GPS Watch Technology

Darryl Smith, VK2TDS
TAPR Board Member.
vk2tds@tapr.org

From what I can work out, I am a bit unusual in the ham radio world. In addition to being active in amateur radio, and being on the board of TAPR, I am a mad keen runner. I started running about four years back, and have never looked back.

After doing my first marathon[1] at the end of last year (2018), I was looking for a new challenge, and decided to try trail running. Whereas most running events are on roads or paths, trail running involves running in the great outdoors away from civilization. And without the limitations of where cars can drive, trail runs tend to be hillier.

You might have worked out from my callsign that I don't live in the USA. I actually live about an hour south-west of Sydney, in Australia. This is an amazing part of the world, and we are blessed with some amazing places to go running. My first marathon started by running over the Sydney Harbour Bridge, and finished at the Sydney Opera House.

But there are some other amazing runs nearby. This coming winter I planned on doing my hardest marathon ever, on a course about three hours west of Sydney. The event is the Glow Worm Trail Marathon[2], and is in an area that could well be described as the middle of nowhere. Not really the middle of nowhere by Australian standards, but its certainly in a rather secluded area.

The closest town is Lithgow, an hour away, with a population of 21,000. Wallerawang (or Wang as it's known by the locals) is closer, but has less than 2000 residents. The entire Marathon is away from the townships in fairly rugged terrain. In fact, you need to drive about seven miles on a dirt road to get to the start line of the event. Cellular service is non-existent, and satellite phones work poorly due to the hills.

The area is so rugged that the Wollemi Pine that grows in the area was only know to exist in fossil records until 1994, and is now the only known survivor of a family of trees over 40m years old.

The event starts and finishes at Newnes, a place that these days consists of just a campground and a general store to support the campers. It has been like this following the dismantling of the railway line in 1940, and closure of the hotel in 1988 following a flood.

---

[1] A Marathon is officially 26.2 miles (or 42.195km) and a Half-Marathon – A race of 13.1 miles (or 21.1km). The distance of the marathon was standardized in 1921 based on the London Olympic Marathon of 1908. An Ultra-Marathon is any race longer than a Marathon.

[2] https://www.glowwormtrail.com/

The event itself consists of two distinct halves. The first half involves running up a hill, over it and down the other side towards Glen Davis, before returning to the start line the same way. The 13.2 miles[3] involves about 3894 feet of climb[4], none of which is on concrete or asphalt.

The second 13.2 miles is thankfully somewhat easier, with only 2345 feet of climb and decent. It also contains the reason for the event – an old rail tunnel about a third of a mile long inhabited by glowworms. That is over a mile of elevation up and a mile back down.

The thing is, I am a fairly good runner. Not the greatest, but I am normally in the top 20% in the races I enter. This year alone I have managed to get under 20 minutes for the 5km and under 3 ½ hours for the marathon. I worked out that running the 26 mile Glow Worm Trail Marathon would probably take me a bit over five hours, non-stop!

To give some perspective, this is the equivalent (if you could do it) of starting in the Yosemite Valley, running up El Capitan, and down the other side. And then turning around and doing the same thing again, all in the space of 26 miles! And if you think this sounds bad, I am already planning a 31 mile race next year, with 7800 feet of elevation[5]!

The entire event takes place in rain forest, in the middle of the Australian winter. I should note however that winter in this part of the world is a relative term, with the conditions likely to not go much below freezing, even overnight. Unfortunately, they likely won't get much above freezing for the entire race, but these are the conditions you prepare for.

Thankfully the conditions were not as bad as the run a friend did in Texas a couple of years ago whilst on holidays. This was a much shorter run, and she was wearing a half-gallon hydration pack filled with drinking water. During the run, the water froze solid. She tells me that event even surprised the organizers with how cold it was.

Given the harsh bush land and the remoteness, event communications are very important. Runners are known to push themselves too hard, not eat and to get injured during events. In a previous event, a runner was badly injured when a tree fell on her whilst she was running. Parts of the course are so steep that if they were any steeper and you would need to start rock climbing.

For the last couple of years, event communications has been handled by WICEN, the Australian Ham Radio emergency communications organization as a training exercise. This year they are aiming to improve the communications on the course by determining the best location for their repeater.

---

[3] Internationally most countries around the world predominantly use the metric system. Whilst Liberia and Myanmar are in the process of converting, the USA has not. As this article is targeted at readers predominantly from the USA, most measurements will be imperial. For reference there are about 5 miles in 8km, and 1000m is about 3281 feet.

[4] Climb – generally when runners talk about climb we only talk about the part going up. Since we normally start and finish in the same spot, we normally descend as far as we have climbed.

[5] That event is the Ultra-Trail Australia 50KM race in Australia's Blue Mountains. I did the 22KM race this year in 2h48m, but that only included 3900' of elevation climb

The great thing about this event is that there are a ton of spots where you can put a repeater. The bad thing is that testing the coverage is a chore. Even getting the repeater installed is difficult, and involves a 2-3 hour trek from the closest parking.

Coverage Site Survey

Over the Easter in mid-Autumn, WICEN wanted to try out a new spot for their repeater. This provided me with a chance to check out the course whilst providing reports of the radio coverage.

The idea was that we would run two parts of the course – we would warm up by running about half of the first half of the course, for a total of about 5-6 miles, and then run the second 13 mile half in full. Alas, things didn't turn out that way.

Unfortunately the guys from WICEN were unable to get to their preferred repeater position on top of the mountain. What looked good from the topographic maps and the satellite photos wasn't so good in real life. After some effort, they found they would need to climb up a 30 foot sheer cliff, which meant the radio test was no longer possible, and also ruled out that spot for a temporary repeater too.

The problem was that this area is not well surveyed, and the shadows on the satellite photos covered the sheer cliff. They mostly wanted to check the coverage on the second half of the course, meaning there was no need to run any further. You can check out where I did run on Strava[6]. I will definitely be heading out there at some stage to just explore the area.

Despite not achieving the aims of the test, I can at least talk about the equipment we were using out there, and how it works.

Radio Gear

As an article about Ham Radio, there is actually quite little to say about the radios we used. During the event WICEN are planning to use DMR digital voice repeaters, but during the test 2M FM was all we needed to use.

Both the WICEN team and myself were using 8W Baofeng dual band handhelds. These radios are inexpensive and did what they needed to do. As a bonus, in this remote area, they are unlikely to cause any interference on the off chance they are not as spectrally as pure as they should be. And Baofeng has been notorious, at least in the early days, for lacking rigorous engineering.

[6] https://www.strava.com/activities/2314605933

I had the opportunity to speak to one of the members of the radio team on a different event after visiting Glow Worm. They told me that for the Ultra-Trail Australia[7] (UTA) event they run multiple repeaters because of the terrain. In case of communications issues on course, they have a team of operators with 13 element UHF Yagi's they can point at the repeaters to provide event communications.

Garmin Forerunner 935

A few members of the running club are partial to the Garmin Forerunner 935 GPS watches. Part of this is that they were significantly discounted last Christmas, but they appear to be more reliable[8] uploading data than some other brands. The watch itself has a passive 64 color LCD display with backlight, GPS/GLONASS, along with heart rate, compass, altitude and cadence monitoring.

Also included are Bluetooth and WiFi. Bluetooth is used to connect to the mobile phone app, which sends data to the Internet should you need that. But Bluetooth has another function in this watch – when you are trying to get a GPS lock, the watch will attempt to use the phone GPS to determine the current position, and likely also to download the current GPS almanac showing the position of all the GPS satellites. This reduces the time to get GPS lock significantly, and dramatically improves battery life.

In this mode, I can log my runs with GPS data for well over 12 hours and probably closer to 24 hours per charge[9]. There is a mobile phone app that uses Bluetooth, although the watch also has WiFi built in. Bluetooth is more energy efficient, and is used to talk to the phone.

A comparison of watches whilst out running shows that a watch paired to a phone running in Low Power Mode takes a lot longer than a phone paired to a phone operating at full power. This means that whilst my watch will generally get GPS lock almost instantaneously, the other watch can take up to a minute to lock. This is likely because the watch downloads positional and GPS satellite almanac data from the phone reducing the time to fix.

One of the surprising advantages to this watch is that it uses physical buttons rather than a touch screen. Runners are often sweaty, and touch screens don't tend to work as well when the screen is wet. With physical buttons, it doesn't matter how wet things are. Whilst the manual suggests not

---

[7] a series of races ranging from 11-100km held in Katoomba, west of Sydney held in May each year. This is the largest sporting event in the Blue Mountains, with over 7000 people competing, and the third largest trail event in the world. https://www.ultratrailaustralia.com.au/

[8] reliable is an interesting word. Whilst mine has been rock solid, others managed to completely lock up a couple of times during running, resulting in loss of data. Thankfully after a restart, the watch is smart enough not to loose the data captured before it crashed, and will let the user continue as if nothing had happened.

[9] I will test this out at some stage. I am looking at a 60 mile race in a couple of years, and it will approach this time, although I do intend to charge the watch during the event with a portable battery.

using the buttons under water, us runners are crazy and will run in almost any conditions, day or night.

There are two features that are missing from this watch that are present on the higher end models. The first is that this unit does not permit the storage and playback of MP3 files. This can be an issue for some people – personally I just play MP3's from my phone, whilst my running companion has headphones that she has loaded MP3 files onto.

The other missing feature is the capability to use this watch as a Credit Card. Garmin has their own solution similar to ApplePay allowing people to pay by credit card using the Paywave non-contact RFID technology. In this case, the watch would use RFID to communicate with the credit card machine to authorize payments. Had it been present, I would need to enter the PIN number on my watch once a day, and whenever I took the watch off. Once again, I use my iPhone instead.

Mapping

One of the other cool features of this watch is the ability to upload a route to the watch, and it will warn you when you go off course. This is a really cool feature, and was rather useful on this run. When I went off course, I managed to work this out after a few hundred feet thankfully.

Alas, since this is a cheaper model, it doesn't have base maps showing streets and other features. As nice as they would be, when you are running off road, trails are often not well documented, even on web sites like OpenStreetMaps.

When I am following a route, I normally have it zoomed into a few hundred feet so I can work out where I am going relative to where I am. The watch does display a small arrow pointing at a direction, but this does not always work in areas of poor GPS coverage.

I did hear a report from the actual Glow Worm event where someone sabotaged one of the races, changing the markings on the trail causing some runners to take the wrong course. This is the first time I have heard of this happening during a race. Having the map on the watch whilst running at least warns you that something might be going on.

Having said that, I have also run in races where the organizers have changed the course at the last minute and forgotten to tell anyone, so no plan is foolproof. In another case, the marshals incorrectly located a turn around point in the Bangkok Half Marathon. They accidently added about 2½ miles to the course. All they could do after the event was re-issue the T-Shirts with the actual distance listed.

At this point I should point out what I mean by an area of poor GPS coverage. For GPS type devices to work properly, they ideally need to be able to see the sky right to the horizon in every direction. Alas, the human body tends to get in the way, but thankfully this isn't too much of a problem with modern devices. More of an issue is when there is terrain or buildings that restrict the 'view' of the sky.

When the view is restricted, GPS is not able to cope as well, particularly with reflected radio signals. This tends to increase the positional error. Thankfully in my experience with watches and phones has tended to be under a couple of hundred feet, and is normally a lot less.

The worst I have ever seen was about 15 years back with a GPS tracking unit I was developing and had mounted in my car. The car and GPS was under my carport, and the GPS 'lost it'. Whilst the car was safely parked, the GPS was reporting a journey of about 150 miles at a speed of about 300 miles per hour. What I think happened was that the software in the receiver failed and started tracking one of the GPS satellites by accident.

In many ways, the watch reminds me of 20 year old Garmin eTrex or Garmin 12 devices, and I suspect that there are still parts of that firmware living in this device.

If you do get lost, the watch has the ability to guide you back to the start, either by using the route you went or direct line of site. This can be a useful feature, although I haven't needed to use it yet.

Routes are loaded by copying a GPX file onto the device. There are some smart ways to do this wirelessly, but the watch also emulates a GPS thumb drive. I tend to use MapMyRun when designing routes and upload them wirelessly using http://dynamic.watch

If the run is one that someone has done before, as a premium Strava subscriber, I can download other peoples runs as a GPX file and upload it onto my watch.

I must say one of the best uses of the route functionality was last Christmas when I wrote the words 'Merry Xmas' in several hundred feet high letters running around the streets near where I live. This run was designed earlier in MapMyRun and the watch told me exactly where I needed to go.

Heart Rate Measurements

The watch measures the heart rate using physical properties, rather than the more common electrical ones, using a photoplethysmogram[10]. To do this it shines a green light onto the skin and monitors how much light gets absorbed. When the blood is flowing past, the amount of green light being absorbed increases. It can actually read the pulse not only in arteries, but also in subcutaneous tissues.

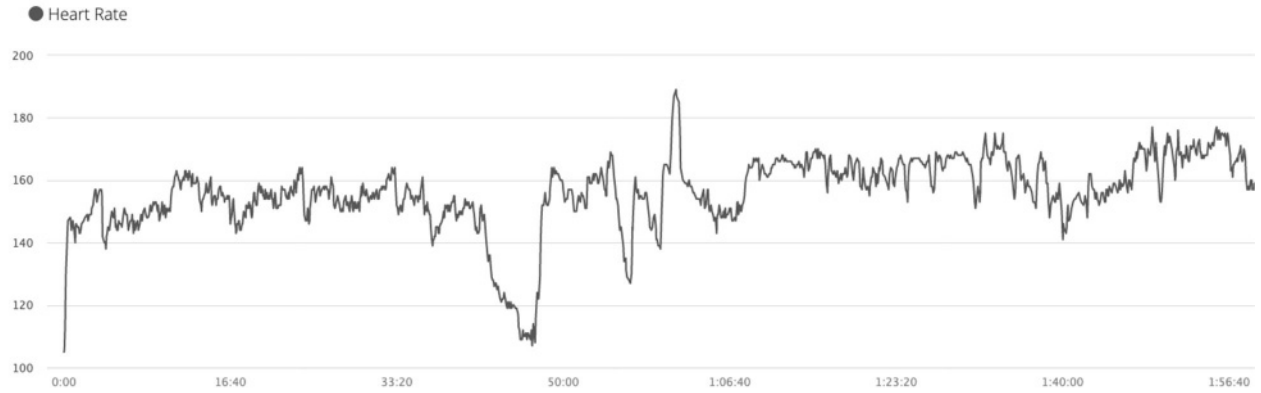
This does rely on the watch band being reasonably tight so that the back of the watch with the green LED is in constant contact with the skin.

Some runners prefer to use an electrical heart rate monitor around their chest that sends data to the watch via Bluetooth or the related ANT+ protocol. These can work well, although I have found in the past that my phone 'steals' the data from other people's heart rate monitors depriving them of the data. This appears to be related to the ANT+ protocol.

[10] https://en.wikipedia.org/wiki/Photoplethysmogram

Being able to monitor heartrate has some great health benefits. As a middle aged male runner, I am in the demographic that seems most prone to having a cardiac event whilst running. In fact, during the recent UTA22 race, my heart rate spiked about 20-25 bpm for a couple of minutes, before getting back to normal.

Based on this, I now have an alarm on the watch telling me whenever my heart rate is higher than it should be. Sometimes there might be a reason for it, but the alarm is a good indicator that I need to be careful.



Since I wear the watch 24/7, it also keeps a track of my average resting heart rate. Depending on how much running I am doing, this is between 50 and 60 bpm. The more running I am doing, the lower the resting heart rate.

Sensor Fusion

Obviously devices such as watches have very small batteries, and need to save energy in any way they can. Anything with a radio transmitter or receiver in it will use up a heap of energy. So ideally, you want to have any radios turned off as much as possible. One of the major battery drains here is the GPS to determine the position and speed of the device.

GPS watch devices save energy by combining data from many sources. This is commonly known as Sensor Fusion[11]. This combines data from desperate sources with the aim of generating more accurate information in the process.

Data sources include three a dimensional compass, accelerometer and gyro, along with an air pressure sensor, giving a total of 10 degrees of freedom. 3D GPS data is also included giving a total of 13 degrees of freedom. Sensor Fusion would use this information to determine the following details:

- Cadence of the runner (Steps per minute)
- GPS Position
- Speed
- Elevation

[11] https://en.wikipedia.org/wiki/Sensor_fusion

One of the important things about sensor fusion is that each of the sensors needs to be measured at the exact same time wherever possible. This is particularly important for the compass, gyro and accelerometer. Essentially an integral is applied to the data, and if the points don't line up, there will be mismatches in the results.

Unfortunately, determining these details is not always that simple. Not all these data sources are available all the time. Pressure sensors often get blocked with water or dirt, particularly when running on trails. GPS receivers may only be turned on for a moment every few seconds.

Kalman Filters

And then there are the errors. Each of these sensors have errors, so the job of Sensor Fusion and Kalman Filters[12] is to determine what the most likely correct solution is, such that the data from each sensor is used, and that errors are minimized.

Think about the average runner. They will be running somewhere between five and 12 miles per hour, and will likely be moving horizontally. When moving vertically, such as on a ladder or stairs, their horizontal speed will be significantly slower.

With this in mind, algorithms and filters are then tuned to search for solutions mostly within a certain range from the last known good position. Using the accelerometer to determine the number of steps being taken is a great way to hone in on the correct result.

An easy way to think about this is by assuming that we know where we are now. If we can work out how many steps a minute the runner is taking, that gives us a fairly good idea where they will be in a minutes time. When you pull in the other data, even without an updated GPS position, you can make a fairly good guess as to the new position.

The guesses are not perfect. An example was a runner who discovered that when they work out on the treadmill that their distance was off by over 10%. This is probably because she takes smaller steps on the treadmill thanks to its incline. Thankfully the watch has a manual calibration mode, which tunes the internal filter. Once the unit was calibrated, it was accurate within about 1% of the correct distance.

This is an easy to understand example of tuning algorithms and filters. Things get a lot more complex when you escape the gym and get into the real world. Thus, one of the first real life applications of Kalman Filters was actually with the Apollo program to take man to the moon! And in case you are wondering, I don't understand most of the Kalman Filter Wikipedia page.

[12] https://en.wikipedia.org/wiki/Kalman_filter

Strava

Although I have mentioned it already in this article, I guess I should describe what Strava[13] is. In essence it is a social network predominantly for runners and bike riders, although other forms of physical activity are also included.

Rather than people posting photos of cute puppies (which I am sure must exist on the site), people upload the GPS traces of their runs and rides. These traces are timestamped so that people can see exactly how fast you went at every point, and where you went. It can also include details like heart rate and running cadence. Friends can then give you likes, or 'Kudos' for your runs.

But Strava goes further than that. Subject to privacy settings, it correlates your runs with others, and indicating who you ran with. Users can also route segments that are used as virtual races. After every run, Strava works out your time on the segments and reports on this. It also allows you to compare your time with others, creating a virtual race.

Like much technology, Strava does have significant privacy implications. They made the news due to their 'Heat Map' feature which allows you to zoom into any part of the world and see what the popular courses are. The problem was that Strava was being used by troops in the middle east. This was identifying the locations of those troops and where they trained.

Some Interesting Runs

Alas, Sensor Fusion does not always get things right. Below is the graphic from one of my runs earlier this year, where I was running up and down a hill[14]. The hill can clearly be seen, but each of the peaks and troughs should be the same as I was just going up and down the same hill. I also started and finished in the same location, so the start and finish of the plot should be the same height. The two are actually out by about 88 feet.

My guess is that this is related to a change in air pressure that happened late in the day. As a rough guide, air pressure decreases for every 30 feet of elevation by 1 hectopascal (hPa). Standard atmospheric pressure is 1013 hPa or 101.3 kPa.

Modern air pressure sensors have the resolution to determine climbing a single step, somewhere around 0.02 hPa. Whilst they have great resolution, their accuracy in determining elevation is not that great. The problem is not the sensors, but mother nature. These sensors can only read air pressure, and air pressure can change enough to cause issues. In this example, a low pressure change of 3 hPa over thirty minutes could have caused the issue.

---

[13] http://www.strava.com. You can see my Strava profile on the following URL https://www.strava.com/athletes/11527827

[14] https://www.strava.com/activities/2265485986

These types of problems are generally corrected by calibrating the pressure sensor using GPS altitude as well as other information sources. As can be seen here, this is not always successful.

Another example shows a comparison of my pace doing hill repeats compared to the hill[15].

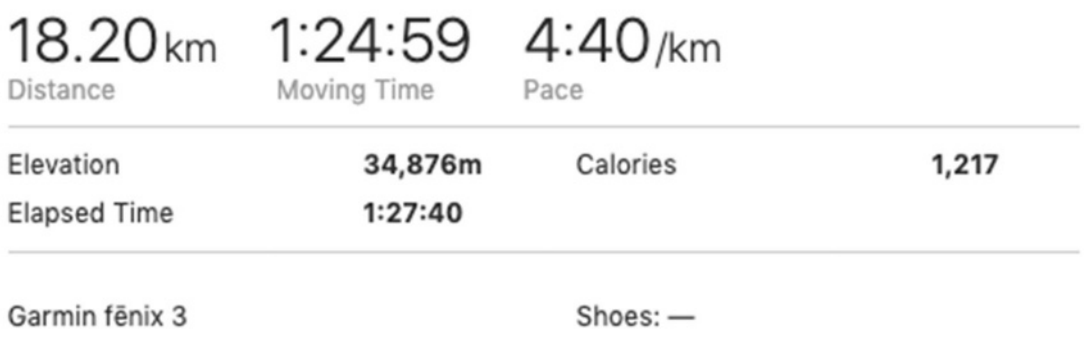
In this case, the hill does look like an almost perfect triangle wave. The pace looks like a rather noisy square wave, which is what you expect. I got slower every time I ran up the hill, but I generally ran faster going down the hill than running up.

15 https://www.strava.com/activities/2214282641

More interesting is the comparison of heart rate to elevation. In this case, the heart rate is an almost perfect square wave. These are the sort of effects you would expect doing signal analysis with integrals and derivatives.

In case you are wondering, these runs were on an old dirt road near where I live called Old Ford Road. It is about 130 years old, and was built as an unemployment project, making it older than the nation on which it stands. As such, it is likely one of the oldest intact roads in the country. These days access is restricted to foot and bicycle traffic, and the road no longer goes any further than the bottom of the hill due to a military base.

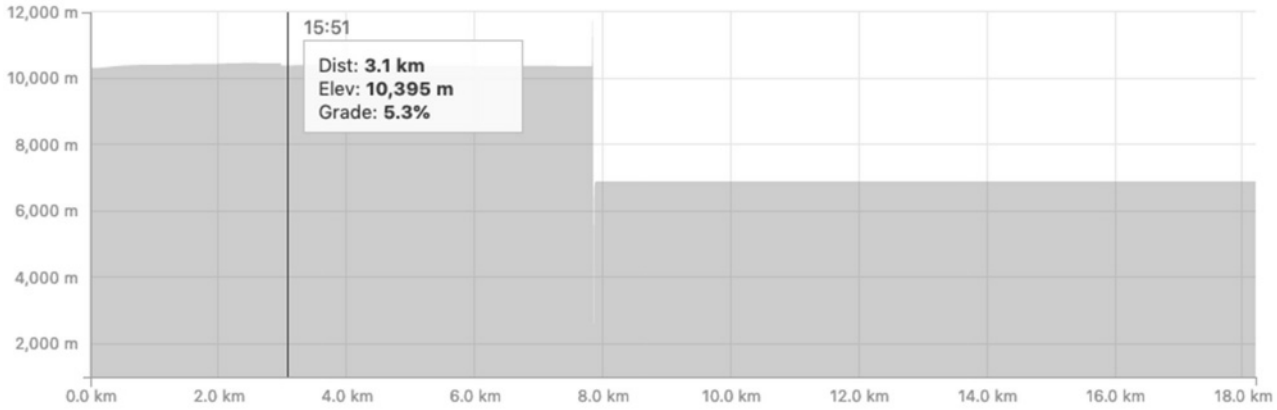
I have found two runs on Strava from other runners that give an example of what happens when things go wrong. In this first example the athlete ran just over 11 miles. The watch believes he climbed 114,000 feet during this run.



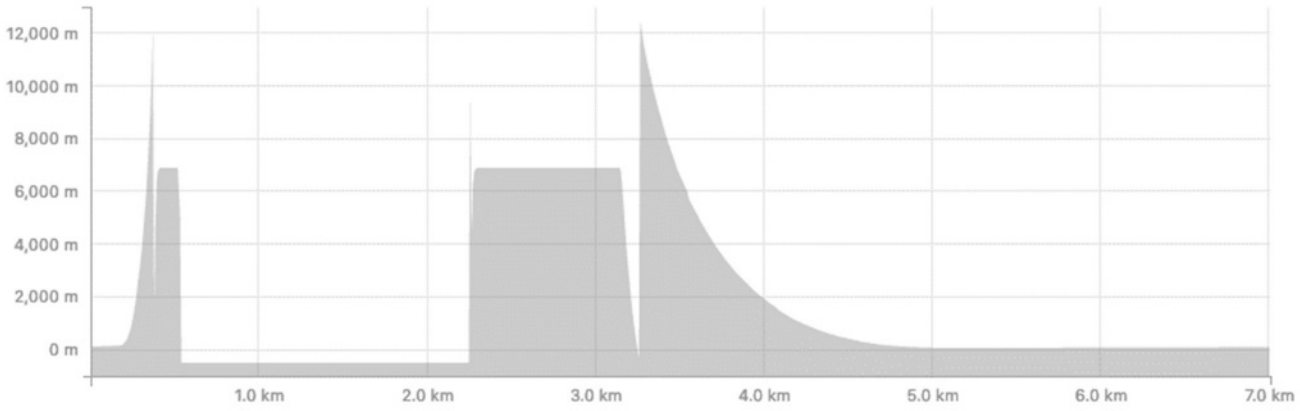
In this case, the watch was an older Fenix 3, which was released two years before the ForeRunner 935, in early 2015. Sensor technology has improved significantly in those two years, as has the processing power available within a device like a watch.

In this case the likely cause of the obviously incorrect elevation is a blocked air pressure sensor on the back of the watch. Cleaning the sensor will likely fix results like this one. It is interesting to speculate what happened in the graph below about the 8km (5 mile) mark.

Before then, the results were high, but there was some variation. Afterwards the graph appears to go to zero and then when it returns, does not change for the entire race. It is possible that either the sensor got blocked further at that time, or possibly the watch knew that there was an issue, and tried to make sense of the results. Whatever the cause, the results are obviously wrong.



Another example appears below. What is interesting in this case, apart from some 'brick wall' changes is the exponential curve with a long time constant. This could relate to a partial blockage, or could suggest an algorithm attempting to fix erroneous results.



Mountain Bike Riding Too

You might be wondering what happens if someone is riding a bike rather than running. Well, there are techniques to get the best results. When you record an activity, the first thing the watch does is ask what sort of activity you are recording, be it a ride or a run, or even a swim.

If you select a ride, the watch will not be trying as hard to determine the number of footsteps that you are making, and will also assume that you will be able to go a bi rather on wheels than running. This is not always a case, but is a reasonable assumption.

The good thing about riding is that you are generally covering more distance, so the errors in reading from GPS tend to be comparatively lower.

Once again, you can get accessories for the watch to improve the accuracy of the readings. One common sensor is worn on the top of the shoe with a 9 or 10 degree of freedom sensor that helps to determine the number of revolutions per minute you are peddling. Another sensor is similar but goes on the pedal, and also measures how hard you are peddling. This allows the software to calculate the amount of energy you are burning.

Whilst we are on the subject of bikes, video games are definitely invading training. Adapters are available for bikes that let you ride in front of a television on bike, competing with other people also in their own homes. What makes this even more interesting is that the adapter forces you to pedal harder going uphill and allows you to coast going downhill.

This makes 'riding' in exotic locations like Paris, London or Washington DC easy. It did however surprise a friend the first time when his colleague checked Strava before work and saw his workmate riding in London before an important meeting.

APRS Whilst Running

One thing I really haven't got into trying is using APRS whilst out running. It is something I do want to try, but I haven't got around to it yet. Part of this is that many of the areas I run don't have very good APRS coverage. I can sometimes fix that by using my car's APRS rig as a digipeater, but in most cases, the increase in coverage would be minor.

I have done a few runs running APRS on my iPhone, but this tended to be on road races, rather than areas with poor mobile coverage. In areas of poor mobile coverage, phone batteries tend to die more quickly, and I would prefer to save the battery in case I need to make an emergency phone call.

I do have plans to carry an APRS rig with me next year when I do the UTA 50km race. This will require some planning, and I will need to consider if I need to carry spare batteries. The weight of the APRS gear is not really a problem, as most trail races already require me to carry up to two liters of water along with other mandatory gear. In this case, the weight of the tracker is minor compared to the weight of everything else.

Other Technologies

Of course, these devices log using GPS, but need some type of connectivity to upload their data for wider distribution.

In the sports tracking world, there are two options available for disseminating GPS data to the wider world, similar to how APRS works. The first is the SPOT Tracker, that uses the Globalstar satellite network. The second are the Garmin inReach devices that use the Iridium satellite network.

In both cases, the device will transmit position reports every 2-10 minutes via satellite before being disseminated via the Internet. Both devices require subscriptions costing about 50% of the hardware cost per year. These units tend to use satellites in LEO, or Low Earth Orbits, as a way to reduce the costs launching the satellites.

The Actual Glow Worm Trail Marathon

I was hoping to get this article finished in the days after the site survey. Unfortunately, as you might be able to work out, this article just kept getting longer and longer and longer. There was more information that I wanted to put it. Then, when I was almost ready, I realized that it was only two weeks until the actual event, so I might as well just wait for it before getting it published.

One of the things with running is that it does take a toll on the body. Doing these type of events is even worse. One rule of thumb is that the recovery time from races is about one day per mile. Thus, a 26 mile event requires almost a month of recovery time. This is not to say that you can't run in that time. More that the body will not be back to peak performance until then.

For me, I am finding that my body recovers enough to be able to actually run fairly quickly, particularly after road races. What I have found is that after marathons, my endurance takes longer to recover. Whereas, I might normally be able to do a 10-15 mile training run at will, I find that I get exhausted after running half that.

Doing events with lots of up and down climbing takes the toll on the legs too. This generally comes in the form of DOMS, or Delayed Onset Muscle Soreness. You might feel fine the day after a big race, but then it will hit you, and going up a single set of stairs will be torture. I am looking at a competing in a race in two years' time with about 15,000 feet of elevation. I don't expect to be able to walk for a week!

The reason I am mentioning this is that after a club 10 Mile[16] handicap[17] race two weeks before the Glow Worm Marathon I managed to injure my quads and adductor in my leg. Treatment helped, but

[16] This race is actually 10 miles long. The race dates back to before Australia went metric. Thankfully, 10 miles translates almost exactly to 16km, making it easy to measure in a metric country.

[17] In most races, the fastest person wins the race. In a handicap race, you are given a time which the handicappers feel meets your ability. In this type of race, the person who beats their handicap time by the most wins the race. In this way, a fit 20-year-old can be beaten in a race by a retiree with arthritis.

in the end, I decided that running this marathon had the potential to cause my injury to get a lot worse. With great reluctance, I decided to pull out.

So, rather than do a tough marathon, I decided to do an easier local trail run[18] instead. Thankfully, this run went well, and I can now resume my training for the multitude of events I have planned for the coming months. I ran just over 15 miles with about 1200 feet of climb in a bit under three hours in wet conditions. Given that my fitness had deteriorated in the last few weeks, this was a good result.

Conclusion

I would like to thank those who helped with this article, either by running with me, assisting with the site survey or proof reading. They know who they are, and I could not have written this article without them.

As for me, I have a few road and trail events lined up. Next year I hope to run the 28 mile Six Foot Track Marathon just west of Sydney if I get in. The Marine Corp Marathon in Washington DC looks interesting, but we will see when I do that. I am also looking at doing the Ultra-Trail Australia 50km race in May 2020, which will definitely be a challenge. Thankfully I have time to train for that.

[18] https://www.strava.com/activities/2453503488