOLS FOR YOUNG MAKERS

Everyone has to start somewhere. While some of us may have been able to use hammer drills from a young age, we didn't always own one. Here's the kind of thing a young maker should be able to safely use

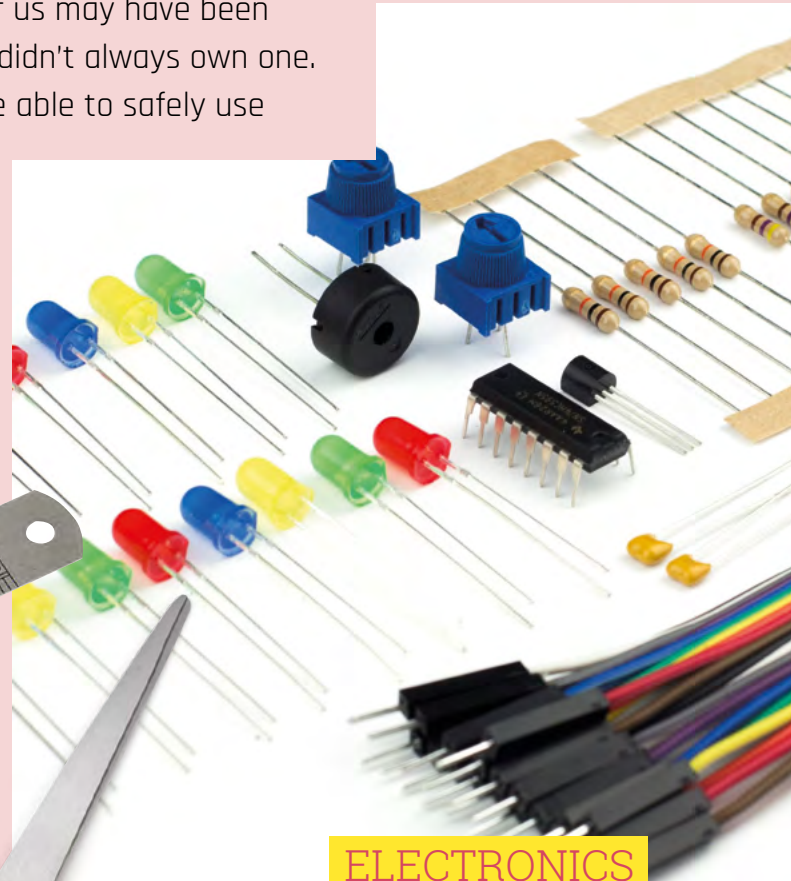
## TOOLS



BREADBOARD



METAL RULER



ELECTRONICS STARTER KIT



GOOD SCISSORS

### Stripping wire with scissors

Scissors can be used to cut wire but did you know you can also strip some of the plastic off them as well? Cut wire needs to have the metal filament inside exposed so you can insert it into a breadboard – just position the scissors about a centimetre or two up the wire, apply gentle pressure, and turn the wire around. Pull on the end of the plastic to try and remove it – if it's not budging, try with the scissors again but apply a bit more pressure.

# MATERIALS

## CARDBOARD

◀ Easily accessible, very cheap, and simple to use. Cardboard is not only great for safer projects but also for prototyping 3D models or projects using wood and metal

## PROTOTYPING WIRE

▶ Sturdy and able to keep its shape, this kind of wire is perfect for breadboard use as you hook up different components

## JUMPER CABLES

◀ An easier way to attach GPIO to breadboards using pre-made wires with connectors that slot easily on GPIO pins

## MAKING WITH CARDBOARD

Tips for perfect builds

### 01 Measuring and drawing

Although cardboard is a great material to use, and you may have a lot of it, using paper to help plan out your projects can also be good. Use rulers and protractors, and any other drawing tools you have, to mark out what you'd like to do, or just trace the paper you've experimented with. We like to use marker pens to get a very visible line, but a pencil can also be good to start with to get it just right.



### 02 Scoring and cutting

For folding your cardboard, you'll need to do some scoring; this is when you use one scissor blade to run across a fold line without cutting through it to make the cardboard easier to bend. Metal rulers are great to keep these lines straight. When cutting, cut a little outside of the lines you drew. You can always trim them down, but it's harder to add cardboard back on.



### 03 Construction tips

Tabs that slot into other parts of the cardboard are a good way to make construction easier and sturdier. You can also use masking tape and then switch to a stronger tape, use Blu Tack for temporary adhesion, or long and thin bent pieces for gluing. Check out more tips from our friends at Adafruit: [magpi.cc/cardboardtips](http://magpi.cc/cardboardtips).



# TOOLS FOR TEENS

With some maturity comes some responsibility. Here are the kind of things an adolescent could use to make some incredible things and put them on the path of being a master builder

## TOOLS

### Model kits

You can learn a lot by building model robots or planes, from engineering of joints to how to clean up cuts with sandpaper. You can even do custom paint jobs with them. Your nearest hobby store should have some, but we also really like the Bandai Gunpla kits.



WIRECUTTER



SOLDERING IRON



CRAFT KNIFE



3D PRINTER



# MATERIALS

## SOLDER

- ▶ Take your builds to the next level by soldering permanent circuits using a soldering iron and some solder



## ELECTRICAL WIRE

- ◀ This stranded wire is more flexible but doesn't hold its shape like prototyping wire – this is useful for soldering anything that might move around a bit more than a breadboard



## PLA

- ▼ Print 3D designs using a 3D printer. PLA is just one plastic you can use, although they all vary in price and use



## 3D MODELLING TO PRINT

### Tips for perfect models

#### 01 Blender

A free 3D modelling program, Blender ([blender.org](http://blender.org)) is great for creating your own custom models to 3D print. It can be a bit tricky for newcomers though, which is why we recommend the excellent Blender learning courses from the Raspberry Pi Foundation: [magpi.cc/blenderprojects](http://magpi.cc/blenderprojects).

Finished files can be output as an .stl file to work with 3D printers.



#### 02 Tinkercad

While a little more basic than Blender, Tinkercad allows you to create simpler 3D-printable files much more quickly than Blender – especially if you're new to 3D modelling.

You can find it at [tinkercad.com](http://tinkercad.com) and it's all done in your browser. It even lets you import image files and such as well.



#### 03 Combining models

A little trick we've learnt while messing around with miniature figures and other things – you can combine two or more models together in Blender for further modification. This is great if you find something on Thingiverse you like, such as a model car, and want to add a bigger spoiler or a character to the print.



# TOOLS FOR ADULTS



WELDER

While you can definitely stick with the tools and skills from the last few pages for as long as you'd like, here are some excellent tools that will really get your creative juices going



JIGSAW

## TOOLS



TOWER DRILL



HEAT GUN



ROTARY TOOL

### Carpentry resources

Steve Ramsey on YouTube has excellent videos with great carpentry tips and tricks, as well as an online course for people really wanting to get stuck in with carpentry: [magpi.cc/carpentysteve](http://magpi.cc/carpentysteve).

# WORK SPACE UPGRADES

## WORKMATE BENCH



▲ These benches not only have grip and vice capabilities, they also help with drilling thanks to holes you can safely drill over, as well as generally putting projects at a good height to work on

## Learn to weld

Welding can be a really useful tool when working with metal, however it can also be complicated and very dangerous. While there are some YouTube videos you can watch, we recommend finding an online or local course you can do that will teach you how to weld safely.



## VICE

▲ If you need to keep an item perfectly still while sanding, sawing, or drilling, a desk vice is the perfect way to secure objects when you don't have any spare hands



## GRIPS AND CLAMPS

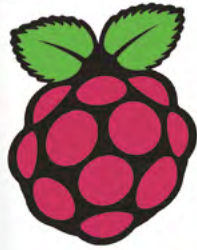
▲ If you need items to stay together when making, some grips and clamps are ideal for holding them in place while you affix them

## Local maker spaces

The expense of tools and materials can really ramp up, and you may not have the space or money for them. This is where a local maker space can be great – these community spaces tend to be filled with all the equipment you could need, as well as folks with experience to get advice from. You could also make a few new friends there.

There's no dedicated website listing maker spaces, so you'll have to use your favourite web search engine for it. [\[7\]](#)

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2022



50 Raspberry Pi  
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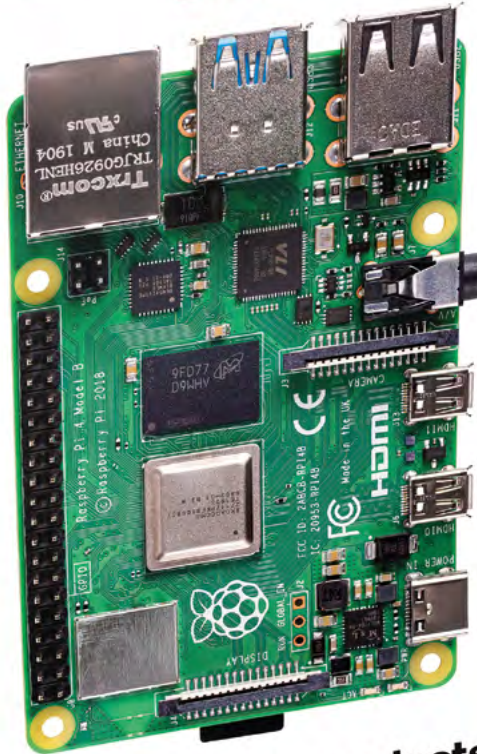
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BeccaCam  
Digital Camera



Raspberry Pi  
Pico projects



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Home Assistant



Raspberry Pi  
Amiga 600



Walking  
Bipedal Robot

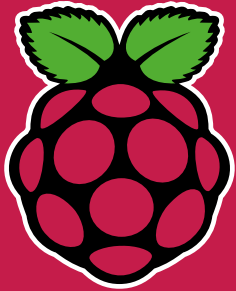


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# Bangle.js 2

## SPECS

### COMPONENTS:

36 mm × 43 mm × 12 mm watch body, with standard 20 mm watch straps; Nordic 64MHz nRF52840 ARM Cortex-M4 processor with Bluetooth LE; 256kB RAM, 1MB on-chip flash, 8MB external flash; 200mAh battery, 4 week standby time

### I/O:

1.3 inch 176×176 always-on 3-bit colour LCD (LPM013M126) with back-light; Full touchscreen (6H hardness glass); Vibration motor; Full SWD debug port

### SENSORS:

GPS/Glonass receiver; Heart rate monitor; 3 Axis Accelerometer; 3 Axis Magnetometer; Air Pressure/ Temperature sensor

► Espruino ► [shop.espruino.com](http://shop.espruino.com) ► £77 / \$98

Develop your JavaScript skills with this hackable smartwatch.

By **Lucy Hattersley**

**B**angle.js is a project by Gordon Williams that aims to place hackable smartwatches on the wrists of makers. Bangle.js 2 is the second iteration of the device, and it swaps the circular screen and buttons of the original for a square touchscreen.

Smartwatches are increasingly part of our digital lives, and as Gordon says: “even if you are an experienced hardware designer, it’s difficult to make a watch that is reliable and useful long-term, let alone waterproof and affordable.”

The hardware is therefore a cheap off-the-shelf unit, built on top of Shenzhen Smart Care Technology’s SMA Q3 ([magpi.cc/smaq3](http://magpi.cc/smaq3)). These units, bought en masse by Gordon, are then reverse-engineered and the stock firmware replaced with an open-source alternative.

So, you get a relatively high-quality watch that is both open-source and programmable.

On the rear sits a four-pin Serial Wire Debug (SWD) port that can be used for connection and charging. You upload apps and code via Bluetooth, and SWD enables direct connection to replace the whole firmware if you wish.

The hardware is pleasant to use. Bangle.js 2 has a 1.3-inch touchscreen display with a single push-button on the right-hand side. The specifications are a none too shabby Cortex-M4 processor, 256kB RAM, and 1 MB on-chip flash and 8 MB external.

There is a choice of three colours: black, blue, and pink. We got the pink model in for testing and it’s a nice-looking watch that your reviewer is happy to wear all day.

Don’t be fooled: the comparison isn’t between Bangle.js 2 and a big brand watch. The default interface is clunky, the text can be tiny, and the bare-bones experience is Spartan. However, a recent 2v11 firmware update has boosted the default text size of the interface and new features are being added all the time.

The real fun begins when you connect Bangle.js 2 to Raspberry Pi and open the Espruino IDE and app store.

## Roll your own

Development takes place in Chrome, and because Raspberry Pi OS ships with Chromium, you’ll need to adjust a few settings to get things working. We enabled Experimental Web Platform Features and Web Bluetooth ([magpi.cc/espruinobt](http://magpi.cc/espruinobt)).

Apps are loaded via a website ([banglejs.com/apps](http://banglejs.com/apps)) that acts as an app store and installation platform,



▲ Based upon an off-the-shelf unit, the Bangle.js 2 is a nice-looking hardware package



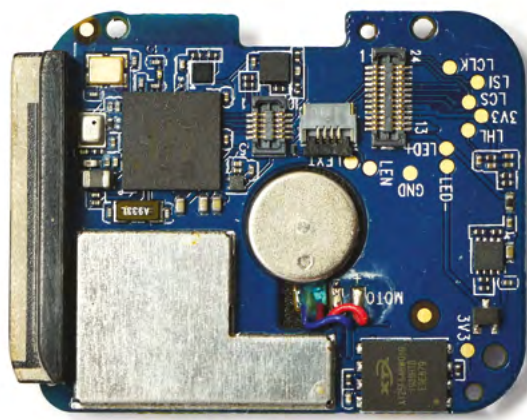
▲ The interface may be bare-bones, but it's what you do with it that counts

“ The real fun begins when you connect Bangle.js 2 to Raspberry Pi and open the Espruino IDE ”

with the bonus that code for the apps is available for inspection on GitHub.

Apps are developed by a vibrant community using JavaScript code. And you can develop your apps using Chromium in Raspberry Pi to access the Espruino web-based IDE ([espruino.com/ide](https://espruino.com/ide)).

Espruino is a JavaScript interpreter for microcontrollers, which turns out to be a good fit for the Bangle. Bangle.js 2 comes with a range of documentation to help you on your development journey ([magpi.cc/bangle2docs](https://magpi.cc/bangle2docs)). The tutorial section ([magpi.cc/bangle2tuts](https://magpi.cc/bangle2tuts)) has a range of development tutorials, including making an app. Some of these were created with the Bangle.js 1 in



▲ The PCB inside Bangle.js 2

mind (which had three buttons) and we needed to swap out the button references to get the starter code working. There are a few tutorials specifically designed for Bangle.js 2, and a great community you can reach out to for support ([magpi.cc/bangleforum](https://magpi.cc/bangleforum)). On the whole, we are having a lot of fun with Bangle. ”

## Verdict

There isn't anything else like Bangle on the market, and it's a great addition to your Raspberry Pi setup. Bangle is a fun way to boost your JavaScript skills, and a great way to integrate wrist-based feedback and interaction into projects.

9/10

# Maker HAT Base for Raspberry Pi 400

## SPECS

### CONNECTOR:

40-pin female-to-female 10cm ribbon cable with plastic clip

### FEATURES:

GPIO header, 4 × push-buttons, piezo buzzer, female breakout header with status LEDs, 3 × Grove connectors (GPIO, UART, I2C)

### COMPATIBILITY:

Works with any Raspberry Pi model

► The Pi Hut ► [magpi.cc/makerhatbase](https://magpi.cc/makerhatbase) ► £9 / \$10

A whole lot more than a simple GPIO header extender. By **Phil King**

**A**s well as extending the pins of Raspberry Pi 400's GPIO header, Cytron's Maker HAT Base has a fair few tricks up its sleeve.

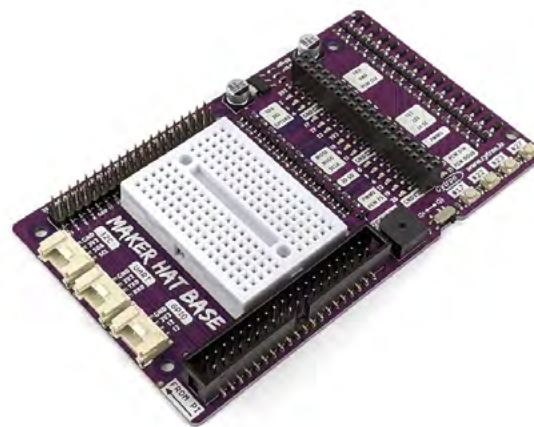
Using a standard HAT with Raspberry Pi 400's GPIO header isn't ideal due to the latter's position at the rear of the keyboard unit, which means that a display or LED matrix HAT faces backwards. Supplied with a short ribbon cable to connect to the GPIO header, the Maker HAT Base makes it easier as you can mount the HAT vertically on the board's GPIO header, just as you would on any other Raspberry Pi model.

The Maker HAT Base is equipped with quite a bit more functionality, including on-board push-buttons, buzzer, and mini breadboard, plus a female breakout header.

## Base for electronics

The sticky-back mini breadboard fits into a space in the middle of the board. Note that if you're using a HAT, it will cover the breadboard – and there's not a lot of clearance. Still, it's a nice addition.

We really appreciate the labelling of the GPIO pins, too, which makes it much easier to find the



▲ The board also acts as a mini electronics lab, complete with breadboard, buzzer, buttons, and breakout header

“ There's a full female GPIO breakout header that you can use even with a HAT attached to the pins ”

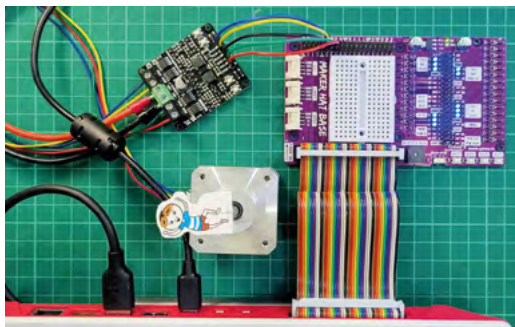
pin you need rather than having to count along the rows. Even better, there's a full female GPIO breakout header that you can use even with a HAT attached to the pins, so you can connect jumper wires to electronic circuits on a separate breadboard. A bonus is the inclusion of four on-board push-buttons and a buzzer (with a switch), pre-wired to certain GPIO pins.

As well as being fully labelled, the female header has a status LED for each pin, which tells you whether it's currently pulled high or low. This should prove useful, especially for beginners, when debugging your own circuits and programs. ”

## Verdict

Far more than a GPIO header extender, this feature-packed electronics breakout board represents excellent value for money.

9/10



▲ With the Maker HAT Base connected to Raspberry Pi 400, this example setup is controlling a stepper motor



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# 10 Amazing: Small projects

Make something that doesn't take up that much space

One of the best features of Raspberry Pi and Raspberry Pi Pico is that they're very small, which means you can slip them into projects or hide them around your house. Here are some of the best smaller projects for you to check out. [M](#)



## ▲ OctoCam

### Zero camera kit

This fun little Raspberry Pi Zero kit will help you attach a camera to a window so that you can track wildlife, or the weather, or whatever you wish.

[magpi.cc/octocam](http://magpi.cc/octocam) | £43



## ▲ Digital Orrery

### Solar system clock

This little clock not only tells you the time, but also depicts the exact arrangement of planets in the Solar System at the same time! You can also move it forwards or backwards to see the planets at that time.

[magpi.cc/picosolar](http://magpi.cc/picosolar)

## ▶ Smart doorbell

### See who's there

Want to make your own Nest-style doorbell? This project will help you do so, without having to go through Google.

[magpi.cc/smartdoorbell](http://magpi.cc/smartdoorbell)



## ▼ Media centre

### Watch and play

It's very easy to turn a Raspberry Pi Zero of any kind into a media centre using something like LibreELEC. Just get a nice case and you're sorted.

[libreelec.tv](http://libreelec.tv)





## ▲ PiGRRL Zero

### Handheld gaming

This very tiny version of the PiGRRL that Adafruit made is about as big as a Raspberry Pi Zero. It's a fun, if not delicate, project to recreate.

[magpi.cc/pigrrlzero](http://magpi.cc/pigrrlzero)



## ◀ Raspberry Beret

### Wearable song reference

Alan McCullagh's light-up beret also has music and a camera, along with a nice 3D-printed Prince... symbol? Logo? It's very cool either way.

[magpi.cc/raspberryberet](http://magpi.cc/raspberryberet)

## ▼ PiE-Ink Name Badge

### Smart identification

This reusable name badge can be customised to display whatever you'd like! Don't abuse this power.

[magpi.cc/smartbadge](http://magpi.cc/smartbadge)



## ▲ Raspberry Pi Smart Watch

### Wrist-bound computing

You could get an Apple Watch, or you could make your own smartwatch with Raspberry Pi and some 3D-printed parts.

[magpi.cc/smartwatch](http://magpi.cc/smartwatch)

## ► Laptop

### Palm-sized computing

This clamshell laptop is very small thanks to a Zero – you could upgrade it to a Zero 2 W now as well, for even faster computing in your pocket.

[magpi.cc/74](http://magpi.cc/74)



## ▼ Autonomous Robotics Platform for Pico

### Tiny Pico robot

This little robotics platform makes full use of Pico, not only in terms of programming but also size.

[magpi.cc/picorobotics](http://magpi.cc/picorobotics) | £41



# Learn AI with Raspberry Pi

Expand your knowledge of artificial intelligence with these resources. By **Phil King**

## Make Your Own Neural Networks

**CREATOR**  
Tariq Rashid

Price:  
£32 / \$39

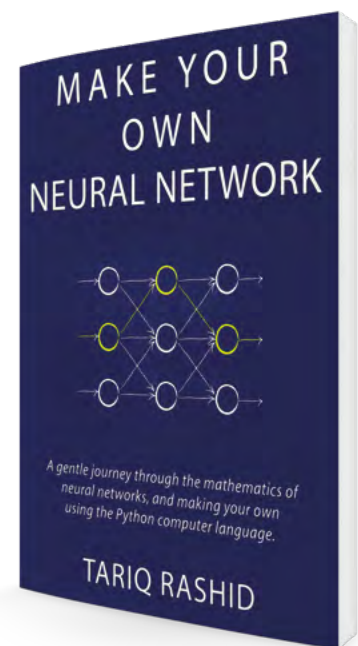
[magpi.cc/neuralbook](http://magpi.cc/neuralbook)

**Artificial intelligence (AI) research dates back to the 1950s, when scientists started creating biologically inspired electronic circuits that could function in a similar manner to the human brain using a ‘neural network’ of connections.**

Things have come a long way since those very basic first machines, but the concept remains the same. Aimed at beginners (no specialist knowledge is required beyond school maths), this easy-to-follow book comprises three main parts. The first teaches

you how neural networks work. The second is more practical, guiding you through the process of using Python to program your own neural network that can be trained to recognise human handwritten characters – a task that is very difficult using traditional approaches to computing.

The third and final part takes it further as you test out your neural network and try to improve its performance. An appendix shows how to get it all working on a Raspberry Pi using IPython and Jupyter notebooks.



## Machine Learning

**CREATOR**  
Coursera

Price:  
Free to enrol

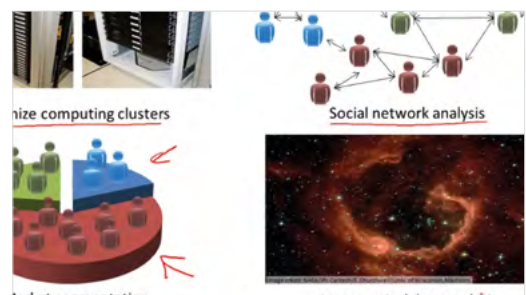
[magpi.cc/mlcoursera](http://magpi.cc/mlcoursera)

**Machine learning (ML) is the science of getting computers to act without being explicitly programmed. It has led to major advances in AI, resulting in improved speech recognition, computer vision, and self-driving cars, to name but a few.**

In this free Coursera course from Stanford University, Andrew Ng takes you through the fundamentals of machine learning in an easy-to-understand manner, via videos and written materials. You will

learn about the most effective ML techniques and how to implement them yourself, so it's a combination of theory and practical know-how.

Areas covered include data mining and statistical pattern recognition, with topics ranging from supervised and unsupervised learning to



best practices in ML. You'll also discover how learning algorithms are applied in fields such as smart robots and medical informatics.

# Teach Your Raspberry Pi

CREATOR


Arm

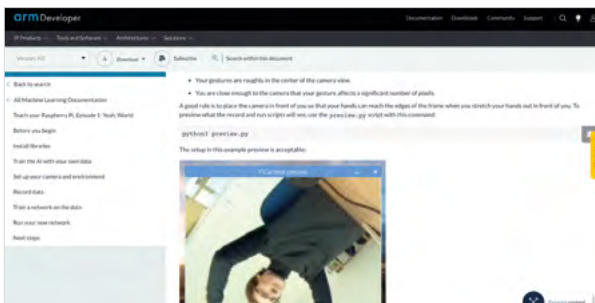
Price:  
Free[magpi.cc/teachyourpi](http://magpi.cc/teachyourpi)

Created by Arm, which makes the Cortex CPUs for Raspberry Pi computers, this is an excellent web resource for artificial intelligence newcomers. While some AI projects require the use of an add-on hardware accelerator

such as Google's Coral USB Accelerator, this one will work on any Raspberry Pi computer, including the Zero.

The tutorial guides you through the process of installing TensorFlow and the necessary libraries before training the AI. This involves setting up a Camera Module and environment, recording some data, and then training a new neural network based on it.

The finished model will be able to tell whether the person on camera is cheering, sitting, or exhibiting random behaviour. Episode two deals with multi-gesture recognition. 



## Online courses

Learn about AI with these free online courses



### INTRODUCTION TO MACHINE LEARNING AND AI

Created by the Raspberry Pi Foundation, this four-week FutureLearn course explores different types of machine learning and shows you how to train your own AI using free online tools.

[magpi.cc/futurelearnml](http://magpi.cc/futurelearnml)

### LEARN WITH GOOGLE AI

Google's education site is a great place to start your journey into exploring AI. The 37 resources here include guides and full courses – start with the Machine Learning Crash Course. [ai.google/education](http://ai.google/education)

### FUNDAMENTALS OF DEEP LEARNING FOR COMPUTER VISION

Computer vision is a subdivision of AI, and this hands-on course from Nvidia shows you how to implement common deep learning workflows such as image classification and object detection.

[magpi.cc/nvidiacv](http://magpi.cc/nvidiacv)

## Books to read

Books to help you discover more about AI

### BEGINNING ARTIFICIAL INTELLIGENCE WITH THE RASPBERRY PI

Covering concepts such as neural networks, fuzzy logic, and deep learning, it also provides practical, fun projects to code and build, culminating in an AI robot vehicle.

[magpi.cc/beginaibook](http://magpi.cc/beginaibook)

### THE HUNDRED-PAGE MACHINE LEARNING BOOK

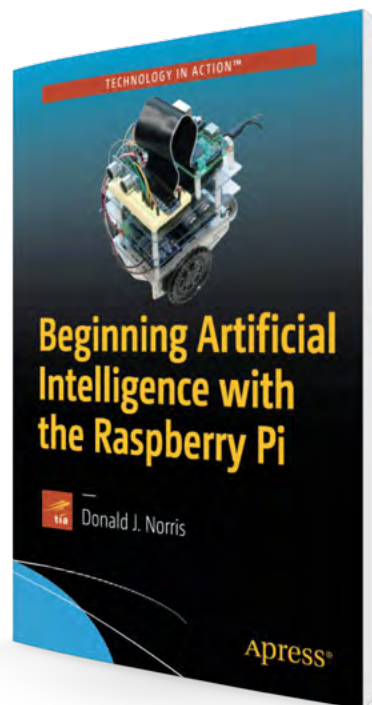
Learn all about machine learning in... it's actually 160 pages, but still an impressively concise introduction to the field, covering the fundamentals in an easy-to-understand fashion.

[themlbook.com](http://themlbook.com)

### HELLO WORLD

If you're interested in the impact AI is having on every aspect of our modern lives, and where it might be heading in the future, Hannah Fry's book is a fascinating read.

[magpi.cc/hwbook](http://magpi.cc/hwbook)





# Alex Glow

AI, robotics, PCB design, 3D printing, art, and more. It's Alex Glow

- > Name **Alex Glow** | > Occupation **Video host**
- > Community role **Maker leader** | > Website **@glowascii**

**If you're involved at all with the online maker community, you've definitely seen Alex Glow's face somewhere.**

Whether doing video tutorials, unboxing, interviewing, or just generally showing off a very cool project, she's everywhere.

"When I was a kid, I'd take apart anything", Alex says about her maker history.

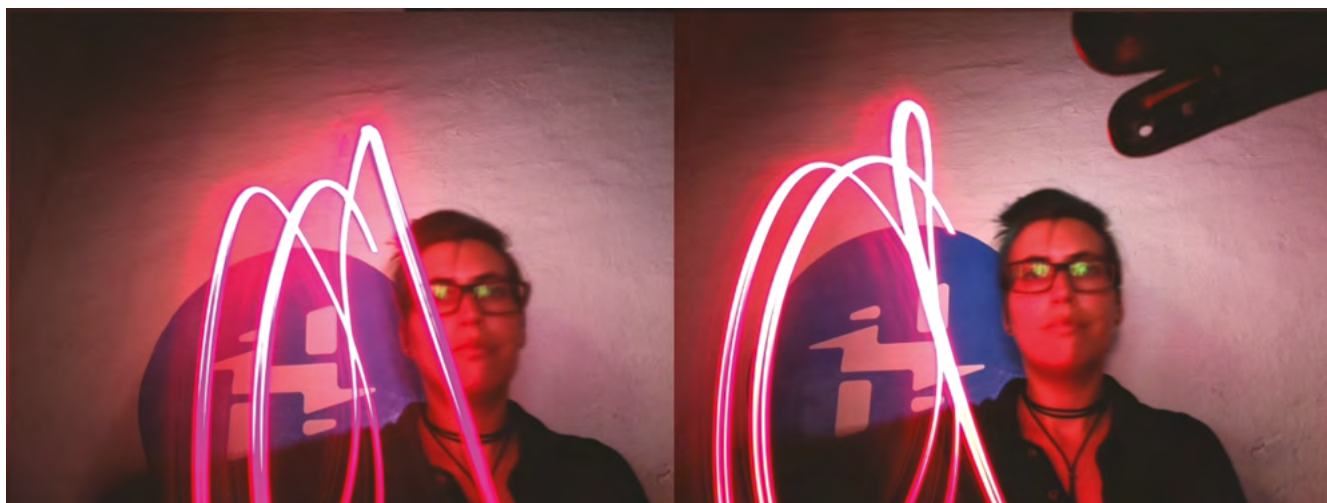
"Keyboards, dolls, and so on. I was raised by many people with their own creative endeavours: my bio-dad showed me how

to solder, my foster parents taught me to crochet, and my adoptive parents made amazing Halloween costumes, foods, and home improvements. As a pre-teen, I got really into fountain pens and creating illuminated manuscripts; then, costumes, cut paper, and 2D wire drawings. I joined the FIRST Robotics team in high school, where I learned how to solder and program a little (beyond what I could do on the TI-83+). I dug deeply into human languages – Spanish,

Russian, and Mandarin – and holography. Something about that art, steeped in the dark, catching ghosts in glass plates, is so magical to me.

I helped start the Ann Arbor maker space (All Hands Active / AHA) and worked at a screen printing shop. I started a weekly blog about my projects in 2009, making juggling balls, notebooks, a crappy amplifier for my mandolin, and more. I worked tech support for years while doing hardware in my free time.

▼ Light writing using long exposure times



Lately, I've been embracing machine-centric arts... AxiDraw pen plotting, 3D printing, laser cutting, PCB design, and so on. But I still love to create with just my hands."

### How did you learn about Raspberry Pi?

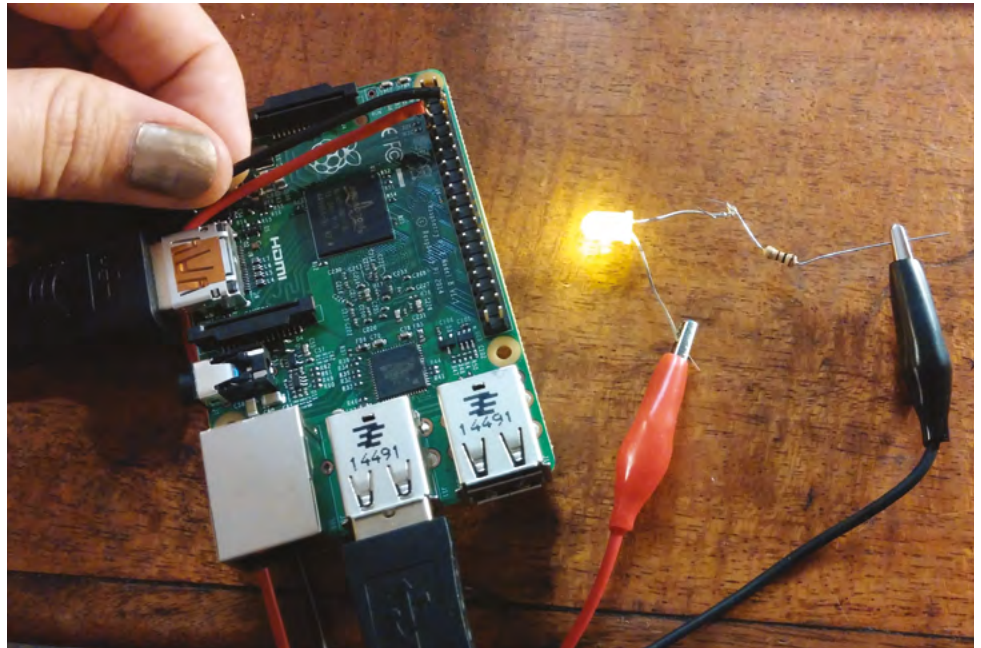
It must have been through friends at AHA... gotta be eleven years ago at this point! I do also have a sheaf of Raspberry Pi ad cards I got at a long-ago Maker Faire, advertising things like Sonic Pi tutorials. No lie, I've probably been carting those around for over a decade now. I'm sure I'll get to them soon.

### What led you to join Hackster?

I was there at the beginning! Our founders, Ben and Adam, had just gotten together and decided to merge their visions into one venture. Ben and I had a mutual friend, Cedric Honnet, who thought I could help them build out a community, reaching out to hardware companies and potential members, plus writing some tutorials to populate the platform. At the time, I thought it would just be "another Instructables", but I soon saw the difference, with the focus on electronics and connecting creators directly with hardware manufacturers.

### What is your favourite thing you've made?

Off the top of my head, it's gotta be one of the companion bots! Either Archimedes or F3NR1R – Archie because he was my first, and because I've gotten so much joy out of connecting with people at Maker Faires and beyond through him... and F3N was only finished [over the last two years], but he has a cute speaking voice and a really fun design. But on another note, I've also been



able to build a long-time dream: a stereoscopic light-painting camera! Using the StereoPi – a dual camera setup for the Compute Module – and a long-exposure raspistill command, I'm able to draw things in the air with an LED, then view the whole thing as a 3D image! Magical. I still need to polish that one and write it up more fully. [\[7\]](#)

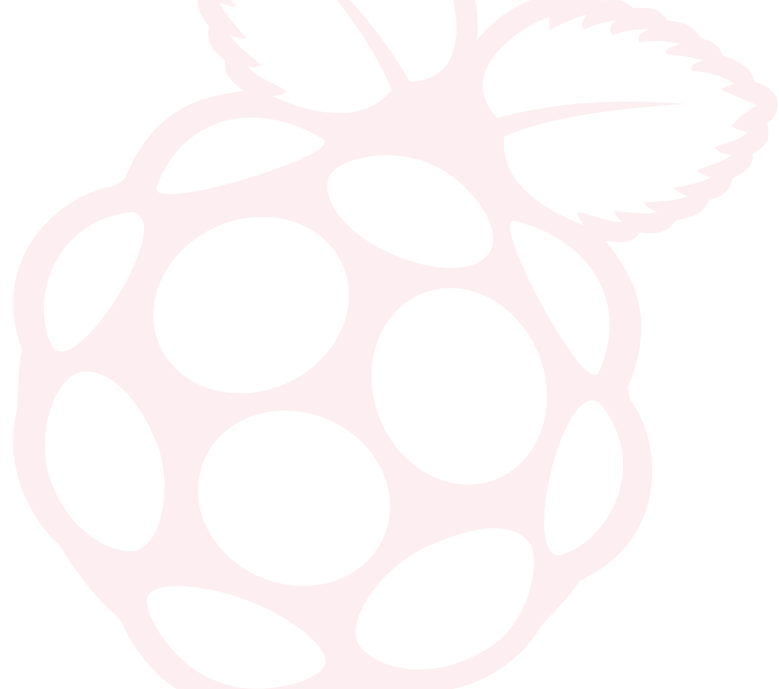
## First Raspberry Pi build

"The first time I blinked an LED with a Raspberry Pi is documented on Hackster. It was a Raspberry Pi 2 Model B, and I was supposed to demo Samsung's SAMI control center for IoT. I was delighted to be able to control GPIO pins from Mathematica! It was so strange to connect the 'imaginary' terminal with a physical LED."



▲ Alex's first Raspberry Pi project

◀ Archimedes is a robot owl, which is often seen on Alex's shoulder



# MagPi Monday

Amazing projects direct from our Twitter!

**E**very Monday we ask the question: have you made something with a Pi over the weekend? Every Monday, our followers send us amazing photos and videos of the things they've made.

Here's a selection of some of the awesome things we got sent this month, and we got quite a lot! Remember to follow along at the hashtag #MagPiMonday! 📸

01. We've always loved the idea of 3D-printing parts for your 3D printer
02. A very classic doorbell updated for the modern age
03. Multi-core programming is a little tricky but the results are great
04. The Apple Watch GUI is very neat, so we like this experiment
05. The audio bit is a nice touch – hopefully the radiators are up to the rest of the heating task!
06. We like that these nodes live in classic computer shells
07. One day we would also like to (safely) create an IoT lawnmower
08. Looks great, and is now a lot lighter without the CRT display inside
09. A fun visualisation of the steps in using flight tracking hardware
10. A great idea for a maker space's wall clock!
11. A fun dice program using LEDs and simple bash scripts



**Dr Footleg - Roboteer**  
@drfootleg

01

Replying to @TheMagPi

I finished my OctoPi with camera and LED lighting set up for my 3D printer, using a Pi Zero 2 W. All mounted using 3D printed cases and arms which bolt onto the metal extrusion that makes up the printer frame.  
#MagPiMonday





**Mark Cantrill**  
@AstroDesignsLtd

02

Replying to @TheMagPi

I finished a #raspberrypi doorbell that i'd been working on over Christmas. Just a simple thing that goes ding-dong for Mrs C... Then while she wasn't looking I sneaked in push notifications to my phone, Alexa announcements via Voice Monkey and it also turns the porch lights on 😊





**03**

**diyelectromusic**  
@diyelectromusic

Replying to @TheMagPi

I've been learning about multi-core programming in Micropython on the Pico, using it for some MIDI note visualisation.

**diyelectromusic** @diyelectromusic · Jan 8  
Two #MIDI visualisations at the same time using multi-core programming in #Micropython on the @Raspberry\_Pi #PiPico using the SSEGLED and RGBLED modules from @Waveshare00

diyelectromusic.wordpress.com/2022/01/08/pic...

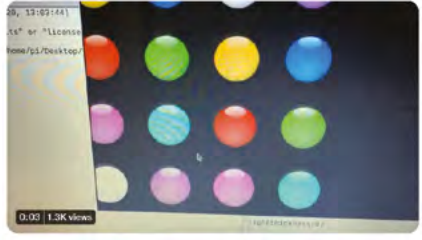


**04**

**Martin Parker**  
@Mr\_MartinParker

Replying to @TheMagPi

An update on my attempt at making a #Python GUI to look like my #AppleWatch. Clickable buttons although no command set but able to drag around and off screen. On another version I have the buttons getting smaller when close to edge of screen. #RaspberryPi




**05**

**Mike Fell**  
@mikefsway

Replying to @TheMagPi

We're minimising stove use due to air pollution. I'm working on a simulator to reproduce the look and sound. Uses a @pimoroni unicornhatmini in a box with translucent cover running adaptation of the forest fire program, while also playing audio. Surprisingly realistic at night!



**08**

**Will Hall**  
@LimeParallell

Replying to @TheMagPi

Not strictly this weekend but I made a custom wall clock 🕒 as gift 🎁 for my school tech dept. It uses a Raspberry Pi Zero to integrate with their @OctoPrint3D system and displays the remaining print time of the 3D printers in the workshop. 🙌



**06**

**Kevin McAleer**  
@kevinmac

Replying to @TheMagPi

#MagPiMonday Here's my weekend project - Setting up clustered-pi.com on a number of Raspberry Pi Nodes, I started with a bunch of RPi 4's and am now moving over to a bunch of Raspberry Pi Zeros. #raspberrypizero2 #retro #3dprint #stem #opensource




**07**

**TGD**  
@TGD\_Consulting

Replying to @TheMagPi

Saw this on #YT last weekend. #Upcycling an old lawn mowing robot with a Raspberry Pi and the PiMowBot software. Nice #IoT upgrade to reuse your old or broken lawn power tools again. #DIY #MagPiMonday #MagPiTuesday

youtube.com  
DIY Automow Rasenmäher mit PiMowBotIT Software und Fi...  
Dieses Video ist ein Summary der Aktivitäten aus dem Projekt im Jahr 2021Zusätzlich zum Software Release von ...




**09**

**muckypaws**  
@muckypause

Replying to @TheMagPi

My latest project, dashboard for flightaware data!




muckypaws.com  
Ground Control to Major Tom - Part 3 - Dashboard  
Following on from my Ground Control to Major Tom project, I offer a simple Dashboard using a two line LCD Display and some cheap components to show ...

**10**

**PSteynberg**  
@PSteynberg

Replying to @TheMagPi

Did this a few months ago. Raspberry Pi 4, old iMac with guts and screen removed. Secondhand LCD screen fitted, sound bar and Pi inside with bluetooth micro keyboard/mouse. Can run Spotify, Netflix, BBC, NowTV, Disney+ etc etc. Looks sexy and very useful.



**11**

**গণতন্ত্র -মারত- Bhārat**  
@Bharatmohanty\_

Replying to @TheMagPi

A RASPBERRY PI ZERO DICE without any high level programming language... (Using shell scripts)

youtube.com  
RASPBERRY PI DICE  
this is the raspberry dice using shell scriptvnc on raspberry pi  
https://youtu.be/qCjCH6RzSR0\*\*\*\*\*RA...



**13**

**Stewart Watkiss**  
@stewartwatkiss

@TheMagPi

I've made some updates to my #RaspberryPi wireless pixel server. Control RGB LEDs / NeoPixels using a web interface.

Now with more sequences.

[youtu.be/ZVnujsKH-oA](https://youtu.be/ZVnujsKH-oA)


#MagPiMonday

youtube.com  
Raspberry Pi NeoPixel Server - Update  
This is an update to my Wireless Pixel Server - controlling RGB LEDs / NeoPixels using a Raspberry Pi. In this video I've...

**12**

**Pierre-yves Baloché**  
@FunkyPiwy

As it is #3DThursday, I finally managed to complete in time my enclosure for @pimoroni great 8" screen, ideal to work with the #raspberrypi400, and others too. Couldn't wait to share it with the community 😊 before the next #MagPiMonday to finish this year's #3Dprinting projects.

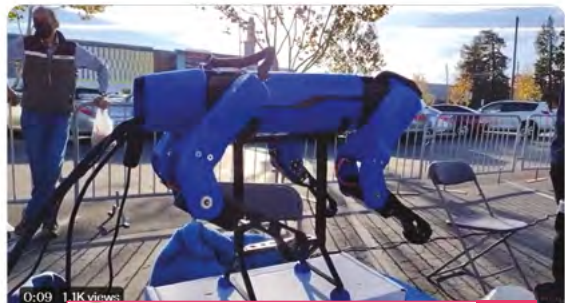


**14**

**D.D.**  
@DRoboticsChick

Replying to @TheMagPi

Had a great time making my spot micro move with a raspberry pi zero 2 w. Added buttons and brought it to #RobotsOnIce to be interactive with kids and grownups!



0:09 1.1K views

**Scott Young**  
@thebotmakes

**15**

Replying to @TheMagPi

I got my pi zero Christmas @cheerlights tree to speak to a adafruit circuit playground bluefruit powered bauble and now have a cheerlights bauble! Never dealt with Bluetooth before but the #circuitpython libraries for Pi helped a lot. I love cheerlights! #MagPiMonday



- 12. The colouring on this being based on Raspberry Pi accessories is great
- 13. Stewart Watkiss from last issue's interview is a great follow for useful updates like this
- 14. This robot is fun for all ages
- 15. The only Christmas project we got over the last month, but it's a cool one

# Best of the rest!

Amazing projects that we were contacted about this month

## HEART RATE DETECTION

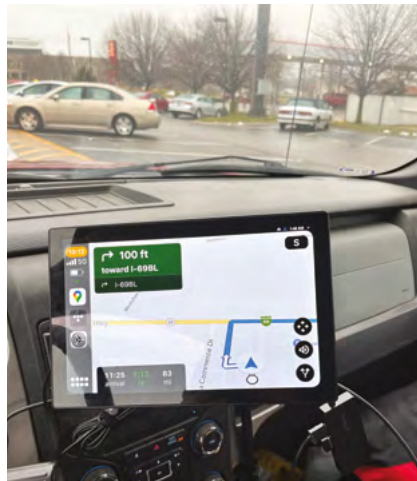
> [magpi.cc/GtyfhE](https://magpi.cc/GtyfhE)

This exceptionally clever piece of tech uses Eulerian Magnification which lets you analyse video frames to determine a heart beat.

## BETTER SAFE THAN SORRY

> [magpi.cc/XSqC1V](https://magpi.cc/XSqC1V)

This funky robot has sensors that let it know if there is nowhere for its foot/leg to go, announces this, and then moves backwards. Clever!



## OPENAUTO PRO

> [magpi.cc/k8QZR4](https://magpi.cc/k8QZR4)

OpenAuto is software that acts like a modern car computer system, and this one is running on Raspberry Pi.

# Crowdfund **this!** Raspberry Pi projects you can crowdfund this month

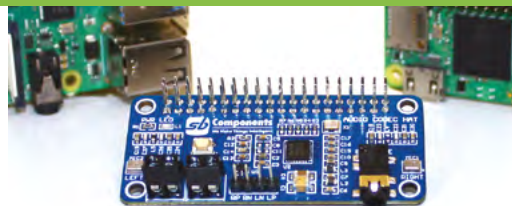
**L76X GPS HAT FOR RASPBERRY PI**  
Setup Global Positioning System for RPi



## GPS HAT

"The extremely compact and powerful GNSS module GPS HAT for Pi is a concurrent receiver module that integrates GPS with the BeiDou system. It's pin-to-pin compatible with Quectel's GNSS module L76 and can receive both GPS and BeiDou open service L1 signals at the same time."

> [kck.st/3qz4wb2](https://kck.st/3qz4wb2)



## Audio Codec HAT

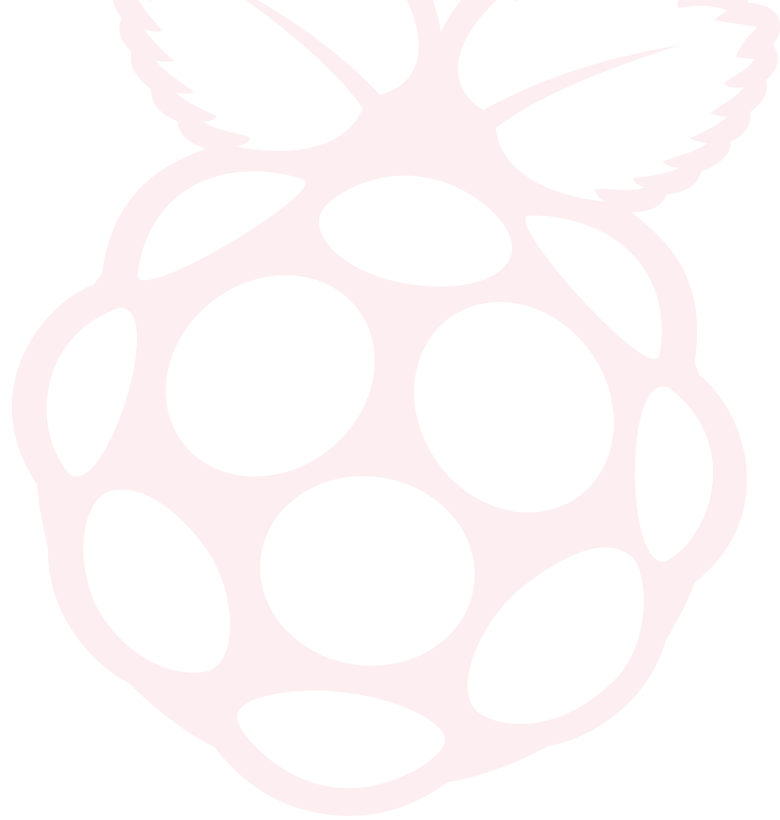
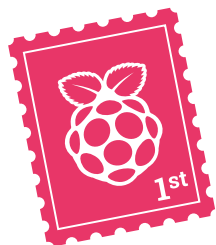
"Audio Codec HAT is a low-power, high-quality stereo CODEC designed for portable digital audio applications which is based on WM8960 IC that have the advantages like low leakage, excellent PSRR and pop/click suppression mechanisms which allow direct battery connection to the speaker supply."

> [kck.st/34ugxqZ](https://kck.st/34ugxqZ)

**CROWDFUNDING A PROJECT?**

If you've launched a Raspberry Pi-related project, let us know!  
[magpi@raspberrypi.com](mailto:magpi@raspberrypi.com)

# Your Letters



▶ A quick little hack and this tinsel is controller by Pico



▲ We're still offering a free Zero 2 W with all 12-month print subscriptions!

## Free gift check

When will my Raspberry Pi Zero 2 W gift arrive after I subscribe to the magazine for twelve months in print?

**lbs** via Twitter

Depending on where you subscribed from, it may take a little while since we are based in the UK. If you are concerned, you can contact [magpi@subscriptionhelpline.co.uk](mailto:magpi@subscriptionhelpline.co.uk) for any and all subscription enquiries, including where your free gift might be.

## #MagPiMonday email edition

I am writing because I have made a project which I would tag with #MagPiMonday, but I'm too young for social media. I have some light-up tinsel that I put on my mini Christmas tree. It's either solid on or solid off. I found on the battery-box a 2-pin JST connector from the display in the shop.

I did not have a 2-pin JST connector, however, so I just connected it to my Raspberry Pi Pico. I now can control my tree with PWM.

**Leo** via Email

Yes, we sometimes forget that not everyone is old enough for social media! You can always email us any projects you make, or get a parent or guardian to send it to us on social media. This is a cool little hack, but remember never to do this with anything with high voltage!

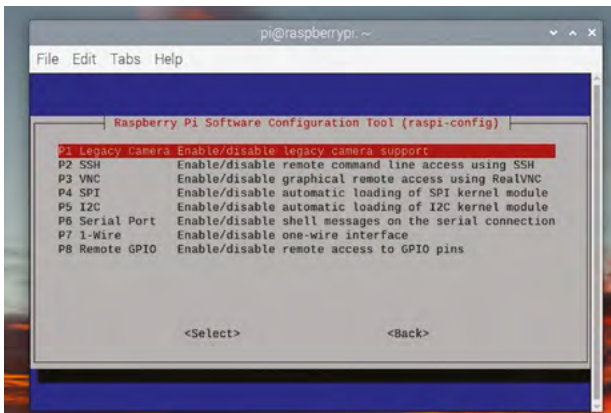


## Cameras and Bullseye

I'm still having trouble figuring out the best way to use cameras now Raspberry Pi OS Bullseye is out. I'm happy to learn new ways to use Camera Modules, but I have some stuff that already works with raspistill. Any tips?

Tan via Facebook

Since release, Bullseye has had some updates that allow it to use raspistill, which is great if you have an existing bit of software that uses it. Otherwise, you can still easily install Raspberry Pi OS 'Legacy', which is the previous Buster version of Raspberry Pi OS. This has some updates, but not all the security stuff that Bullseye does. For the long term, you should consider using Bullseye.



▲ You can activate legacy camera options from raspi-config in the Terminal

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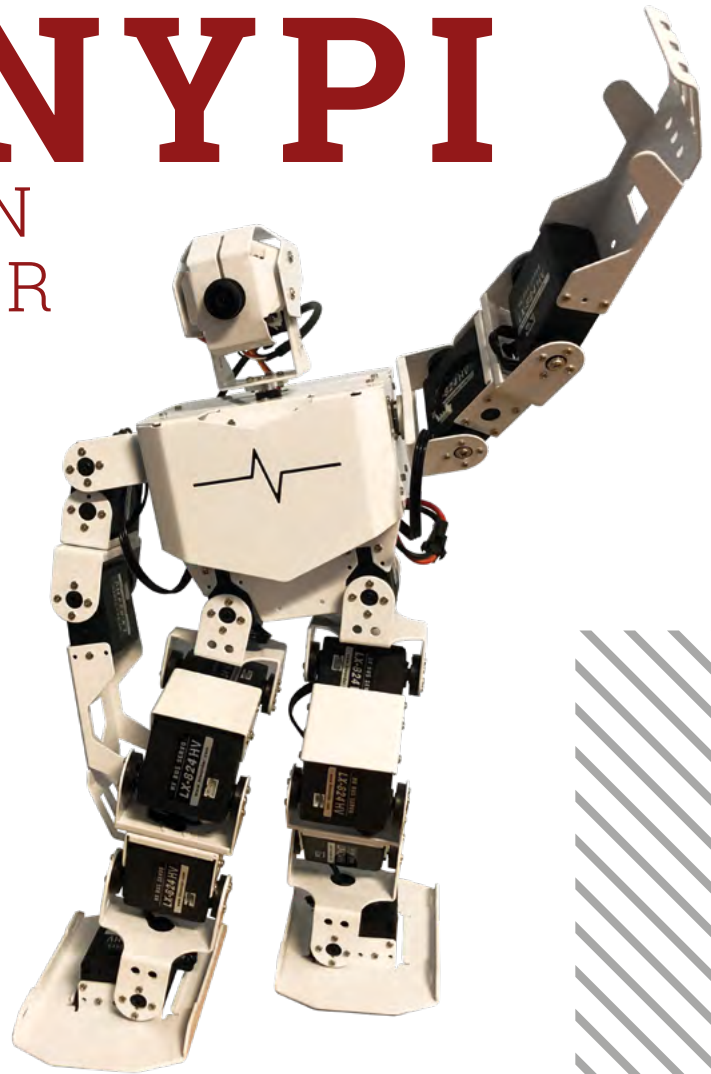
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WIN

# A TONYPI

IN ASSOCIATION  
WITH HIWONDER

TonyPi is an incredible humanoid Raspberry Pi robot which we reviewed way back in issue 111. It's 37 cm tall and specialises in object recognition, and is easily remote-controlled to move as well. We have one to give away.



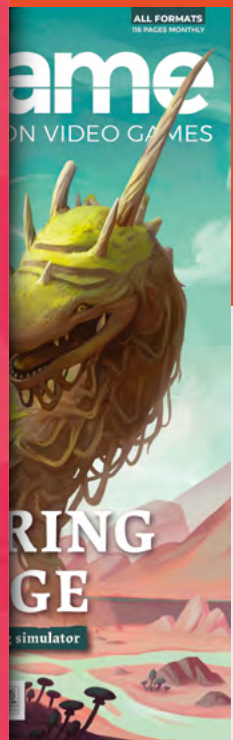
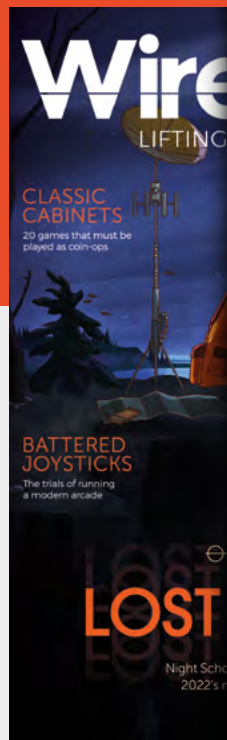
Head here to enter: [magpi.cc/win](https://magpi.cc/win) | Learn more: [hiwonder.hk](https://hiwonder.hk)

## Terms & Conditions

Competition opens on **26 January 2022** and closes on **24 February 2022**. Prize is offered to participants worldwide aged 13 or over, except employees of the Raspberry Pi Foundation, the prize supplier, their families, or friends. Winners will be notified by email no more than 30 days after the competition closes. By entering the competition, the winner consents to any publicity generated from the competition, in print and online. Participants agree to receive occasional newsletters from The MagPi magazine. We don't like spam: participants' details will remain strictly confidential and won't be shared with third parties. Prizes are non-negotiable and no cash alternative will be offered. Winners will be contacted by email to arrange delivery. Any winners who have not responded 60 days after the initial email is sent will have their prize revoked. This promotion is in no way sponsored, endorsed or administered by, or associated with, Instagram or Facebook.

# Wireframe

Join us as we lift the lid  
on video games

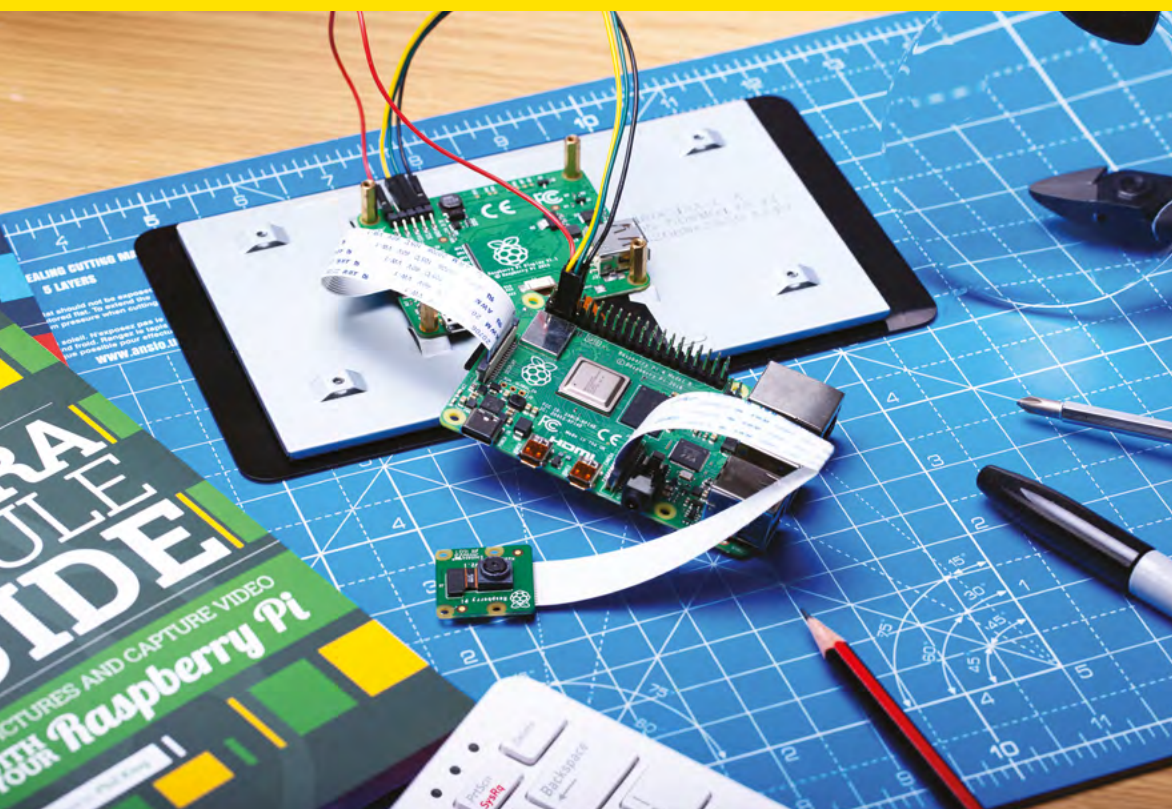


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# Travel in time

**K.G. Orphanides** wants you to play and program imaginary retro games

**P**eople get excited about old games. It's not exactly a secret, given the ongoing boom in remakes, remasters, and repackaged classics. But there's something special about trying to come as close as you can to the original gaming experience.

Perhaps the most surprising thing I've found over years of building emulation systems is how broad their appeal is. Kids who have never known a time without HD screens and realistic 3D take to pixelated platformers and EGA edutainment software without a blink.

Even the difficulty spikes of old-school arcade classics, designed to separate players from their money as efficiently as possible, become artful punctuation in the language of play, thanks to the save states and infinite credits of an emulator-based arcade cabinet.

With greater access to development tools, approachable languages, and supportive communities, game creation is also being radically democratised. And just as there are many people who love to play retro games, there are plenty of individuals and development teams who have set out to create their own.

This can go as far as full-scale releases on physical cartridges and

major digital platforms, particularly when it comes to the rich world of Sega Mega Drive and other classic consoles, but both the aesthetic and the inherent technical limitations of developing for older hardware have appeal.

Technical limitations in resolution, memory size, and audio voices can make your game simpler to program. This has directly led to the rise of Fantasy Consoles, virtual 8-bit

and an unofficial ARM build of Pixelorama ([magpi.cc/pixelorama](http://magpi.cc/pixelorama)) is now available.

More modern retro aesthetics can be found in the low-rez horror games exemplified by the Haunted PS1 Demo Disc series ([magpi.cc/hauntedps1](http://magpi.cc/hauntedps1)).

Although Unity and Unreal Engine don't run on Raspberry Pi, the impressive Godot engine does ([magpi.cc/godot](http://magpi.cc/godot)), albeit with a few limitations.

## “ Pixel art is still going through a years-long renaissance ”

machines that run on your computer. Priced at \$15 (£11), Pico-8 ([magpi.cc/pico8](http://magpi.cc/pico8)) is the best-known of these, with official support for Raspberry Pi and a great community.

Pixel art is still going through a years-long renaissance, with many artists deliberately adopting 256-, 16-, and even four-colour palettes. You'll see these choices reflected in games as disparate as Unpacking (through its EGA camera filter) and The Eternal Castle, a 'remake' of a game that never existed. If you want to start making pixel art on Raspberry Pi, Aseprite ([magpi.cc/aseprite](http://magpi.cc/aseprite)) can be compiled,

We've got you covered if you want to begin your journey into retro game programming right here with PyGame Zero ([magpi.cc/pygamezero](http://magpi.cc/pygamezero)).

Meanwhile, for those who want to get a feel for techniques from the past and present, BBC BASIC ([magpi.cc/bbcbasic](http://magpi.cc/bbcbasic)) is available for Raspberry Pi, while developing with using C++ and SDL is far more fun that it has any right to be. [↗](#)

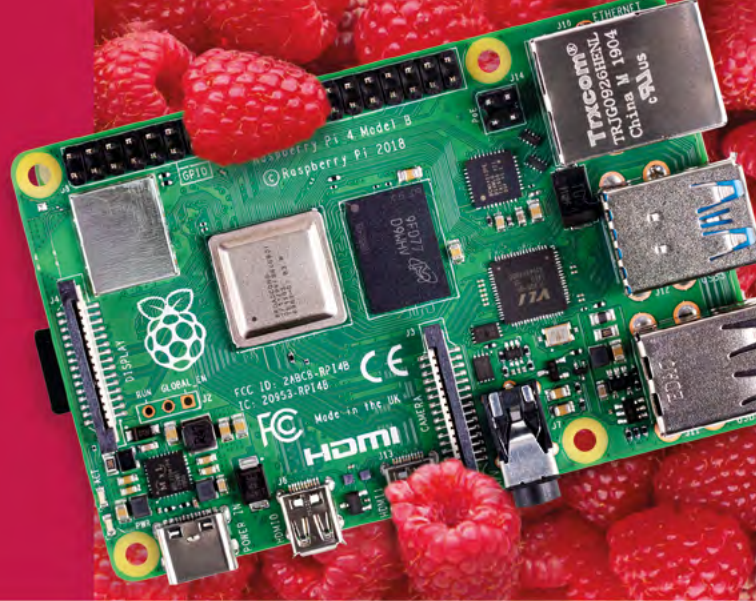
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K.G. variously makes weird games, DIY emulation consoles, music, documentation, lost software archives and, quixotic builds.

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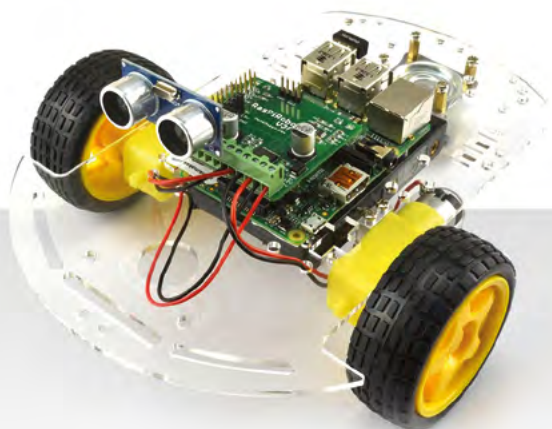


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