Geotagging with GPS

Capture and Process

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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 1/5th second) 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 [1] 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 [2] encourage users to name images, star their favourites and make scrolling through collections faster. The online photo sharing website flickr [3] 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 [4] 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 [5], 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:

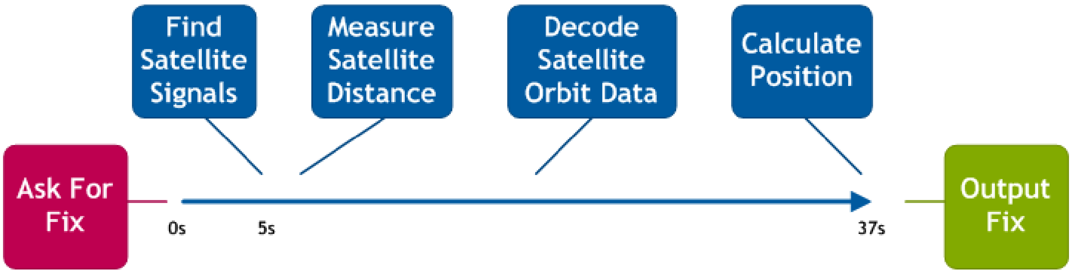


Figure 1 – Work done in a conventional GPS Receiver

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

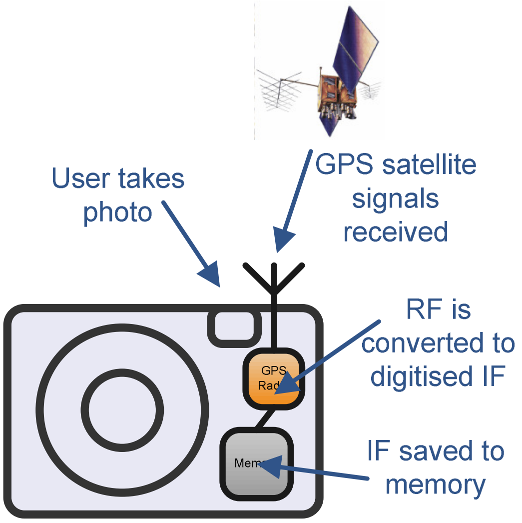


Figure 2- Capturing GPS IF data

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
- The camera clock records the time of the photo (and therefore of the GPS capture)
- The GPS signal sample is put into a file, and embedded in the photograph or cross-referenced with the photograph image

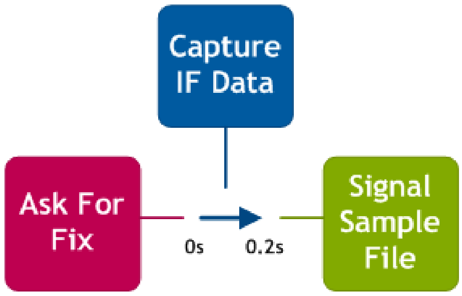


Figure 3 – Work done in a Capture and Process camera

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, the batteries typically used in current cameras have a battery capacity of around 11,000J and can take 220 pictures; 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 negligible 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.

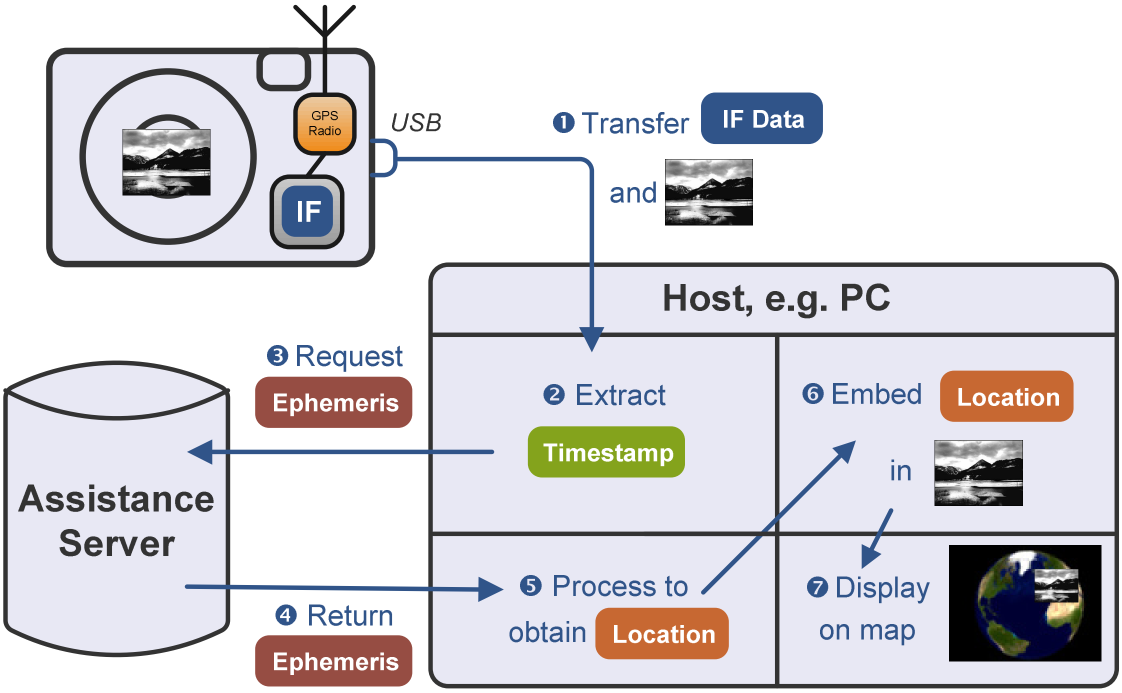


Figure 4- Processing captured GPS IF data and geotagging a photograph

The processing proceeds as follows:

- The camera is connected to the host, which may be a convenient PC, or another internet connected processing platform, and the pictures are downloaded
- The capture data and timestamp is extracted from the image for each photo
- The Server is contacted, and information about the orbits of the GPS satellites over the period of time of interest is 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

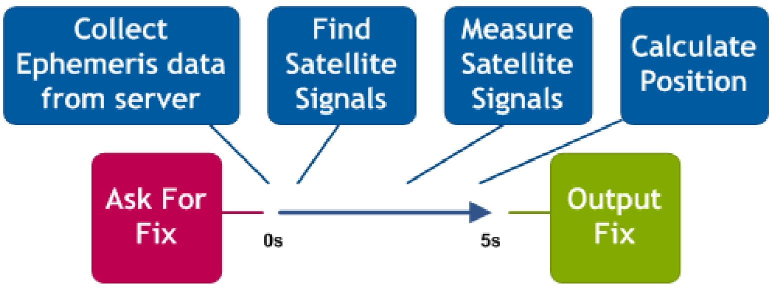


Figure 5 - Work done to process a capture

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 cross-calibrate the camera clock timestamps 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

GPS POSITIONING 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	128KB
Sensitivity of first fix	-144dBm first fix -147dBm subsequent fixes
Accuracy of GPS fix[2]	5m CEP 50% 25m CEP 90%
Time to compute first fix[3]	0.5-2.5s
Average time to compute fix[3]	<0.5s 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 1.87GHz Core 2 Duo E6300 PC with SSSE3, and using the SSE2 instruction set, see below.

The probability of a successful GPS position fix varies with signal level, as shown in Figure 6. These results are from simulations, with all satellite signals at the same signal level. In practice signal levels are much more variable, and the situation is illustrated and discussed in the following sections.

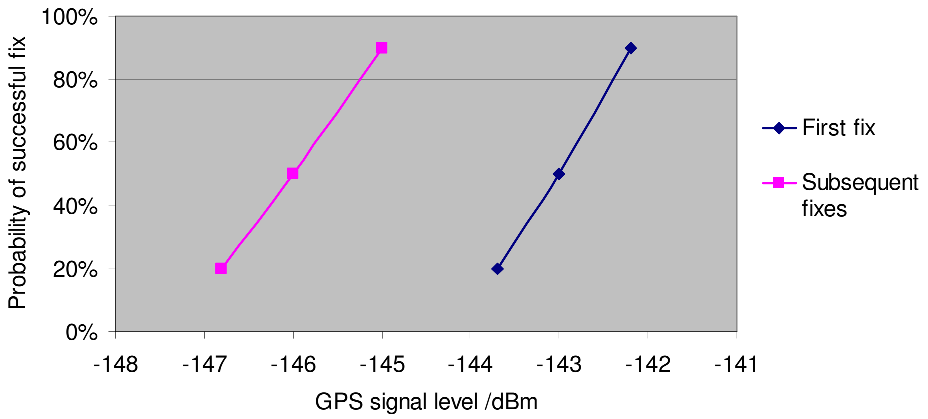


Figure 6 Sensitivity for a GPS IF Data capture

GPS fix availability

Several factors combine to give a Capture and Process software system that can give good fix availability.

1. No download of satellite signals is required. As explained above, conventional navigation system have to receive strong signals from each satellite to be used, for up to 30 seconds, before signals from that satellite can be used to contribute to the position fix. This is not a requirement for Capture and Process systems, in which a fix can be calculated simply if there sufficient GPS signals that happen to be visible when the signal is captured.
2. No continued operation or tracking is required. Therefore there is no need for a normal view of the sky even when nominally “off”, for position tracking, or for updating satellite information. The user can go in and out of buildings and vehicles, with poor or no satellite visibility, and the device can be kept in the users’ bag, and just got out when it is to be used.
3. The GPS signal sample can be collected when there is minimum noise and interference from the camera. Sensitivity is normally in practice limited by interference from the Camera device. As explained below, the GPS signal can be captured in a small interval when the Camera is quiet, to give good performance.
4. All the signal captures are stored and are available to be processed later, and the software can processes them in any order, and repeatedly. The software can use information from one signal capture that happened to be taken with strong signals present to help solve another signal capture with weak signals, even if the strong signal capture occurred later in time than the weak signal capture. This occurs, for example, when coming out of a building.

Nevertheless, despite the worldwide coverage of GPS and the advantages of Capture and Process, GPS will never work everywhere. There is always the possibility of situations in which GPS signals will not be received, or the user puts the camera in a case and moves it. The software is designed to handle these situations, in which there is no GPS location fix,

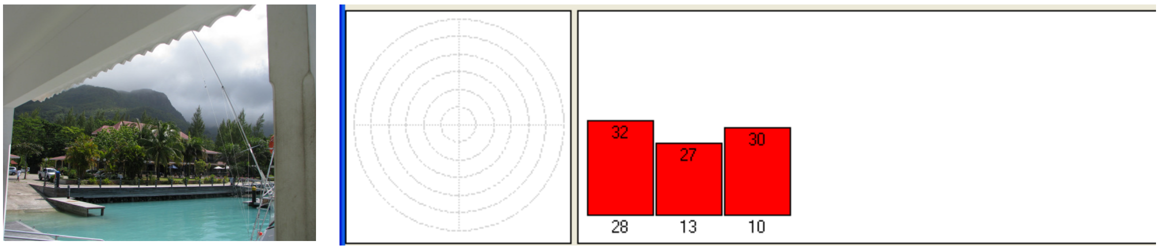
- by using information from neighbouring fixes to estimate the likely position
- by allowing the user to copy the location from one fix from one photograph to another

Because this is done with the application, on the PC or with the service, it is easy for the user to edit if desired.

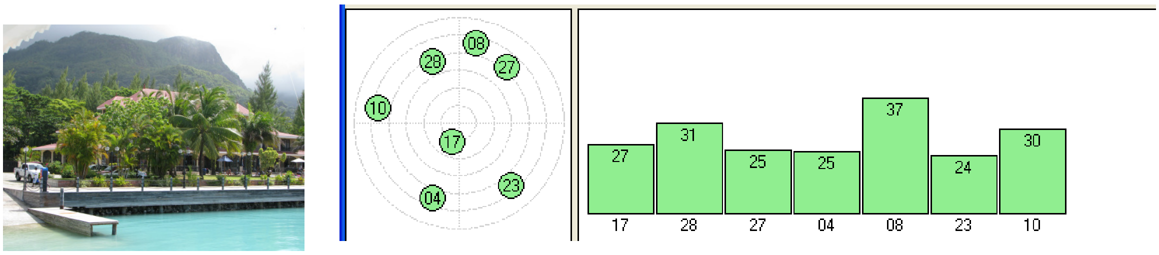
Iterative Geotagging

Capture and process allows iterative geotagging, as illustrated by the example below, of three photos taken on arrival in the Seychelles islands in the Indian Ocean, each with the GPS signal captured for geotagging. The photos are taken in difficult situations, from and then just outside a concrete building, which blocks GPS signal visibility. Remember that the photos could have been taken anywhere in the world – the software has no prior knowledge of where the user was.

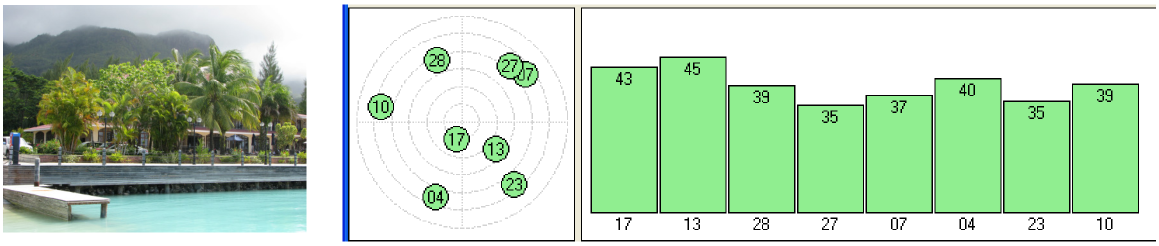
The photos are shown in Figure 7, together with the GPS signals found, and the position fix produced.



(i) Photo from deep inside a balcony, at 10:30, -4.646N, 55.477E (estimated location)



(ii) Photo from on the balcony, at 10:31, -4.646N, 55.477E (position assisted GPS fix)



(iii) Photo from outside the balcony, at 10:32, -4.646N, 55.477E (GPS fix)

Figure 7 Geotagging, coming out of a building

The iterative geotagging of the photos proceeds as follows.

1. A GPS fix of each capture of GPS IF data is attempted in turn. The first photo taken has poor satellite visibility, and no GPS fix is possible. The second photo is similarly unsuccessful, with only three satellite signals being found, and no fix being possible. Then for the third photo the GPS signal search is successful, and the location in the Seychelles is found, as shown.

2. The GPS analysis is then repeated with the help of the information from fixes achieved from later captures. The second photo GPS capture is analysed again, using the information from photo (iii), this time successfully finding 7 satellite signals, shown in Figure 7, and successfully performing a GPS position fix.

3. Finally, the location of other photos is estimated. Since the first photo is known to have been taken shortly before the second photo, it must be close to photo (ii) so it is given an estimated geotag.

The result is that all three photos are given a useful geotag - even though the GPS signals are weak (sometimes below that needed to demodulate satellite data), and the good fix environment is only experienced after the first photos have been taken.

Photo	Signal conditions	GPS fix	Interpolated position	Result
(i)	bad	Not possible	Possible once neighbouring photo located	-4.646N, 55.477E 25.0m 10:30:23.0
(ii)	marginal	Not possible initially, but possible once a neighbouring photo located		-4.646N, 55.477E 25.0m 10:31:07.5
(iii)	good	Possible		-4.646N, 55.477E 31.0m 10:32:05.8

Table 2 Results for the three photo geotags

These achievements would not be possible by a conventional GPS system designed for navigation.

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 3 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	0.3s 50%[4] 0.3s 90%	0.9s 50% 2.5s 90%
Time to compute subsequent nearby fixes	0.3s 50% 0.3s 90%	0.3s 50% 0.3s 90%

Table 4 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

[4] Meaning "50% of fixes are calculated within 0.3s, in this test case"

So for example, to process and calculate the GeoTags for 10 signal samples captured in proximity poor signal conditions most of the time would take less than

2.5s (for the first fix) + 9 × 0.3s (for the subsequent fixes) = 5.2s (altogether)

And the average time to fix for the set of samples is 5s/10 = 0.5s/fix.

With the trend of improving processor performance it is to be expected that the time to compute a fix to continue to diminish.

ADDING CAPTURE AND PROCESS GEOTAGGING TO A CAMERA

Capture and Process GPS can be integrated directly into a digital camera, or - for adding to existing cameras - the GPS Capture and Process functionality can be provided by an external hot shoe accessory.

In both cases the GPS radio functionality is simplified, as there is no baseband processing required.

Adding Geotagging to a Camera

The GPS capability for geotagging can be added to a camera with relatively little impact on the camera hardware or firmware.

Electronics hardware

For Capture and Process GPS, only a signal capture circuit needs to be added to the device. The hardware elements required are outlined below.

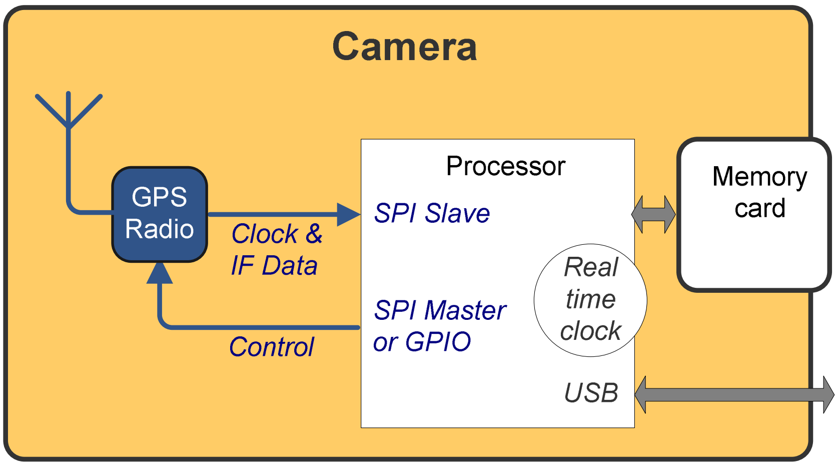


Figure 8 Essential features of a typical implementation in a camera

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 IF Data into the existing camera processor, typically over an SPI bus.

The signal data rate is typically 6-12Mb/s, depending on the choice of RF front end, and the signal transfer interface should be driven by the crystal oscillator of the GPS receiver, to ensure that all the signal samples are correctly captured. A slave interface is therefore required in the camera host.

The camera processor stores the GPS signal IF Data in flash memory, together with the picture and the time at which the photo is taken.

A simple control interface may also be required to configure and activate the GPS receiver. This may be provided by a second SPI interface (operating in master, control, mode), or by explicitly programmed GPIO pins.

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

Camera software

There is only little extra firmware that is required to control the geotagging GPS signal capture, as the receiver is simply switched on, possibly programmed for correct operation, the signal captured, and then the front end switched off again.

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

There are no standby functions to configure, and the user need not be aware of current GPS status. Since the fix calculation is not performed or used on the camera itself, there is no requirement for maps or other fix-handling applications on the camera.

When the image data is downloaded, then the captured GPS signal is also downloaded.

The application software on the PC links to the downloaded images, and the server, and interfaces to the user application either through an API, or the standard EXIF interface.

Interference avoidance

The GPS receiver has the difficult task of detecting the very weak signals from the GPS satellites. Meanwhile, a camera is a piece of electronics with a powerful processor, sensor and display, with many electronic signals circulating, and producing electromagnetic interference. Particular sources of interference are likely to be:

- the high current motor drives for the lenses,
- the high speed image transfers from the sensor, and into the flash memory
- the high frequency clock from the image processing DSP
- the electronic drive to the LCD display, with the long lines and reasonable current level
- clock lines, which widely run around the device

In practice the sensitivity of a GPS function in a camera is limited by this interference

Fortunately the Capture and Process approach only needs a small sample of GPS signal, and this can be chosen to be captured at a time when the camera is quiet. For example this can be included in a photo sequence of events in the camera, such as that shown in Figure 9.

Figure 9 Sequence of camera and GPS capture events for geotagging in a camera

If this is done then the camera will be particularly quiet during the capture of the GPS signal, and good sensitivity can be achieved.

A Photo Geotagging Accessory

The geotagging functionality can most readily be added to existing cameras by an accessory using the hot shoe interface. The accessory simply captures a sample of GPS signal every time a photo is taken, by means of the trigger from the hot shoe.

The hardware block diagram is essentially the same as before, although in this case the microcontroller and memory are dedicated to the capture device accessory, as in Figure 10.

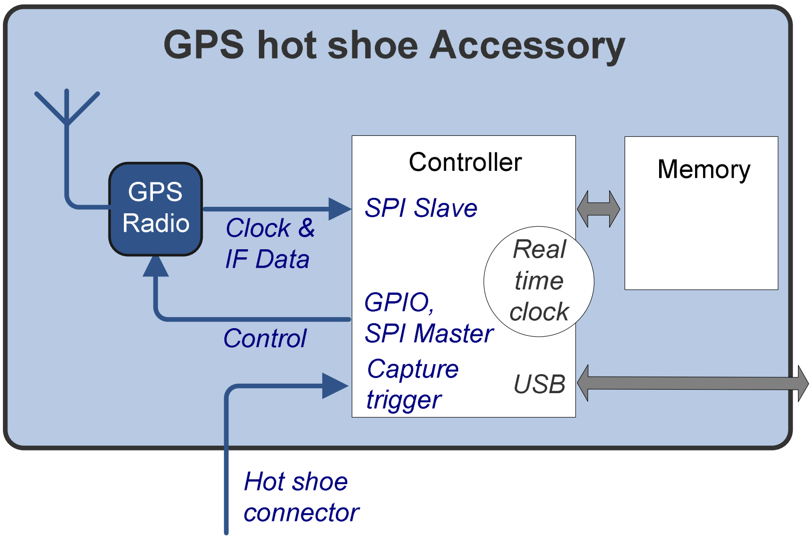


Figure 10 Main features of a typical implementation of a GPS geotagging accessory

To use the accessory device

- the GPS signal captures are downloaded onto the user's PC from the accessory
- the photos are downloaded from the camera into the PC

The software application then

- matches up the captures with the photos
- calculates the geotags, as before

GPS Radio

The GPS radio consists of

- a low noise amplifier, matched to the antenna
- a SAW filter to remove strong out of band interfering signals
- a receiver integrated circuit, which mixes the incoming GPS radio signal to a low intermediate frequency, filters it, and samples it with an ADC to produce a bit stream of the IF signal
- a temperature controlled crystal oscillator, used for the oscillator in order to provide sufficient temperature stability, despite variations in ambient and device temperature

The radio may also include one or more voltage regulators, depending on the power supply arrangements.

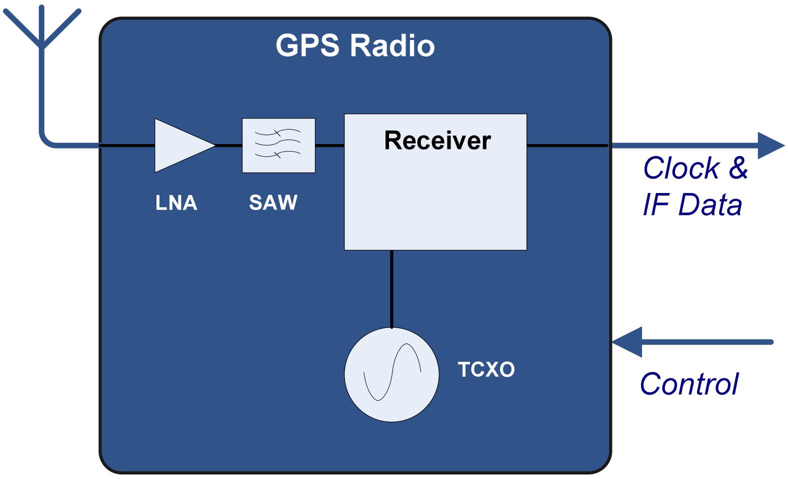


Figure 11 GPS radio receiver functionality

Depending on its particular design, the receiver may need to be configured prior to use.

There are two attractive ways of implementing the GPS Radio, depending on the application requirements – a module, or a chip on board design.

Radio module

For many applications minimum size is an important requirement. As there is no baseband processor in Capture and Process the radio can be made very small. This is illustrated by a GPS front-end receiver module, the GRM8650 from Rakon [6], shown below in Figure 12.

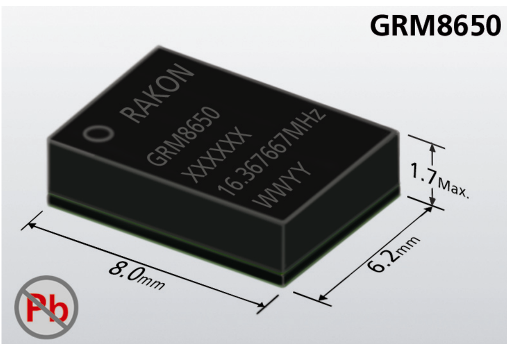


Figure 12 GRM8650 GPS radio Front-end module

This compact unit provides all the required GPS front-end functionality in a small package, including GPS radio receiver, filtering, and oscillator TCXO, ready-tested. The footprint of this module is $52mm^2$.

Chip on board reference circuit design

For some applications the design team will wish to do the development, manufacture and testing of the radio for their printed circuit board, and an example reference circuit from SiGe [7] is shown below in Figure 13.

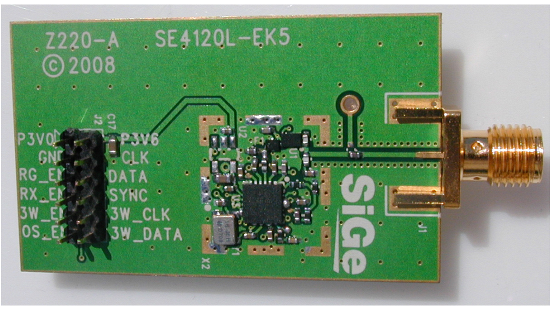


Figure 13 SE4120L Digital Camera reference design and evaluation kit

As in the case of the module, the hardware content and costs are minimal, as the Capture and Process approach does not requiring the cost, board area, or testing of a baseband processor. The bill of materials for the components in this radio reference design is around $2.5.

Antenna

The antenna is an important feature of all GPS equipment, as it has to collect the signals from satellites. It has to be designed together with the design of the casing, appearance and use of the camera.

For the placement and design of the electronics and the antenna the things to consider from the point of view of GPS performance are, in order of importance:

1. Avoidance of interference coupling into the antenna
2. A good ground plane
3. The antenna design, gain and efficiency
4. The effect of the hands and body of the user
5. The orientation, use in landscape and portrait mode – clockwise and anti-clockwise

With this in mind, it is not necessary that the antenna points vertically upwards in nominal landscape operation, as the user will take photographs in a variety of directions, and GPS satellites are anyway widely distributed in the sky. Design freedom and good results for Capture and Process geotagging can also be obtained with an antenna that faces forward, away from the user.

A circularly polarised antenna, such as a patch, is normally used. This gives best performance for the circularly polarised signals from the satellites, and it also rejects reflections which generally have the opposite, wrong, polarisation, and which otherwise could mislead the receiver signal processing.

USE OF GEOTAGS

Mapping of photographs

Capture and Process for digital cameras has been thoroughly tested by collecting samples from around the world and processing them. Figure 14 shows an example of a trip around London mashed up with Microsoft Virtual Earth.

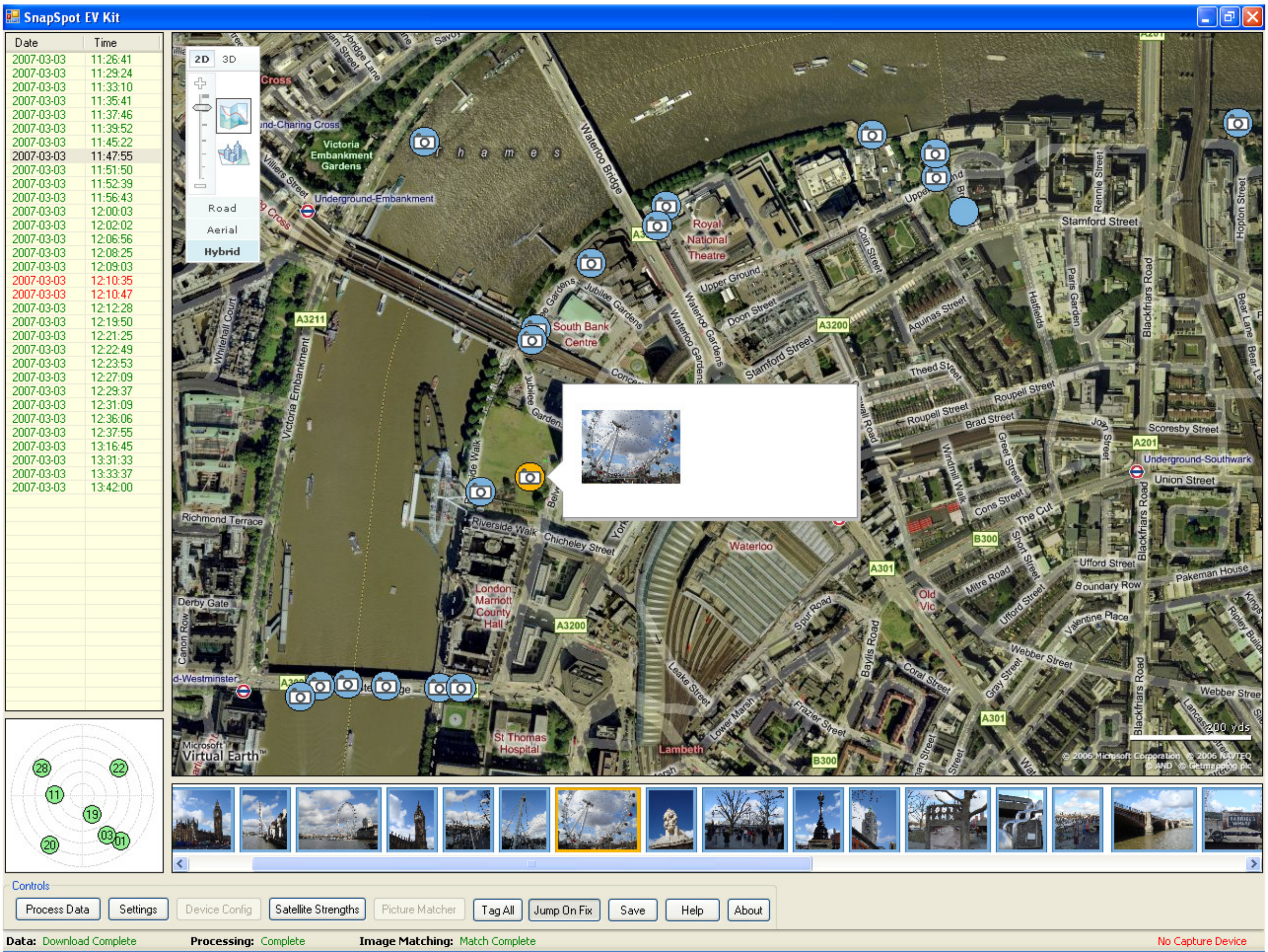


Figure 14 Experiments with Capture and Process for a camera

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 the time of the photo, and the colour is used to indicate the result of the processing.

The signal samples are linked with the picture files. The images are displayed along the bottom of the window, and are then displayed on the map. This provides a clear and effective view of where you've been, and where you took the photos.

For illustration, the satellites visible when the selected photograph was taken are shown in the bottom left corner.

Labelling and finding

Latitude and longitude are actually not that helpful to a user, what is more useful is the address description of the location where the photo was taken.

This is obtained by a query to a database, which contains map address information - a process called "reverse geocoding". (Turning an address into a latitude and longitude is called "geocoding".) The address can then be embedded in or associated with the photo.

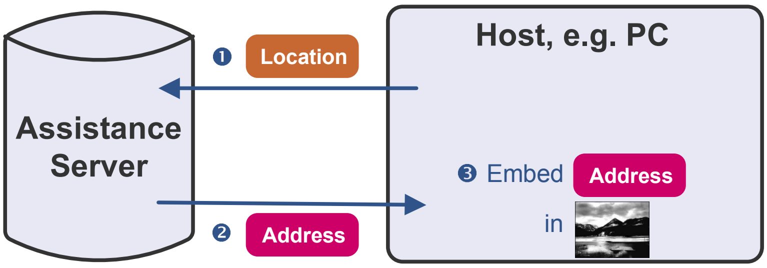


Figure 15 Reverse Geocoding to find the address

The result is a familiar address, which can be used for labelling, sorting, and finding photos.

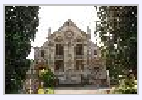
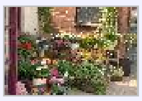
Photo		Address	POIs
	DSC_0025.JPG 6.38 MB May 14, 2008 12:38:50 PM	Castle Keep Redhill Surrey United Kingdom	
	DSC_0032.JPG 6.24 MB May 14, 2008 12:50:23 PM	West Street, A25 Redhill Surrey United Kingdom	West Street (20 m)
	DSC_0038.JPG 4.41 MB May 14, 2008 12:53:34 PM	West Street, A25 Redhill Surrey United Kingdom	West Street (20 m)
	DSC_0041.JPG 6.47 MB May 14, 2008 12:57:21 PM	Park Lane Redhill Surrey United Kingdom	Reigate Park (20 m) Hotel (100 m) Restaurant (50 m)
	DSC_0045.JPG 4.62 MB May 14, 2008 1:01:31 PM	High Street, A25 Redhill Surrey United Kingdom	

Figure 16 Automatically Geotagged and labelled photographs

Figure 16 illustrates the geotagged photos, complete with details, location address, and nearby points of interest.

LOGGING WITH CAPTURE AND PROCESS

A Logging device

A design for a small, long lifetime GPS logger capture device using Capture and Process is shown in Figure 17 below. The user simply presses a button to trigger the capture of a GPS sample and hence geotag their location. Alternatively, the controller can be programmed (via the USB interface) to capture IF Data periodically, at a convenient interval. In between captures the device is simply asleep.

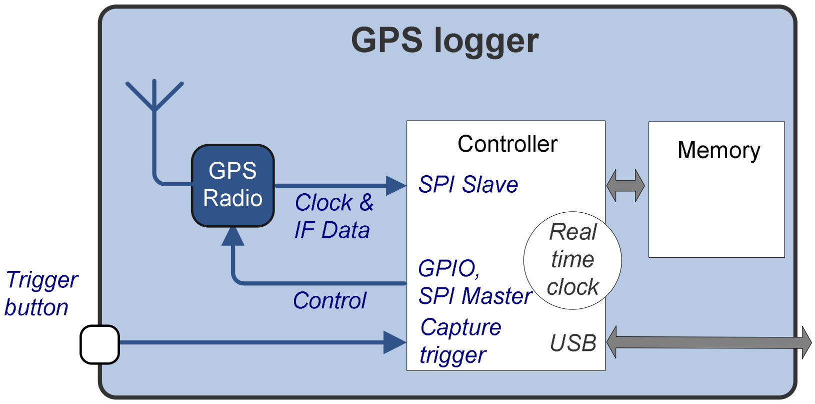


Figure 17 USB GPS Logger Design

This uses the r.f. circuitry already described, and captures signals, stores them in the flash memory, and then uploads 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. An example is shown in Figure 18.

Figure 18 USB GPS Logger example

It is 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 19 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.

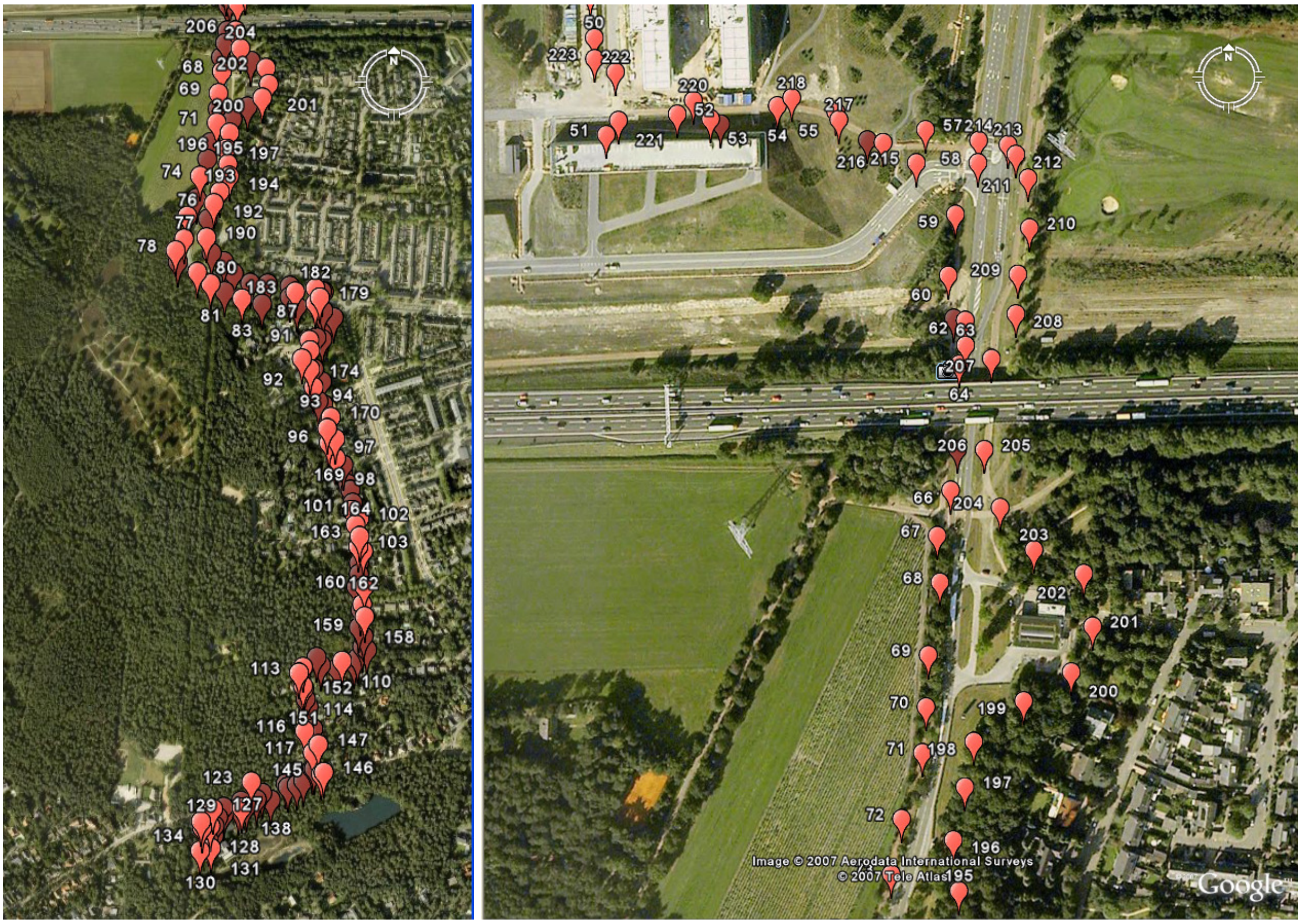


Figure 19 Experiments with Capture and Process for a Logger

SUMMARY

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

Location can be captured instantly for every photo - in less than $1/5^{th}$ second - 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 have shown good accuracy, better than 10m, in outdoor usage worldwide. As a result the user can see where photos were taken, and can sort and find their photographs.

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
ADC	Analogue to Digital Converter
API	Application Programming Interface
GPIO	General Purpose Input/Output
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
POI	Point of Interest
RF	Radio Frequency
SAW	Surface Acoustic Wave (an RF filter technology)
SPI	Serial Peripheral Interface
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

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