Software algorithm for decoding GPS from spatially encoded video

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1. Introduction

Spatial encoded video is used for a large number of mapping projects for various applications (McCarthy T., 1999). GPS data can be encoded onto the video or audio track using different techniques. One encoding/decoding hardware system, designed by Navtech (NavTech, 2007), enables 1 Hz GPS ASCII data strings to be encoded onto a single audio channel of any video recording format. Frequency shift keying modulation (FSK) (Miyagi M., 1968) techniques are used to encode GPS data stream onto audio stream during data acquisition. This GPS stream can be decoded using the same encoding hardware system during post processing whilst a frame-grabbing card is used to digitise single frames of video. Both image and GPS data streams are synchronised on GPS time and are saved to hard disk. These data-streams can be retrieved and analysed in a GIS for various mapping applications. Post processing of the data using frame-grabbing card has, to date, proved to be cumbersome and inefficient. This is due, for the most part, to the setup and operation of frame-grabbing cards. To overcome these limitations, a project was initiated with the key objective of simplifying this approach. This centred around development of a software decoder that can retrieve GPS data directly from the captured spatial video data files without the need for specialised hardware. An obvious advantage of this software algorithm is the ability to transfer audio video using any digital format, onto a PC desktop, using standard methods and systems. GPS can then be retrieved and displayed synchronised to the video stream using software, without the need for frame grabbing cards and cables.

2. Background

This work is part of a PhD research project, investigating spatial video data structures for High Definition Video (HDV) and was undertaken to facilitate a more detailed understanding of the processing requirements for existing Spatially Encoded Digital Video data sets. Spatial Video comprises standard video data that is linked to GPS and so has explicit spatial-temporal attributes such as date, time, position and view angle. It has many uses in various GIS applications and asset tagging systems and generally functions as an enhanced visualization tool. A number of organizations have developed this technology worldwide, (Blueglen Technology, 2005; Red Hen Systems, 2005; RouteMapper, 2007).

Decoding testing was carried out using data streams that were acquired as part of other research projects at the National Centre for Geocomputation. These were acquired from a vehicle mounted system that collected route corridor survey data sets and totals approximately two hours of video. The equipment used in this instance was supplied by Navtech systems, comprising a CamNav GPS encoder/decoder. This device encodes GPS signal to the audio channel of the video data stream through the MIC input jack on any conventional camcorder, (NavTech CamNav, 2004). The Spatial Video data sets are made up of NMEA GPS ASCII strings, Figure 1. An optional trigger point character is also shown in Figure 1 by the 0 entry before every GPS data string set.

```
0
$GPZDA,120241.00,26,02,2006,00,00*60
$GPRMC,120241.00,A,5323.2228,N,00635.1483,W,21.8,221.6,260206,,*1A
$GPGGA,120241.00,5323.2228,N,00635.1483,W,1,09,1.3,138.5,M,,M,,*63
0
$GPZDA,120242.00,26,02,2006,00,00*63
$GPRMC,120242.00,A,5323.2179,N,00635.1554,W,22.7,221.5,260206,,*1A
$GPGGA,120242.00,5323.2179,N,00635.1554,W,1,09,1.5,138.6,M,,M,,*69
0
$GPZDA,120243.00,26,02,2006,00,00*62
$GPRMC,120243.00,A,5323.2128,N,00635.1626,W,23.5,220.9,260206,,*17
$GPGGA,120243.00,5323.2128,N,00635.1626,W,1,10,1.4,138.6,M,,M,,*63
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Figure 1. Sample GPS NMEA messages and Trigger Points.

3. Encoding Data Structure and Analysis

The analysis work performed on this project comprised two stages. Firstly, the data structure format that enables the GPS to be encoded onto the audio channel had to be clearly defined and understood. Secondly, a suitable video format was required that would provide the necessary flexibility for decoder development.

3.1 Data Structure

NavTech systems provided support by supplying a CamNav specification document (NavTech CamNav, 2004) for the encoding/decoding hardware and defined the encoded GPS data structures. This FSK wave form is a continuous ninety six byte transmission structure that has an overall duration of 192ms per frame. All frames began with byte zero as the frame synchronisation byte, and ended with byte ninety five as the check sum for the whole structure. This data frame was encoded as a continuous series of symbols, each with 250µs duration, onto the audio channel. Each zero binary symbol was defined by an audio signal inversion at the interval above while a one binary symbol has a second signal inversion at 125µs. Based on this data structure some basic calculations and assumptions could be made. These included data frame structure, frame byte positions and symbol partitions. The symbol partitions are sent Least Significant Bit (LSB) first by the encoder which necessitates a binary string representation to be reversed for visualisation. Thus, this frame structure should facilitate the encoding of ninety four GPS data string characters.

3.2 Decoder Development

Almost any digital video capturing equipment can be used with the CamNav hardware as long as it has an audio input port with which to encode the GPS to the audio channel. Thus, many different video formats would be encountered based on the particular video codec's used with different types of hardware. Therefore, a generalised approached was adopted where all sample sets of captured GPS encoded video were uploaded to a PC in Microsoft Windows Media Video (WMV) format. As part of the software GPS decoder a WAV file creation component was developed to separate the GPS encoded audio stream from the video stream. The primary reason for this step was to separate the development and testing logic of the audio decoder from a video stream format that was little understood during the initial stages of development. WAV file format data structures is detailed in two technical source documents (Microsoft, 1992; Bosi M. *et al.,* 2003).

4. Decoding Process

The important initial steps that were taken during the decoding process involved some basic software development that facilitated easy analysis of the WAV file format. This software was written to allow any sound file to be traversed in a number of different ways based on the known data structures previously studied. It was thus possible for the WAV file to be analysed from any given starting and ending byte locations where each byte could be viewed as a single or double byte sample. Byte conversion formats were also provided in ASCII, Unicode, Signed and Unsigned Integer format. For example, this functionality allowed Bytes 0 to 4 to be displayed in ASCII format to identify the File chunk header which will always read 'RIFF' or Bytes 36 to 40 which define the start of the audio data section with the ASCII descriptor 'data'.

The decoding process comprised four distinct stages and a total of five different operations, Figure 2. Stage one involved using this analysis tool to understand and gain familiarity with the WAV file data structures. The various project data files were objectively analysed to ascertain similarities in byte positioning and data contents. Stage two involved the extraction of audio data byte chunks. These were extracted as signed integer audio sample values, for stereo and mono formats. Stage three comprised two operations where these data sets were examined to determine wave structure and location of signal inversion points. These operations proved very time consuming as large numerical data sets were processed and measured for inversion points at numerous points in the audio sample files. Finally, the fourth stage entailed processing of signal binary symbols so that these could be structured into byte sized group structures that could then be converted to their ACSII character representations (IEEE Long Island, 2005).

Once all this manual decoding analysis had been completed a full software requirements and specifications document could be defined. This resulted in the first version of a software decoder being developed that extended the existing analysis tools functionality. This extension could now facilitate a full analysis of any of the sample sets of GPS encoded audio files and could complete a full GPS decode through software alone.

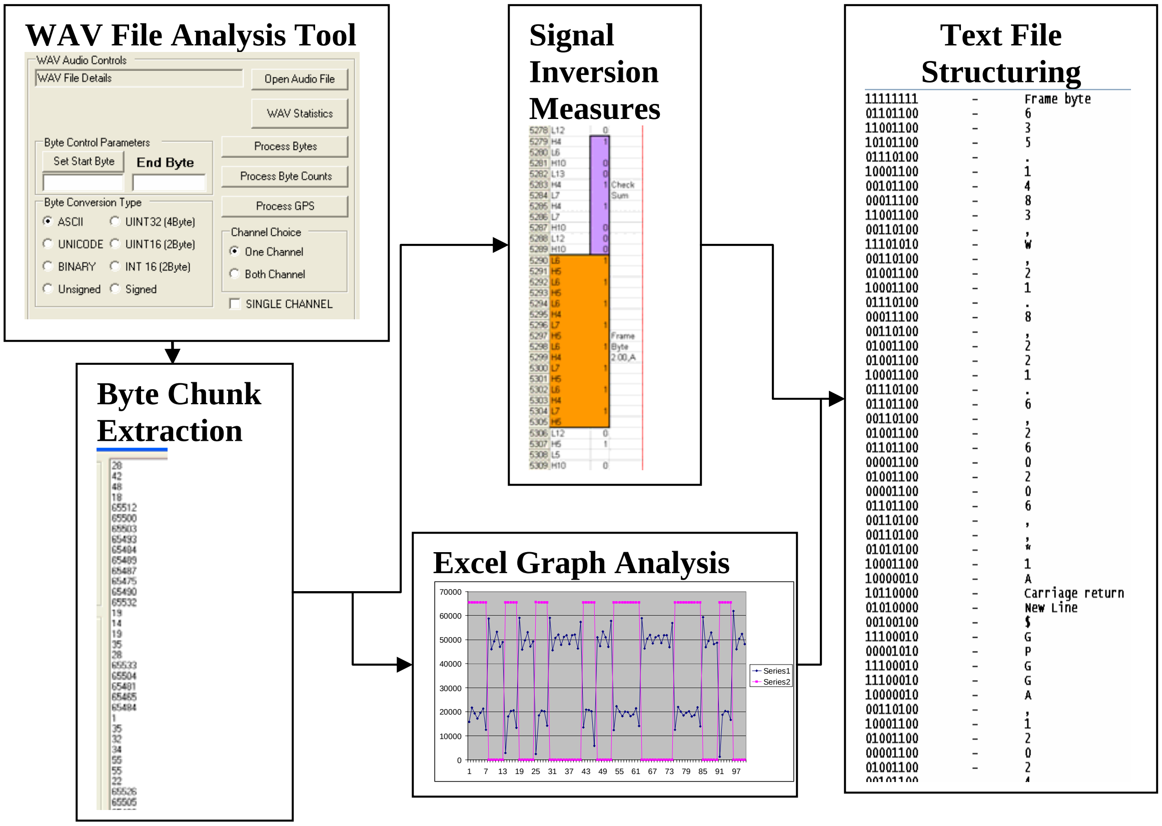

Figure 2. Decoding Process Stages.

5. Decoder Results

Analysis of the encoded frame structures for a number of different video segments showed an average of ninety two GPS data string encodings instead of the expected ninety four. The missing byte symbol structures were always 0x00 padding or ballast bytes, which were sent when hardware propagation delays affected the GPS signal reception, conversion and transfer through the encoder. It has also been shown that the software decoder method provides at least one more complete GPS data string from the audio files than that produced through the hardware version. It is assumed that the synchronisation procedures that the hardware decoder performs or the serial port data handling architecture could be the reason for the first full GPS NMEA message to be dropped.

Figure 4 displays a sample of the manual decode work preformed, with all the symbol groupings and complete ASCII conversions shown. This sample can be clearly related to Figure 1 which was produced through the use of the hardware decoder. The decoded GPS data string in this sample relates to the second half of line three and the first half of line four from figure 1.

11111111	-	Frame byte
01101100	-	6
11001100	-	3
10101100	-	5
01110100	-	.
10001100	-	1
00101100	-	4
00011100	-	8
11001100	-	3
00110100	-	,
11101010	-	W
00110100	-	,
01001100	-	2
10001100	-	1
01110100	-	.
00011100	-	8
00110100	-	,
01001100	-	2
01001100	-	2
10001100	-	1
01110100	-	.
01101100	-	6
00110100	-	,
01001100	-	2
01101100	-	6
00001100	-	0
01001100	-	2
00001100	-	0
01101100	-	6
00110100	-	,
00110100	-	,
01010100	-	*
10001100	-	1
10000010	-	A
10110000	-	Carriage return
01010000	-	New Line
00100100	-	$
11100010	-	G
00001010	-	P
11100010	-	G
11100010	-	G
10000010	-	A
00110100	-	,
10001100	-	1
01001100	-	2
00001100	-	0
01001100	-	2
00101100	-	4
10001100	-	1

Figure 3. Manually decoded GPS from Symbol groupings.

6. Conclusion and Future Work

The main hurdle of this research project has been overcome, namely decoding GPS using a software algorithm. This was clearly demonstrated by comparison between results from software and hardware decoders. No significant barriers were encountered in the general approach that was used to complete this project. Future work in this area would include a more refined implementation of the software decoder which at present is only available as part of a larger WAV file analysis tool. Other work has started to develop the algorithm to decode directly from the video file, avoiding the current requirement for intermediate WAV file formats. Future work could include integration with GIS and extending this algorithm to handle latest HDV formats.

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