Is the SCP-ECG Format Suitable for Inpatient Ecg Management?

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Abstract

SCP-ECG (Standard Communications Protocol for Computer-Assisted Electrocardiography) is a signal-specific format drawn by the European Committee for Standardization with the goal to be widely used in the ECG field. According to it, a software prototype has been developed and tested in a complex clinical setting.

The program extracts information related to the patient, the global measurements, the ECG interpretative statements and the binary data of the ECG. The first information is visualized in a clear textual format while the latter is used to reconstruct the ECG recordings.

The validity of the decoding algorithm was analytically tested using the ECG reference records supplied by the SCP-ECG standard. The differences between the original data and the reconstructed data were always below the limits set by the standard.

The software prototype seems suitable for inpatient ECG management, as part of a large conventional clinical database system.

1. Introduction

In the last years, the communication demand of physiological signals and data within hospital information systems increased considerably. However, proprietary formats didn't allow free exchange of data. To avoid this major difficulty several international organizations started cooperative projects to establish a widely-accepted protocol for transmission and storage of the signals between devices and computer networks. This work led to at least three major standards: DICOM (Digital Imaging and Communication in Medicine; http://medical.nema.org/dicom/2003.html), HL7 (Health Level Seven; http://www.hl7.org/library/standards.cfm) and SCP-ECG (Standard Communications Protocol for Computer-Assisted Electrocardiography; http://www.cen tc251.org/TCMeet/doclist/TCdoc02/N02-015-prEN1064. pdf). The first two are applicable to one-dimensional signals as general purpose object-oriented protocols. The latter represents an ECG-specific format, supported also by cardiology experts, that has been implemented by several ECG manufacturers with good chances to become in the next years a 'de facto' standard in the ECG field, at least in Europe. SCP-ECG has been worked out within the Advanced Informatics in Medicine project Nr 1015 in 1989-90, yielding to prestandard version 1.0 in 1993 and version 1.3 in 2000 by CEN/TC251 Committee. In February 2002 the standard version 2.0 was approved and published.

In order to adopt this standard to decode and visualize 12-leads rest ECG recordings coming from different ECG machines, we started in October 2002 a project involving the Cardiology Unit of the Hospital of Pordenone, the Electric, Electronic and Informatics Department of the University of Trieste and the INSIEL SpA Company operating in the sanitary field. A software prototype written in Borland C++ 4.0 Professional has been developed and tested in a complex clinical setting.

2. The decoding algorithm

The data record is divided into different sections each with a given identification number (Figure 1). The program starts reading section 0 and section 1 which are mandatory in the standard and then it processes the other 2 to 11 sections which are optional. In the file may be present other sections, not considered here because they are manufacturer specific. Section 0 contains pointers to the other sections. Section 1 contains information concerning the patient and the ECG identification. The program performs a loop to read all the tags and to extract most significant data as: ID, First and Last Name, Sex, Date of Birth, Height, Weight, Drugs, Systolic and Diastolic Blood Pressure, Date and Time of Acquisition, Filters.

Sections between 2 and 6 deal with the compression method of the tracings (see Figure 2 for the flow of the decoding algorithm). Section 2 defines the Huffman table(s) used in encoding [1]. Huffman coding creates variable-length codes. Symbols with higher probabilities get shorter codes. They have the unique prefix attribute, which means they can be correctly decoded despite being of variable length. To efficiently decode a stream of Huffman codes, a binary tree is constructed from the table. Escape codes may be present to dictate a change of Huffman table during the decompression phase.

Section 3 defines the leads, how they are recorded, if median beats are used and the number of samples.

Section 4 contains the location and width of the QRS complexes for median subtraction and the pointers to the protected data segments where low pass filtering and

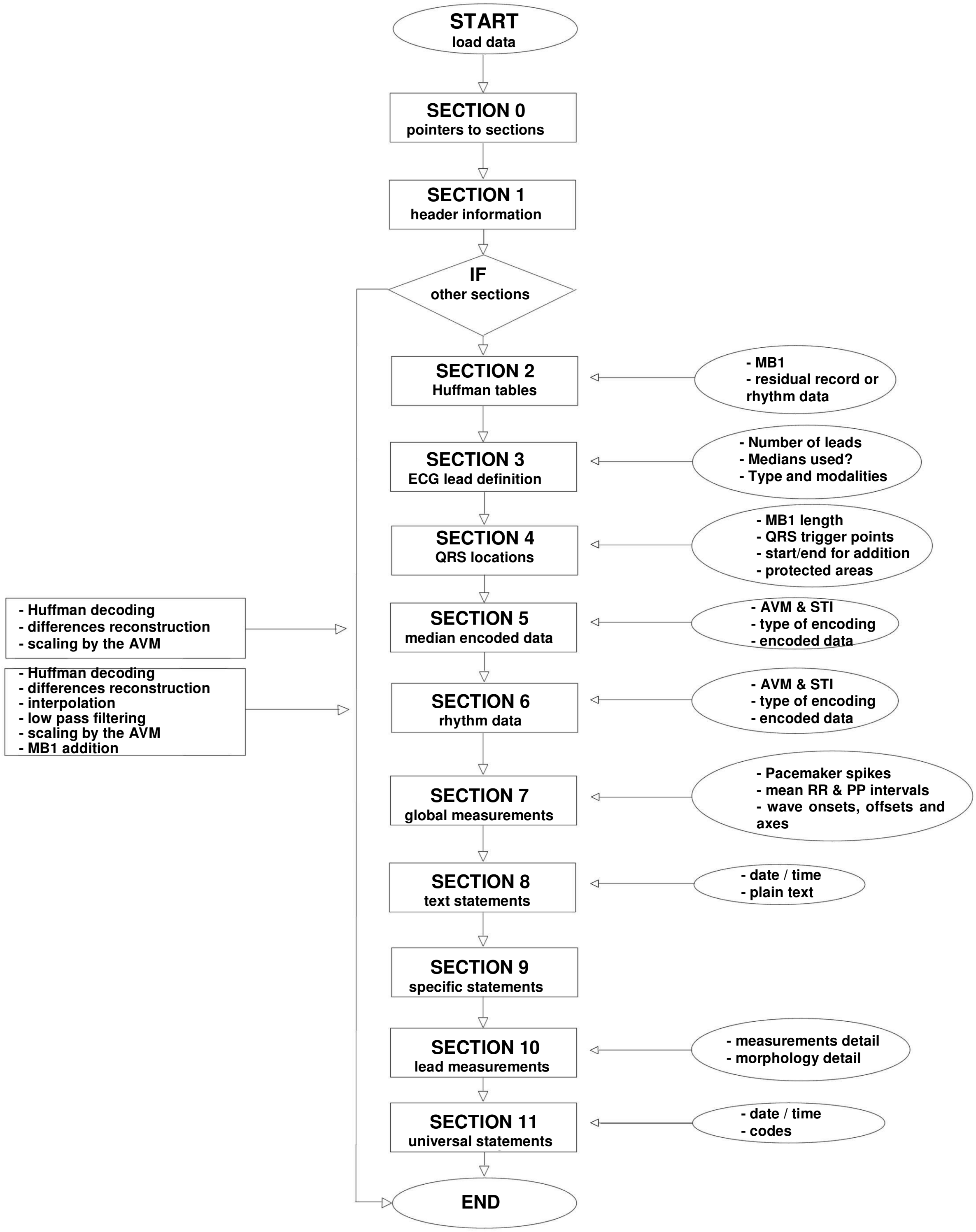


Figure 1. Flow chart of the SCP-ECG file structure and of the related information and operations.
Legend: AVM = Amplitude Value Multiplier, STI = Sample Time Interval, MB1 = Median Beat of type 1.

decimation of the residual signal are not allowed.

Section 5 includes the median encoded data. After applying Huffman decompression, a first or second differences reconstruction is operated for each lead to obtain the median beats.

Section 6 contains the rhythm data if no medians have been subtracted or the residual signal after medians subtraction. At first the Huffman table is used to decode the residual signal. Then a first or second differences reconstruction, an interpolation, a low pass filtering and a scaling are operated on the residual signal before adding it to the reference beat previously centred on each QRS complex (Figure 2). The reconstructed tracings are shown in a 12 leads 10 seconds real dimensions format on the screen (Figure 3) or in a 3 leads 5 seconds zoomed format. A previously validated anti-aliasing technique is applied [2]. User interface allows the physician to set markers, so that amplitudes, interval durations and drift can be precisely measured.

Section 7 memorized global measurements such as RR and PP mean intervals, P-Q-T onsets, offsets and axes, Pacemaker spike measurements data if any. This data is shown by the program in the upper-left box on the screen (Figure 3).

Section 8 contains a text version of the latest diagnostic interpretation of the ECG. This is shown by the program in the upper-right box on the screen (Figure 3).

Section 9 is reserved for manufacturer specific implementation of diagnostic statements.

Section 10 contains the measurements detail of each recorded lead separately and is presented as a plain text, at the moment.

Section 11 comprises the most recent interpretation and over reading data, coded according to the protocol.

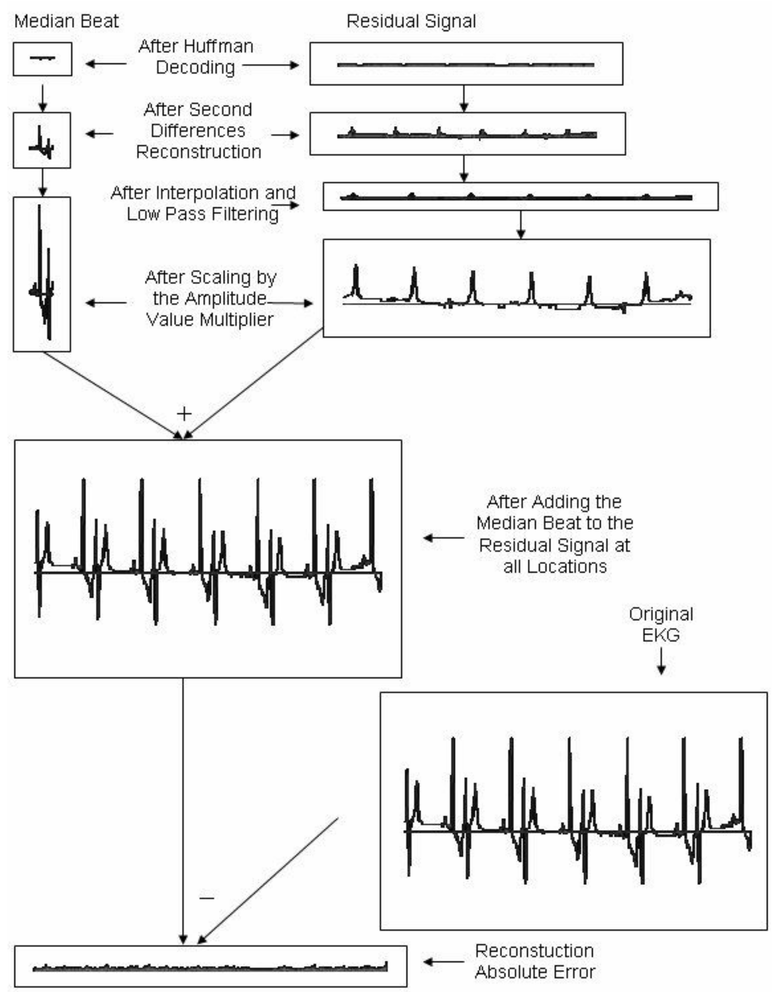
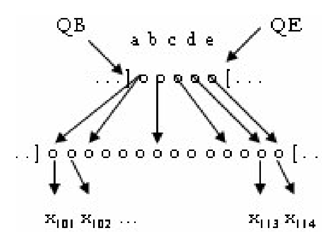


Figure 2. Flow of the decoding algorithm

2.1. The interpolation

We included this section to detail some difficulties arisen in the reconstruction sequence of the decimated samples. The standard suggests manufacturers to resample the original signal from 2 ms to 8 ms outside of "protected zones" which means away from QRS complexes. It explicitly suggests to consider multiples of 4 samples to be decimated, but we found it not true in some test files. In the example below we have 14 samples (x_{101} … x_{114}) to be expanded from 5 samples (a .. e). QB and QE delimit the no protection zone.



We treated x_{101} through x_{112} as suggested (x_{101} = a; x_{102} = a; x_{103} = a; x_{104} = a+(b-a)/4; x_{105} = a+2*(b-a)/4; x_{106} = a+3*(b-a)/4; x_{107} = b; x_{108} = b+(c-b)/4; x_{109} = b+2*(c-b)/4; x_{110} = b+3*(c-b)/4; x_{111} = c; x_{112} = c) and then inserted the last samples d and e in positions x_{113} and x_{114}.

This point has been discussed with the project working group and yielded to sample files rebuild and important protocol improvements.

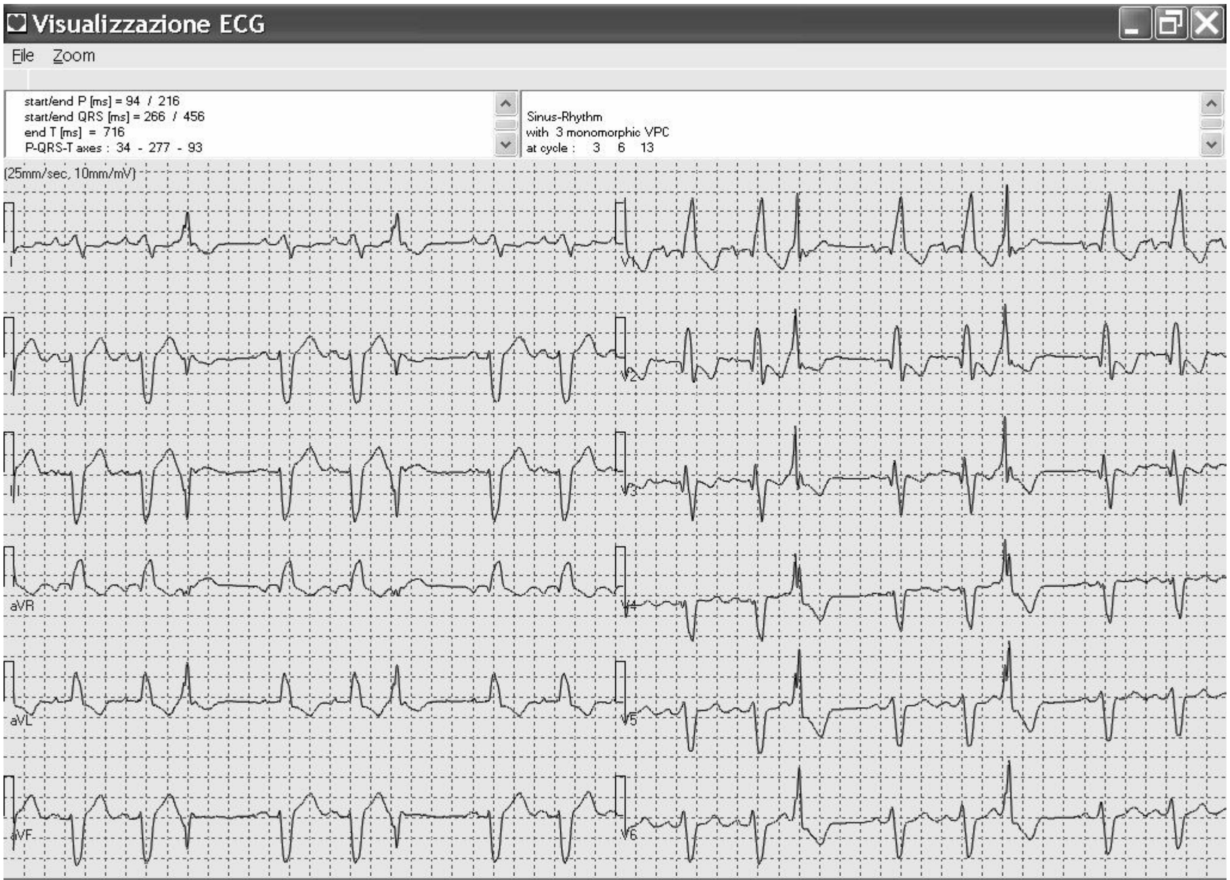


Figure 3. A screenshot of the program in a 12 leads 10 seconds real dimensions format. Global measurements are shown in the upper-left box. Diagnostic interpretation of the ECG is shown in the upper-right box. (test file: pfe105.scp)

3. Results

The validity of the decoding algorithm was analytically tested using the ECG reference records supplied by the SCP-ECG standard. The differences between the original data and the reconstructed data were always below the limits set by the standard. Applying the program on files preliminarily given by two major ECG manufacturers, discrepancies due to proprietary SCP-ECG implementation or version were found.

4. Conclusions

The software prototype can be used for retrieving and visualizing ECG records coming from instruments of different manufacturers that use the SCP-ECG format. This new opportunity seems suitable for inpatient ECG management, allowing the physician to easily obtain integrated textual and graphical information from a large conventional clinical database. Our interest now focuses in sharing information with manufacturers to let the project to become effective in complex clinical setting.

Acknowledgements

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References

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