Geotagging with GPS

Capture and Process

Dr Chris Marshall

28 January 2008

Cross Oak Lane, Redhill, Surrey RH1 5HA, UK
T: +44 (0)1293 815378   F: +44 (0)1293 815739
E: info@geotate.com

www.geotate.com

geotate
auto geotagging

WHAT IT IS AND HOW IT WORKS

Geotagging is the labelling of digital content with location. It is a powerful and increasingly popular means of looking at, sorting, finding, and sharing all sorts of things, from photographs and videos to points and events of interest. In the age of user generated content it is a powerful means of linking and accessing information.

Capture and Process is a new geotagging GPS technology which can instantly capture outdoor location, and is ideally suited to geotagging because of its instant response, and very low energy consumption.

A short sample of the GPS satellite signal (less than 0.2s) is simply captured and stored at the time and location of interest. For example the sample can conveniently be stored together with the picture image in the memory of a digital camera. There is no delay or waiting for any processing task to be performed – the user can carry on with what they were doing.

Later the user uploads the signal samples to their PC, and then accesses the Capture and Process Server. The system then processes the signal sample to calculate the location where the samples were captured, and so creates a geotag.

The geotag can now be used to plot the event on a map, and be used for sorting the images, or for other applications.

Capture and Process GPS technology can be used to make logging devices with long battery life (weeks, months or years), or to conveniently include an easy-to-use geotagging function in a camera.

THE BENEFITS OF GEOTAGGING

Location is an extremely powerful form of metadata, that can enhance the organisation, presentation and searching of data. The geotagging of photographs is an excellent example of how this capability is used in a mass-market environment.

Now that digital cameras are widespread, people typically take as many photos as they like, and choose which ones to look at later. As a result, people are building up massive photo collections. In a recent survey [] 27% of respondents claimed to have between 1,000 and 5,000 digital photos, 11% had more than 10,000 pictures.

This shift has created significant problems in effectively organising, searching, sharing and understanding photograph collections. People rarely name their pictures, and so rely upon a rough recollection of the date, time and folder name to find them. Unfortunately this system frequently fails, and many pictures are effectively “lost” on users machines. People are struggling to maintain and enjoy their image collections.

The technology to organise photo collections is improving. Elegant tools such as Google’s Picasa [] encourage users to name images, star their favourites and make scrolling through collections faster. The online photo sharing website flickr [] has built its name and dominant market position through encouraging the semantic tagging of images and 2.5 million geotagged photos are uploaded onto flickr’s photo site every month by users, whilst facebook [] has shown the value of being able to identify the subjects in pictures.

Clearly, geotagging would help vast numbers of people to organise their images effectively and to do so automatically. So why isn't everything around us geotagged? Surely our emails, documents, pictures, videos and activities would all benefit if we knew the location in which they were created or edited. The reason is that capturing information with conventional location technology is complex and slow.

Some tools are available to manually tag a photograph by selecting its location from a map, but this is a time consuming process, and prone to error. The best worldwide position-finding technology is undoubtedly GPS; but systems have traditionally been built around the real-time navigation useage model. Until now, none has been designed for quickly acquiring locations automatically, on demand at all times.

TRADITIONAL APPROACH TO GPS

The GPS system is well known [], with at least 24 GPS satellites orbiting the Earth at an altitude of 20,000km. By listening to their signals a GPS receiver can measure the time taken for the satellite signals to reach the receiver, can calculate the distance of the user from the satellite, and therefore find out where he is.

The tasks of a conventional GPS receiver are as follows:

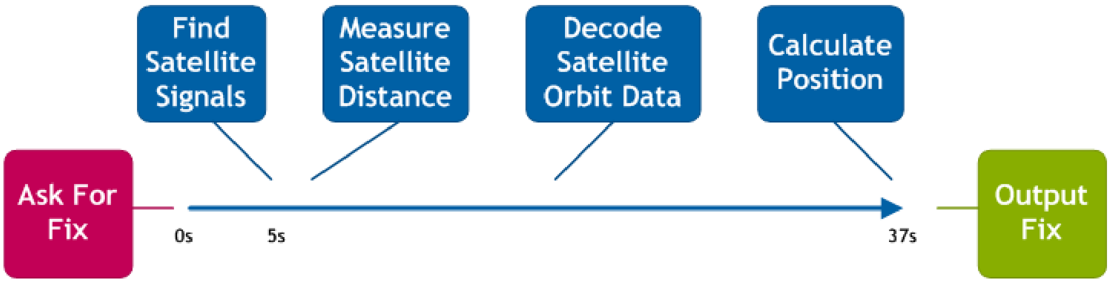


Figure 1 – Work done in a conventional GPS Receiver

Firstly the GPS receiver searches for the weak satellite signals, then it measures their relative timing accurately to give the distance to the satellites.

In order to calculate where the receiver is, the receiver must first find out precisely where the satellites are in space. This “ephemeris” information is transmitted slowly by the satellites, repeated every 30s. The need to demodulate this signal is the primary factor that slows down the response time of a GPS receiver. Only after it has decoded the orbit information for (at least) four satellites does the GPS receiver calculate a position fix.

Subsequent position fixes when tracking can then be carried out quickly because the satellite orbit information is now known and can be reused, and also because it is easy to keep continuous track of the satellite signals once they have been found.

This system design works fine for navigation on a journey, where the user is prepared to wait a minute or so to start with, and then wants to track position continuously, using energy while doing so.

However this type of system is *not* suitable for the ad hoc use typical of geotagging applications. For example, camera application users expect instant “point and shoot” operation, want it to be small and light to carry around everywhere, and demand a long battery life.

CAPTURE AND PROCESS GPS

Capture and Process is a new GPS technology for geotagging that enables the user to capture the location almost instantaneously, by recording the raw GPS signal itself.

In the device a small sample of the GPS satellite signal is captured and stored in memory. Then later, the signal samples are uploaded to a PC, and processed by the PC to calculate the location where signal was captured.

This means that the processing power of the PC is used to quickly and accurately process the signal in software and calculate the user's location. This can be done when convenient, using the resources of the PC and assistance information provided by a server connected over the internet.

As a result the device itself acts instantly, can be small and lightweight, and can have a battery life of many months or even years.

The two steps, Capture and Process, are now described in more detail, using the case of a digital camera as the prime example.

Capture

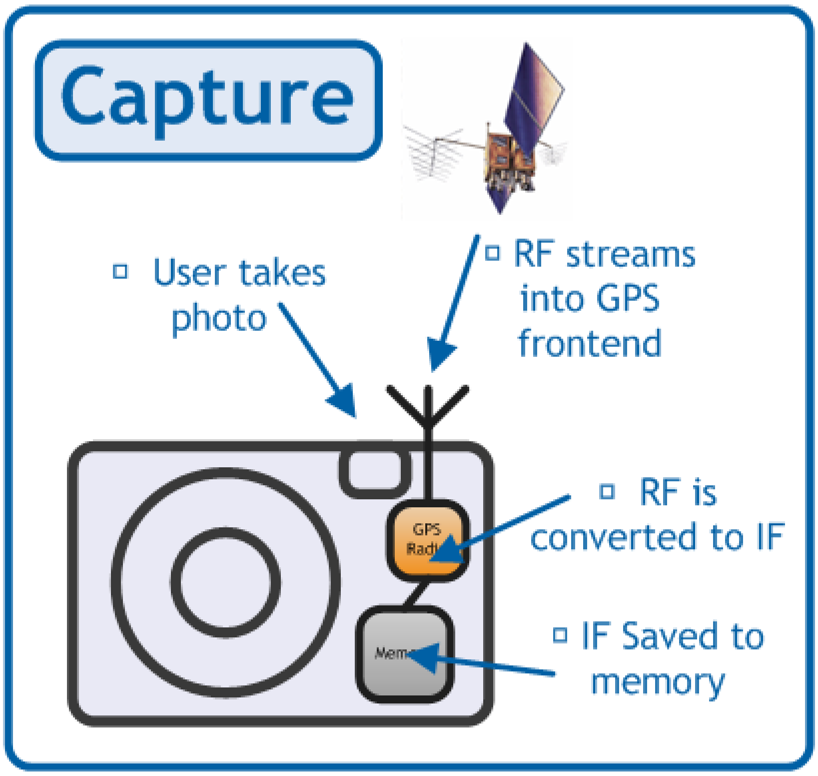


Figure 2- Capturing IF data

When a photograph is taken, the following simple sequence of events takes place:

- the camera requests the capture of GPS data.

- The GPS radio in the camera is switched on, and RF signal is streamed into the GPS front-end radio, which down-converts the signal to an Intermediate Frequency and outputs the raw sampled signal as a digitised signal stream.
- This raw signal is passed to the camera processor, which stores it in flash memory. Typically only a small sample of <200ms of signal is acquired and captured each time a picture is taken.
- The GPS radio is switched off again
- A timestamp is written to the capture record
- The GPS signal sample is put into a file, and embedded in the photograph or cross-referenced with the photograph image

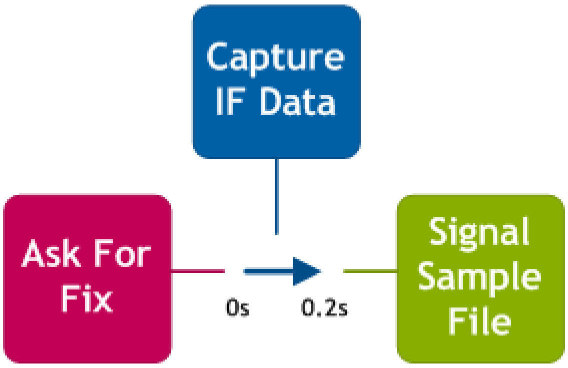


Figure 3 - Work done in a Capture and Process camera

Note that the camera does not carry out any processing of the signal sample – it only stores the raw GPS signal. The camera does not measure or know the latitude and longitude of the event, and the signal sample must be processed using additional information, before the location can be obtained.

This approach minimises the time, energy consumption, and complexity of the camera, by keeping everything in the portable device straightforward and simple. Capture and Process only consumes power when a picture is taken, and even then it just uses about 10mJ per capture for receiving and storing the signal.

This is a very small energy consumption; for comparison current cameras typically have a battery capacity of 11,000J and can take 220 pictures, which is a typical energy consumption of around 50J per picture. So the energy consumption of the GPS capture represents only 0.02% of overall camera energy consumption, and will therefore have negligable effect on the camera's battery life.

Process

The processing stage is where the algorithmic work is done, and the location is calculated. As mentioned, this process is initiated later when the camera is connected to a PC.

In order to avoid the device having to carry out the difficult and time-consuming step of receiving and demodulating the satellite "ephemeris" data about where it is in space, a server keeps an archive of all the satellites' navigation data.

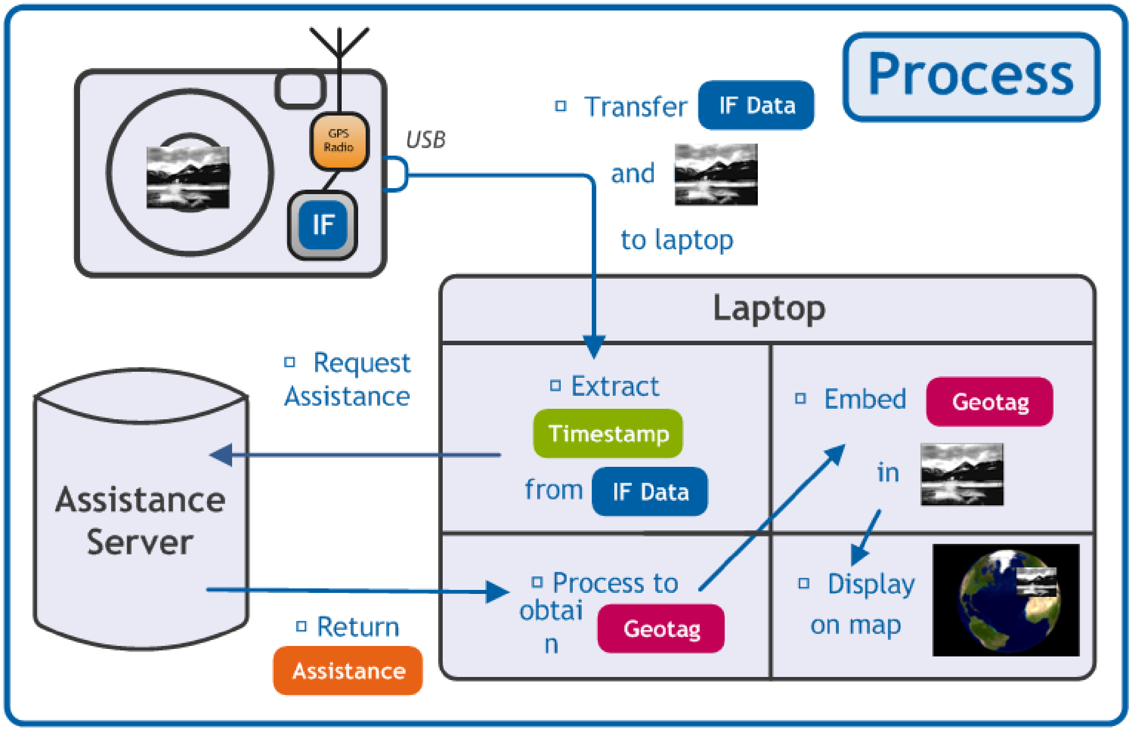


Figure 4- Processing captured IF data and geotagging photographs

The processing proceeds as follows:

- The camera is connected to a PC, and the pictures are downloaded
- As each photo is retrieved, the capture data is extracted from the image, and loaded into the Capture and Process Engine
- For each capture the timestamp is extracted
- The Server is contacted, and the orbital information about the GPS satellites at that time are downloaded over the Internet
- The system then analyses the data to find the satellite signals, measures the "pseudo-range" distance to each satellite it can find, and calculates a geotag position fix of location and time
- The location is then provided to the photo mapping application, which provides a visual image of the location, such as a dot on a world map

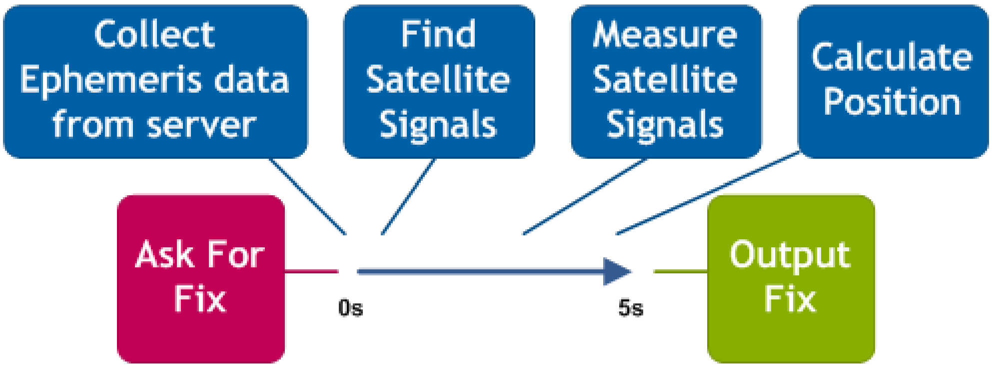


Figure 5 - Work done to process a capture

Three innovations have been necessary to make this processing system practical:

- A full historical archive of GPS satellite information, allowing fixes on samples collected anywhere in the world, at any time
- Advanced algorithms to extract and measure the GPS satellite signals and accurately determine location based on only a small sample of captured signal
- Creation of a signal processing system that is tolerant to relatively large errors in the camera clock, which only needs to be accurate to within 10 minutes.

The Server, providing satellite information

As has been indicated, the service is a key element in providing accurate information about the orbits of the GPS satellites in space, and assisting in the processing of the signal data in order to determine the location of the signal capture.

The server performs the following tasks:

- It collects detailed information about the GPS satellites and their orbit around the Earth, the so-called "ephemeris" information
- It archives this information, to build a database of the orbit and status of all GPS worldwide
- It provides a timing service, to calibrate to UTC (Coordinated Universal Time)
- It authenticates enquiries and matches them with the type of device being used

Then, when properly authorised to do so…

- It provides assistance including ephemeris information about where the satellites at the times when the time stamps of the signal samples were made

PERFORMANCE

General Specifications

Typical performance results achieved by Capture and Process are as follows:

Specification	Typical outdoor usage results
Time for device to capture GPS signal	<0.2s
Energy used by device	10mJ per capture[1]
Size of captured GPS IF signal data	140KB
Accuracy of GPS fix[2]	5m CEP 50% 25m CEP 90%
Time to compute first fix[3]	0.5-5.5s
Average time to compute fix[3]	<1s per fix

Table 1 Performance Characteristics

[1] Comprising 5mJ for the GPS circuitry, and an estimated 5mJ energy used by the processor storing the signal data in memory.

[2] The accuracy varies according to the GPS signal conditions, see below.

[3] Using a 2.8GHz Pentium 4 and outdoor GPS signal samples, see below.

Accuracy

The accuracy achieved depends on the GPS satellites from which signals are can be captured by the device; the number, position in the sky, and signal strength.

Performance	Good signal conditions[1]	Poor signal conditions[2]
Accuracy of GPS fix (single fix)	5m CEP 50% 11m CEP 90%	12m CEP 50% 25m CEP 90%
Accuracy of GPS fix (subsequent neighbouring fixes)	4m CEP 50% 6m CEP 90%	8m CEP 50% 15m CEP 90%

Table 2 Results for measuring the accuracy performance

[1] Good outdoor conditions with signals at -130dBm

[2] Poor outdoor conditions with signals at -140dBm

If more than one signal samples are captured in quick succession (as will often be the case for taking photographs), then the accuracy performance improves for subsequent position fixes. It can be seen that the system gives typical accuracy to within around 10m, worldwide, an excellent performance in practical terms.

Time to compute the GPS location

When the user is processing the signals later to establish the location, the time to calculate a fix for the PC processing varies according to how difficult it is to find the signals. The first position fix is the most difficult, as the processing has no idea where in the world the GPS sample was captured. After the first fix has been found, subsequent fixes are easier and quicker to calculate, as more information is known. The results from experiments with over 2500 samples are shown below:

Performance[1]	Good signal conditions[2]	Poor signal conditions[3]
Time to compute first fix	0.6s 50% 0.6s 90%	2.5s 50% 4.0s 90%
Time to compute other nearby fixes	0.4s 50% 0.6s 90%	0.4s 50% 0.7s 90%

Table 3 Results for measuring the time to compute fix

[1] On a 1.87GHz Core 2 Duo E6300 PC with SSSE3, and using the SSE2 instruction set

[2] Good outdoor conditions with signals at -130dBm

[3] Poor outdoor conditions with signals at -140dBm

So for example, to process and calculate the GeoTags for 10 signal samples captured in proximity takes typically

2.5s (for the first fix) + 9 × 0.5s (for the other fixes) = 7s (altogether)

And the average time to fix for the set of samples is 7s/10 = 0.7s/fix

GEOTAGGING WITH CAPTURE AND PROCESS

This section explores how geotagging with Capture and Process works in two typical applications.

The first, digital cameras, illustrates the value of performing an instant capture of the GPS signal.

The second, a small lightweight logging accessory, illustrates the low power consumption, enabling weeks, months or years of operation.

Photo Geotagging

Adding Signal Capture to a Camera

For adding the geotagging capability to a camera only a signal capture circuit needs to be added. The hardware elements required are outlined below.

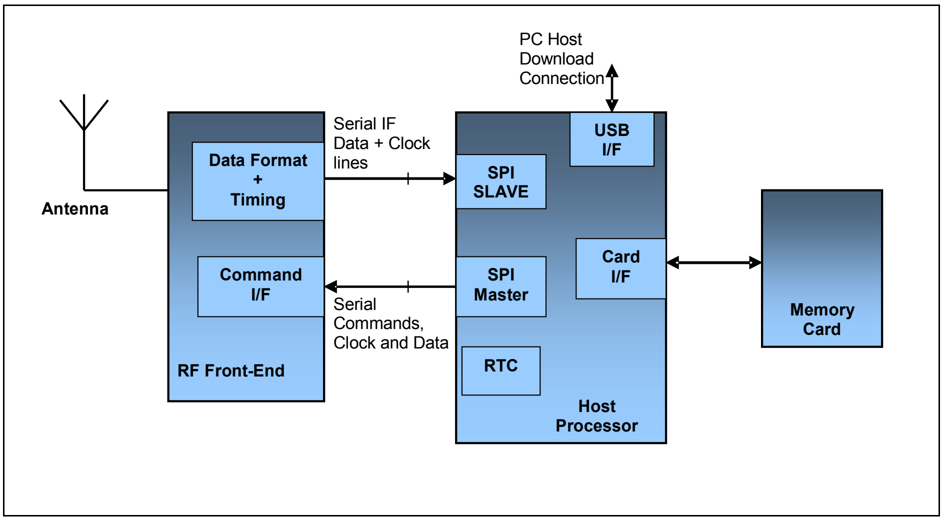


Figure 6 Essential features of a typical implementation

Note that only a GPS antenna and radio receiver are needed – there is no baseband processing IC required.

For each capture, every time a photograph is taken, the GPS radio receiver simply passes the GPS signal into the host processor, typically over an SPI bus, and the processor stores the signal in flash memory. (A simple control interface is often required to configure and activate the GPS receiver.) The sample is given a time stamp by the real time clock.

The sample may then be embedded into the JPEG file, or associated with the image in any other convenient manner.

When the images are downloaded from the camera to the PC, typically over USB, then the GPS signal samples are also downloaded to the PC.

Example Module for integration in a camera

For camera applications minimum size is an important requirement. The small size of a typical Capture unit is shown below. The GPS front-end receiver module, the GRM6510 from Rakon [] appears placed next to a metric ruler.

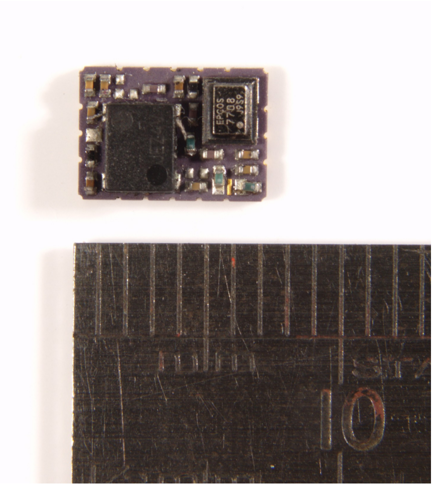


Figure 7 GRM6501 GPS radio Front-end module

This compact unit provides all the required GPS front-end functionality in a small package, including GPS radio receiver, filtering, and oscillator TCXO. The footprint of this module in the form illustrated is just 7mm × 5mm, 35mm^2. A GPS antenna is all that then needs to be added.

Practical Testing

Capture and Process for digital cameras has been thoroughly tested by collecting samples from around the world and processing them. Figure 5 shows an example of a trip around London mashed up with Microsoft Virtual Earth.

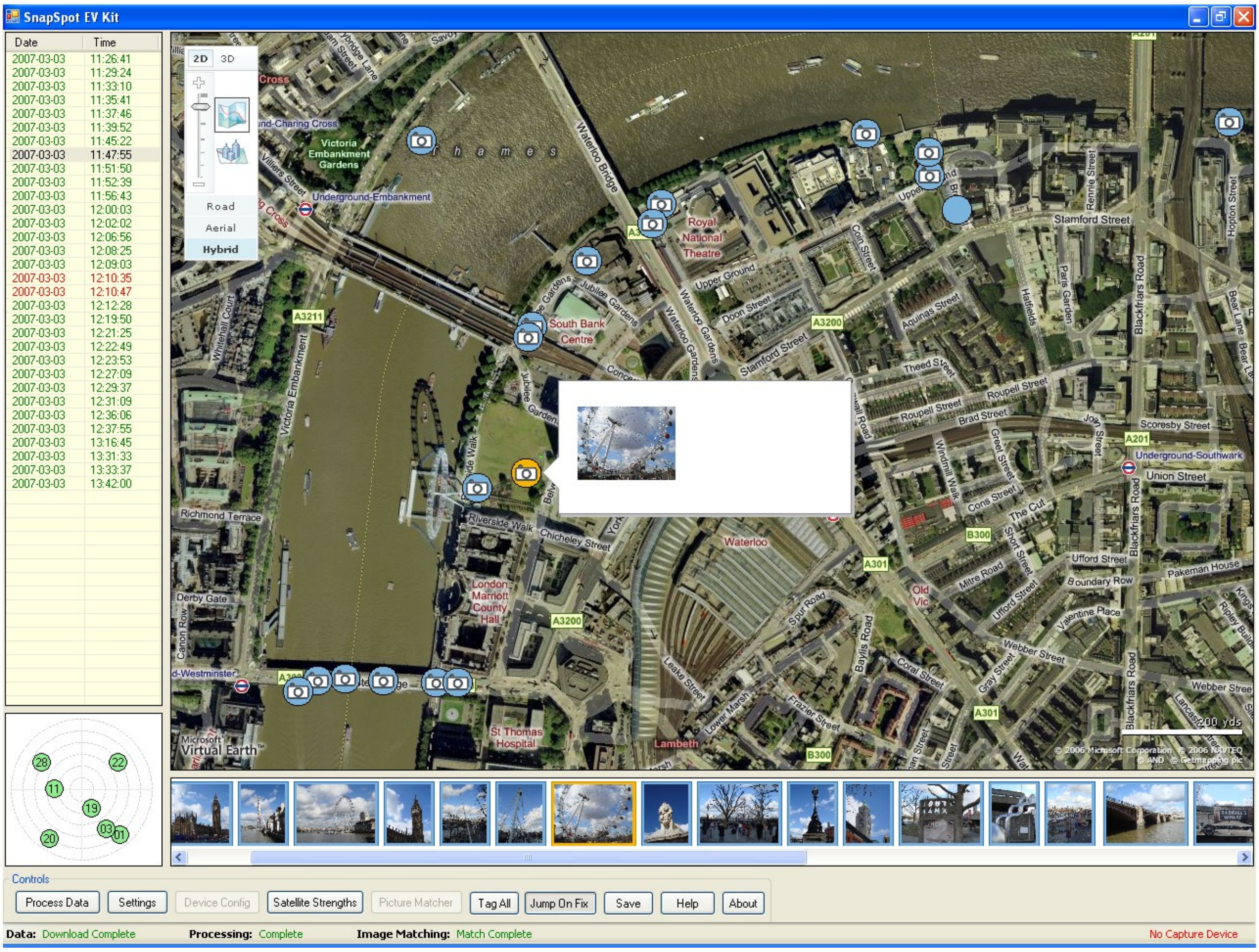


Figure 8 Experiments with Capture and Process for a camera

The list of data files in the left hand corner shows the collected set of IF signal files collected. Each IF data entry is shown by a timestamp, and the colour is used to indicate the result of the processing.

The signal samples are linked up with the picture files which were taken at the time. The images are displayed along the bottom of the window, and are then displayed on the map. As can be seen, this provides a clear and effective visual record of where you've been, and where you took the pictures.

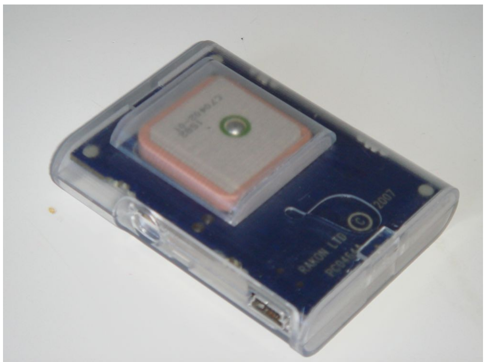
Note also that any particular picture can be selected and highlighted for further information, including information about the satellites visible at the time, displayed bottom left.

Experiments in real situations with with over 1,000 sample data files shows a location fix success rate of an impressive 96%.

Logging

A Logging Accessory

A design for a small low cost battery operated USB GPS logger capture device is shown in Figure 9 below.



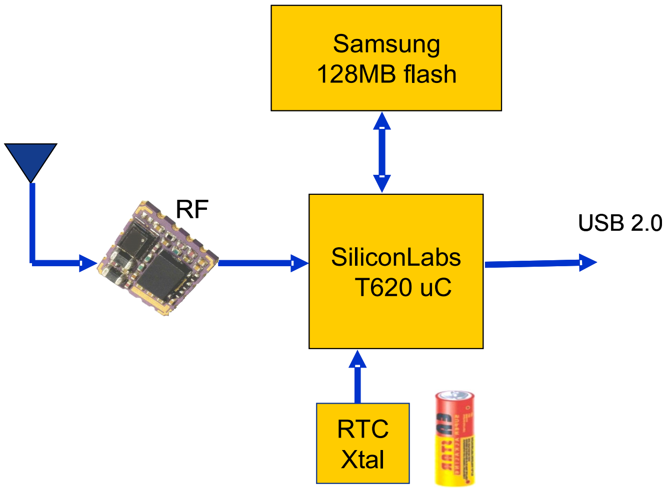


Figure 9 USB GPS Logger Design

This simple device is able to capture signals, store them in the flash memory, and then upload them over USB for processing on the user's PC. Its design is straightforward, with a component bill of materials of around $7 and weighing just 20 grammes. It's also easy to use, with just a single button to capture one or a set of signal samples, and has a long battery lifetime.

Battery Lifetime statistics

Since no signal analysis is performed on the device, and the signal capture only takes <200ms, very little energy is used by the capture device.

In one example experiment, a test device was run recording a signal sample at 10 minute intervals, 24 hours a day for 10 days. This captured a total of 1000 position fixes over the 10 day period, without recharging the coin cell battery.

The low energy consumption (10mJ/capture) to receive and store the signal sample means that a battery life of many months or even years can be achieved by a lightweight, convenient device. This would be undreamt of with conventional GPS technology.

Practical Testing

In Figure 10 the results are shown for a bicycle journey through the countryside in the Netherlands, with the lightweight logger device worn on the cyclist's wrist.

The logger captured signal samples every 5 seconds, and then these were downloaded from the device and processed. Despite the added difficulties of travelling through woodland, which makes GPS reception more difficult, the route taken can be seen clearly. The detail shows the different routes taken by the cyclist when travelling out and back.

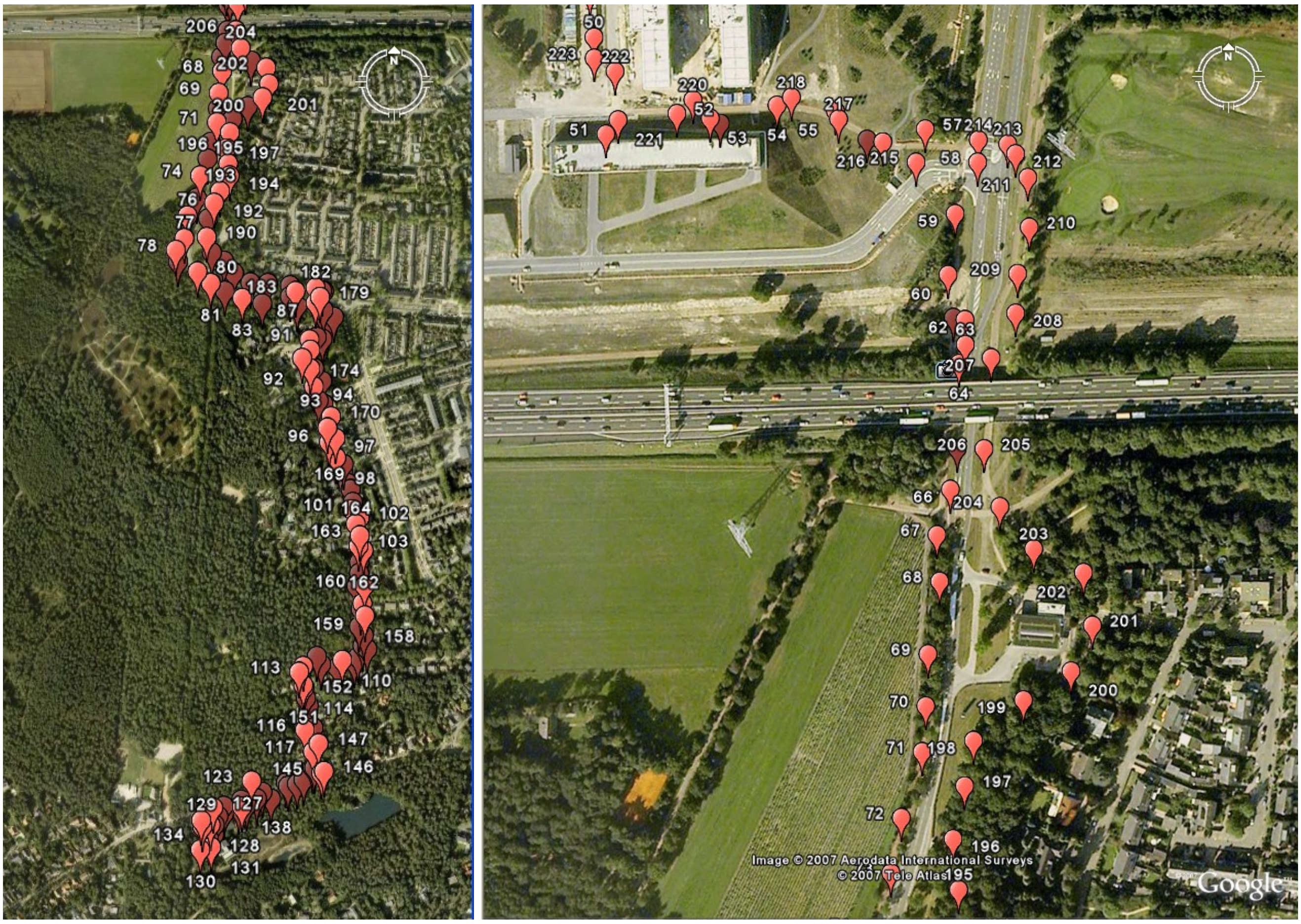


Figure 10 Experiments with Capture and Process for a Logger

SUMMARY

Capture and Process provides a very effective new GPS technology for conveniently capturing GPS signals for geotagging applications.

Location can be captured instantly - in under 0.2 seconds - using a simple, small and convenient device to store the GPS signal, with negligible energy consumption and very long battery life.

Using the stored fragment of GPS signal the location is quickly and easily calculated later with the help of a server connected to the users PC.

Trials worldwide have shown good accuracy (better than 10m), with a good fix location produced in 96% of cases.

In conclusion, the unique new Capture and Process GPS system is ideal for geotagging photographs, and also opens up many other exciting applications for logging locations.

GLOSSARY

Term	Meaning
GPS	Global Positioning System
GUI	Graphical User Interface
IF	Intermediate frequency
L1	GPS L1 link centred at 1.57542GHz
LBS	Location Based Services
LNA	Low Noise Amplifier
NMEA	National Marine Electronics Association
SSE2	Streaming SIMD Extension instruction set 2 from Intel
TCXO	Temperature Compensated Crystal Oscillator
USB	Universal Serial Bus
UTC	Coordinated Universal Time, previously known as Greenwich Mean Time

REFERENCES

1. Tabblo Marketing Survey, http://blogs.zdnet.com/ITFacts/index.php?p=12307
2. http://www.imaging-resource.com/EVENTS/CDXF02/1037652588.html
3. http://connect.educause.edu/blog/StuartYeates/theriseandriseofflic/1297
4. http://blog.agrawals.org/2007/10/10/the-power-of-the-social-graph/
5. Understanding GPS - Principles and Applications - E.D. Kaplan - Artech House - ISBN:0-89006-793-7
6. Rakon GRM6510 Data Sheet, Rakon Ltd