A Matlab Graphic Interface for Multisensor Data Analysis and Algorithms Performances Evaluation in the Frame of Antipersonnel Mines Detection

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Abstract: As part of the development of a multisensors handheld system for landmines detection, the need for having available an easy-to-use offline tool appeared, in order to visualise and perform a quick analysis of measured data.

The *Quick Look Facilities* (QLF) tool is a convenient graphic interface which allows such basic tasks as detailed analysis of data and performance evaluation of processing algorithms implemented in the real system. This tool presents the opportunity of an off-line replay of all processings which are run in real time by the handheld system. As changes of main parameters value of the processing algorithms are easy-to-make, optimisation of these algorithms can be realised.

Moreover, because of its evolutionary ability, the QLF tool can be used for performance evaluation, on acquired data, of new processing algorithms before their implementation in the real system.

The QLF tool was developed with Matlab 5.2 [1] and the Matlab Graphic User Interface (GUI) [2].

Keywords : real time system, off-line replay, performance evaluation, graphic interface, multisensor fusion

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1. Introduction

The main purpose of the QLF tool is the visualisation of recorded data by the handheld multisensor system. The latter is composed of three different sensors : a Ground-Penetrating Radar (GPR), a metal detector (EMI) and three passive radiometers (PRFs). At all times, data from each sensor are stored in a common specific file called STO file (STO stands for STOrage file). To allow visualisation and quick analysis of measured data, it was a necessity to have available a convenient and easy-to-use tool which could be run in-the-field, on a portable computer, for example. The goal of a quick analysis is, first, to get a global view of detection results and to make sure of the good working of sensors. Secondly, it permits rough tuning of some parameters so that to optimise further trials, directly in-the-field. As the trials data are systematically stored, the QLF tool can be further used for a more precise analysis and for performance evaluation of algorithms. For example, the whole trials data can be used for determination of detection and false alarms rates. Finally, the QLF tool can be used as a test platform for the performance evaluation of modified algorithms, using data from anterior trials. Eventually, new algorithms can be tested and evaluated before being integrated into the handheld multisensor system.

In the first Section of the article, the basic functions of the QLF tool, such as the visualisation of data, will be referred We will then introduce one of the most important aspects of the QLF : the "off-line replay" function. Graphical examples (screen shots) will be shown all along. Finally, there will be a presentation of a multisensor fusion tool which is not implemented on the handheld system but which permits, among other things, fusion in the frame of evidence theory of measured multisensor data.

The whole QLF tool was designed using the GUI tool from Matlab 5.2, which was chosen for its convenience and, above all, because processing algorithms were conceived using Matlab.

2. The *Quick Look Facilities* Tool

2.1 The File Menu - STO File Format

First, a data file must be loaded. This is done by selecting **Load** in the only available pop-up menu **File** (Figure 1). In fact, two kinds of files can be loaded : the STO and MACADAM files. Initially designed for STO files, the QLF was extended to MACADAM files which are multisensor data files from a previous trial campaign. Even if the file formats are different, QLF applies for both of them. In the following, we will only consider STO files as everything remains the same for MACADAM files.

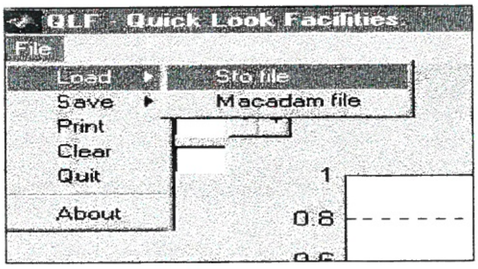

Figure 1. Loading A STO File

Data of each sensor are stored in a single file, called STO file, together with all the algorithms parameters. For each sensor, the STO file contains the raw data, the pre-processed data (processed raw data with pre-processing depending on sensor), the processed data (binary data obtained from pre-processed data with processing depending on sensor) and the result of fusion (logic fusion of processed data of all sensors). The way data are recorded corresponds to each scan done with the multisensor head during measurement. A scan is constituted of several dwells which are single measurements (Figure 2). Scans are what can be displayed with QLF. Depending on sensor, a dwell is either a single value (EMI and PRFs) or a depth dependent function (GPR). Thus, a scan is either an 1–dimension plot or an image (2-dimensions plot). An example is provided in Figure 4.

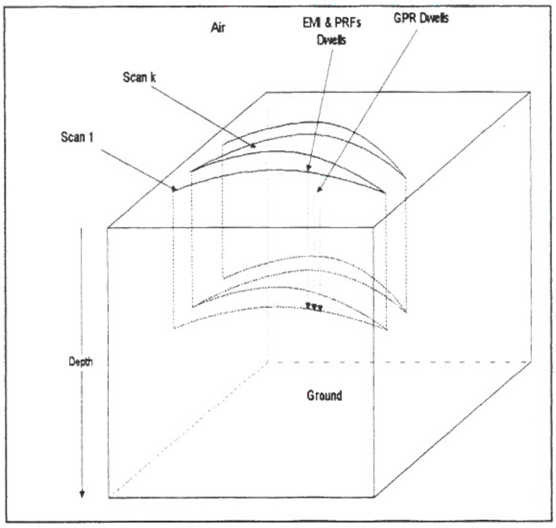

Figure 2. Structure of Data

The number of scans contained in a STO file is indicated in the Information Box (Figure 3) once the file is loaded.

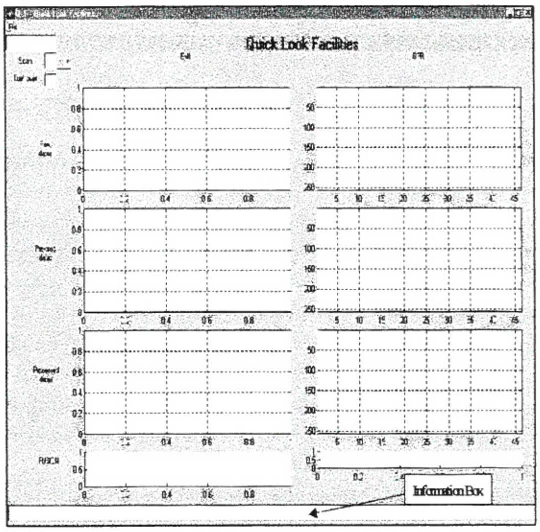

Figure 3. QLF Main Window

2.2 The Display Menu

QLF allows visualisation of each scan of a STO file. This can be done for each sensor and each type of data (raw, pre-processed and processed) which are all stored in the STO file. By entering the scan number in the dedicated box, all data from EMI and GPR, of the chosen scan, are displayed on the main window, together with the result of fusion of all sensors binary decisions (Figure 4).

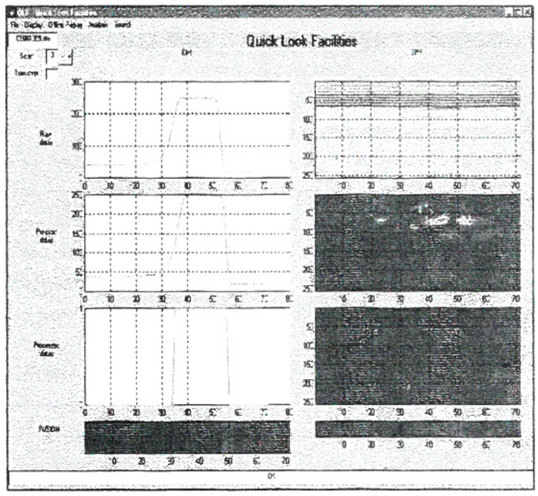

Figure 4. QLF Main Window, Visualisation of EMI and GPR Data of the Third Scan

As there are three PRFs, data from these sensors are displayed on another dedicated window by selecting **PRF** on the **Display** pop-up menu (Figure 5).

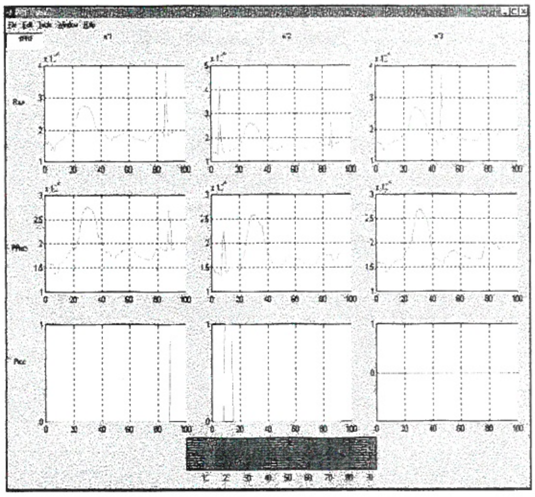

Figure 5. Visualisation of PRFs Data From Each Individual PRF Sensor and Fused PRFs Data

Apart from data visualisation, some other information can be displayed. For example :

- Localisation (if available), by selecting **Display>Localisation**.
- Localisation and detections (if available), by selecting **Display>Detections.** See Figure 6 for an example.

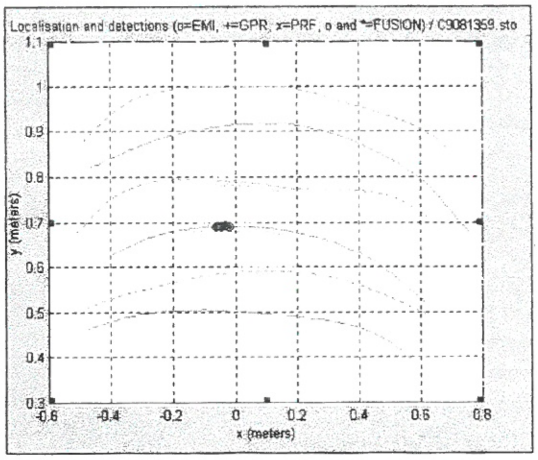

Figure 6. Localisation and Detection Visualisation. Each Curve is a Scan. A Continuous or Dotted Curve Depends on the Scanning Direction (from left to right or from right to left)

- Speed of scanning (if available), by selecting **Display>Speed**.
- Sizes of scans (number of dwells), by selecting **Display> Scans Sizes**. See Figure 7 for an exampl

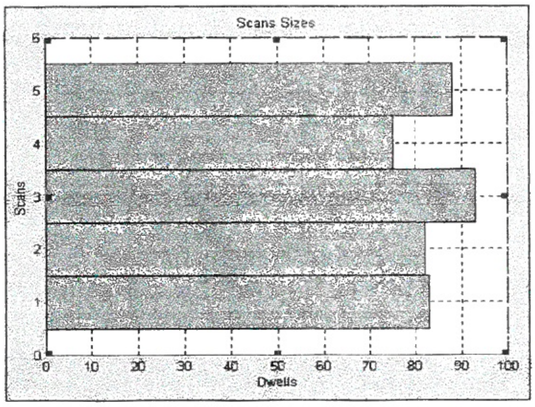

Figure 7. Graphical Visualisation of Scans Sizes

- Number of scans, by selecting **Display>Infos> Number of Scans**.
- Algorithms parameters values, by selecting **Display>Infos>Parameters Values**.

Depending on the type of data (graphical or textual), display is done on an independent window (localisation, for example) or in the Information Box (as parameters values).

2.3 Off-line Replay

In addition to visualisation, the possibility of replaying all the data processing is given to the user. This powerful option allows an off-line replay of all processing under the same conditions as those of the real time system. Moreover, changes of the algorithm parameters can be done using measured data without the need for other in-the-field trials. For each sensor, three steps can be replayed off-line from the **Off-line Replay** pop-up menu (Figure 8). These steps are :

- From raw data to pre-processed data : **raw –> pproc**.
- From pre-processed data to processed data : **pproc –> proc**.
- From raw data to processed data : **raw –> proc**.

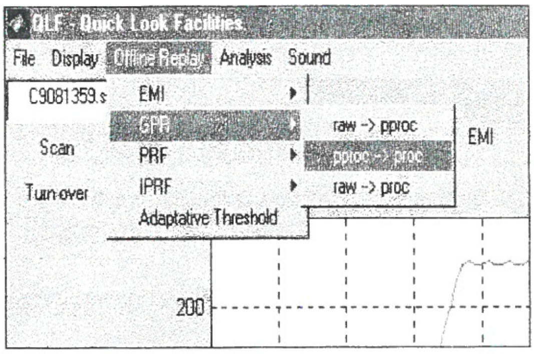

Figure 8. The Three Off-line Replay Steps

Whatever the replay step chosen, a new window is opened to display the results of the replay together with original data (that is, the data stored in the STO file) for comparison. In advance to replayed data being displayed, an intermediate window, depending on the replayed sensor, is opened (Figure 9) the purpose of which is to allow possible changes of the algorithms parameter values. The original parameters values used during the in-the-field measurement are called back.

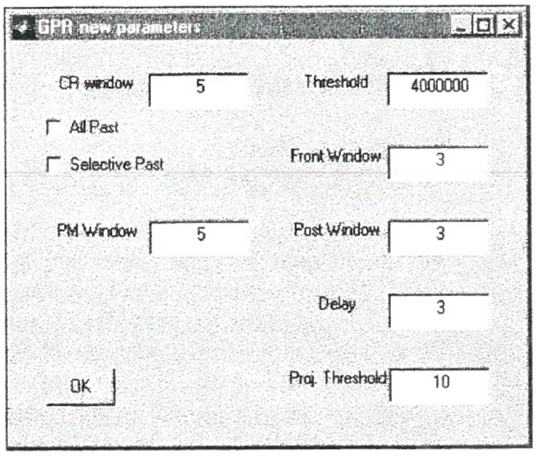

Figure 9. GPR Original Parameters Values Which Can Be Changed to User Convenience

Figure 10 provides an example of pre-processed to processed off-line replay step for the EMI without any change of parameters.

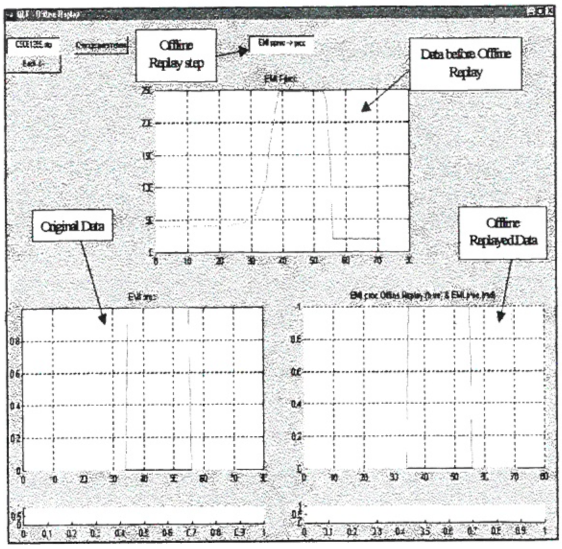

Figure 10. Off-line Replay of EMI Data

Further changes can be done by pushing the **Change Parameters** button. An example of effects of the parameter values modification on GPR data is given in Figure 11.

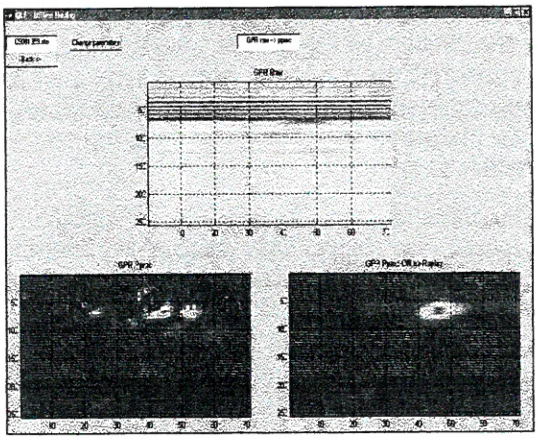

Figure 11. Effects of Some Parameters Values Changes on GPR Data

The display of the PRF Offline Replay window is different from the display of EMI and GPR because of the number of PRF sensors but, in principle, it remains the same.

2.4 Other Functions

As the QLF was used for in-the-field acquired data analysis, users asked for the improvement of several algorithms. The modified algorithms were tested on the recorded data using the QLF. For example, a modified GPR processing algorithm, **Adaptive Threshold**, is available in the **Off-line Replay** pop-up menu (Figure 8).

Moreover, the multisensor system provides a sound output depending on which sensors are detecting and the importance of the detection. This sound output can be simulated using the QLF via the **Sound** pop-up menu (Figure 12).

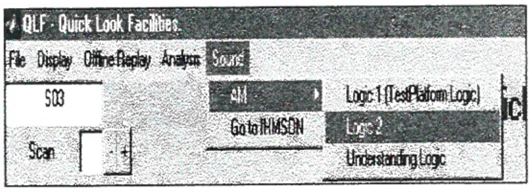

Figure 12. Sound Menu

3. Multisensor Fusion

In our view the QLF, though initially designed for the visualisation and quick analysis of STO files, is expected to be an evolutionary tool. In this frame, new tasks were added. These additions have not been implemented yet in the real system but they use the data measured by the multisensor head (the STO files). In fact, two main tasks were added. First, a features extraction method for GPR data based on a time-scale analysis [3] and, secondly, a multisensor fusion task.

3.1 Time-scale Analysis of GPR Signals

The QLF tool can be used for carrying out such an analysis by selecting **Multisensor Fusion** in the **Analysis** pop-up menu of the main window (this menu appears in Figure 12, for example). A new window is then opened (Figure 13) which permits to work almost independently of the QLF main window.

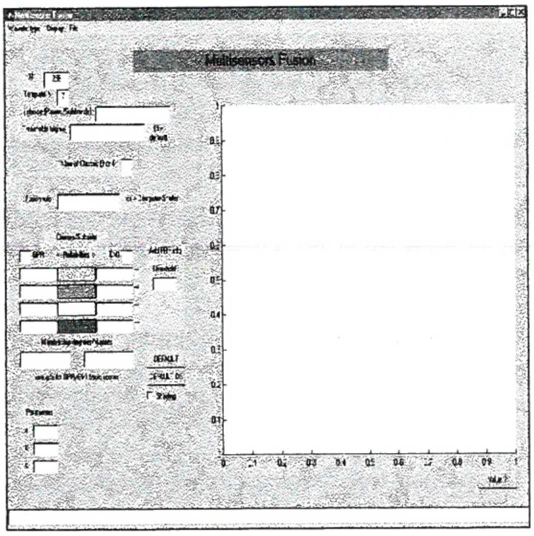

Figure 13. Multisensor Fusion Window

Analysis of GPR signals (dwells) is based on a multiresolution analysis which implies a decomposition of the GPR signal into filtered signals, called subbands. We use a Fast Wavelet Transform algorithm [4] based on Quadrature

Mirror Filters (QMFs) associated with the chosen wavelet (Figure 14).

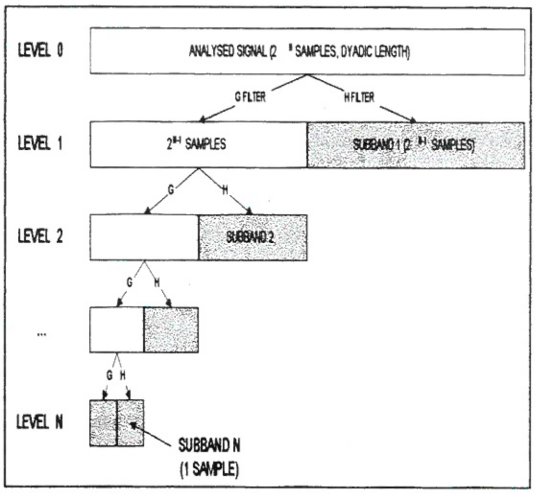

Figure 14. Multiresolution Analysis. In grey, subbands of the wavelets basis which is the considered basis. H and G are the QMFs.

The original GPR signal must be of dyadic length. If not, the signal is padded with zeros to a dyadic length set by the user (default value is 256).

The wavelet, that is the QMFs, and the number of coefficients of these filters are user chosen by selecting from the **Wavelet Type** pop-up menu (Figure 15).

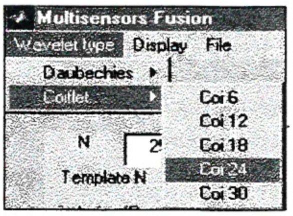

Figure 15. Choice of the Wavelet and Number of Coefficients of the Filters. Here, the Coiflet wavelet with 24 coefficients filters is selected.

Then, parameters are computed on the subbands of decomposition [5]. Parameters are the first to the fourth order moments of each subband and the maximal coefficient of the whole decomposition. As this method applies to each dwell of a scan, we obtain the evolution of each of the parameters in each subband, along the considered scan.

It appears that the presence of an object leads to a localised variation of some parameters. In order to detect such variations, a so-called "template matching" method [6] applies on the parameters evolution along scans. This method is based on an intercorrelation computation, which lets a value into the interval [0,1] be obtained. This value is a measurement of the resemblance between the parameters' localised variation and the template. The template is characterised by two features: its width in dwells and its shape. Width can be set by the user (Figure 18, 'Template N' box) but shape is chosen to be Gaussian (Figure 16).

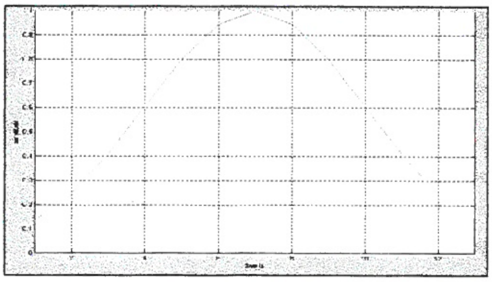

Figure 16. Used Template With Width Equal to 13 Dwells

As information about the variations amplitude was lost when using the "template matching" method, we multiplied the result of this method by the normalised evolution, along the scan of interest, of the considered parameter on the considered subband. Normalisation is done by dividing this evolution curve by a threshold, in order to obtain values within the interval [0,1]. The value of thresholds depends on the considered parameter and subband and, is set by the user (see Figure 18). As the two elements of the product are within [0,1], the result will also be within [0,1].

In order to help the user set the thresholds values, the latter can display intermediate results such as the parameters evolution curves or the result of 'template matching' method. Visualisation is done by selecting **Features** (see Figure 17 for an example) or **X-corr** in the **Display** pop-up menu (see Figure 25). Choices for visualisation of the computed parameters and subbands are done as explained thereafter.

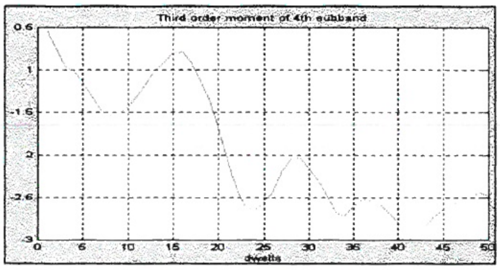

Figure 17. Third Order Moment on Fourth Subband, Computed for A Given Scan

From a single scan, we obtain numerous evolution curves of all parameters computed on the whole subbands. For reducing the number of curves two means are used:

1. Computation of only some chosen parameters on some chosen subbands. Choices are made by the user.

2. A fusion task of which goal is to obtain a single evolution curve.

As said before, the user can select subbands, parameters and thresholds. A convention, summarised in Table 1 and Figure 18, is used.

Table 1. Convention for Subbands and Parameters Choices

Parameter	1st order moment	2nd order moment	3rd order moment	4th order moment	Maximum of coefficients
Number	1	2	3	4	5
Subband	1	2	3	4	...
Number	0	1	2	3	...

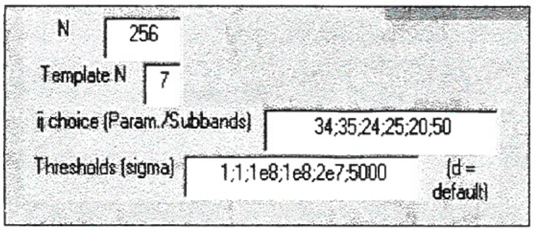

Figure 18. Convention for Choices. Example: 34 means 3rd order moment computed on the 4th subband (see Table 1) and the corresponding threshold is 1. The semicolon is used as a separator.

The feature fusion task is an arithmetic mean of all the selected evolution curves which leads to a single curve, called the GPR basic detection score. By selecting GPR in the **Display** pop-up menu, the result of the method application, that is the GPR basic score, is displayed (Figure 19).

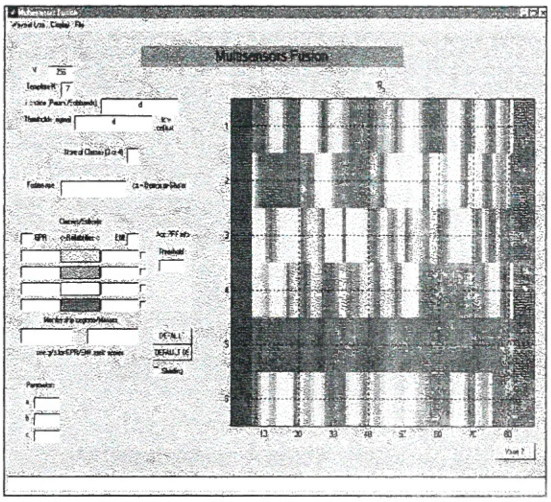

Figure 19. Example of GPR Basic Score, Computed on Six Scans

The wavelets based analysis was performed using a Matlab toolbox created by Ojanen [7].

3.2 Decision Fusion

Determination of the EMI basic detection score is straightforward. As the amplitude of the EMI signal is always between 0 and 255, we just have to divide this amplitude by 255 in order to obtain the EMI basic detection score. Once the GPR basic detection score determined, a decision fusion of these two sensors may be performed. The user must specify three main elements of the fusion task: the fusion rule [8], the classes and the membership degrees to classes for either sensor (EMI and GPR). The way the user sets these elements determines the theoretical frame: probabilities or evidence theory. Once again, the user must follow conventions for his specifications. Figures 20a and 20b explain these conventions in the case of probabilities.

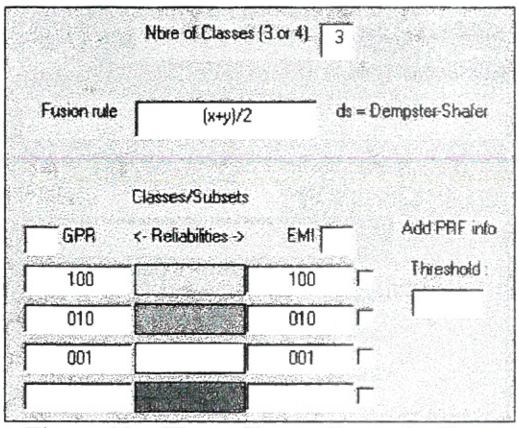

Figure 20a. Three Classes Example. Here, the fusion rule is the arithmetic mean. The letters 'x' and 'y' represent each sensor (membership degrees). Any expression using these two letters can be written and will be interpreted as the fusion rule. Each class is represented by a row (and a colour).

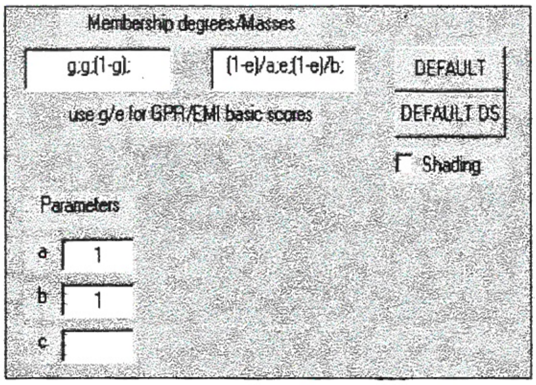

Figure 20b. Three Classes Example. Allocation of membership degrees is done by the user and assigned to each column. Here, a column is a single class (Figure 20a) as we are in the probabilities frame. In this way, membership degree assigned by the GPR to the first class is 'g', that is the GPR basic score. The one assigned by the EMI to the same class is '1-e' (as the value of the parameter 'a' is 1), which is the complementary value of the EMI basic score.

As the real meaning of a class is determined by the user, the latter must be coherent when assigning membership degrees of each sensor.

The user may choose to work in the frame of evidence, or the Dempster-Shafer theory [9]. In this case, the fusion rule is the Dempster, or orthogonal combination rule which is selected by writing 'ds' in the dedicated box. The main distinctive feature of the Dempster-Shafer (DS) theory is the possibility of allocating a membership degree or mass to a subset and not only to a single class. Figure 21 gives a typical example.

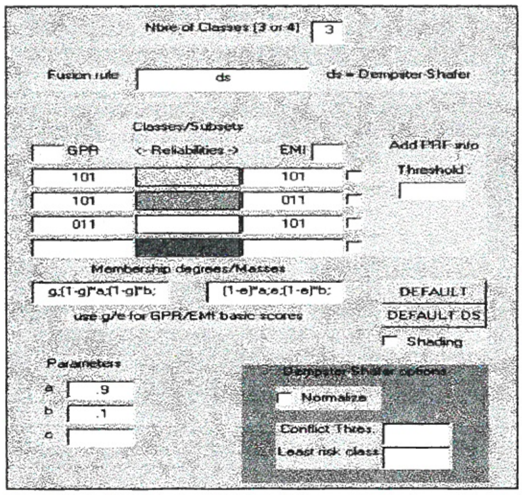

Figure 21. Three Classes Example in DS Theory Frame. Rows are individual classes and columns are subsets. A '1' means the class is included in the subset. A subset is the union of all selected classes. Of course, a zero means the class is not selected. Masses are allocated to subsets or columns. In this example, the third column is the particular subset containing all classes which represents total ignorance and is called the discernment frame in the DS theory.

Once classes, fusion rule and membership degrees are given by the user, decision, that is determination of the class membership of each dwell, is computed and displayed by selecting **Multisensor** in the **Display** menu (Figure 22). Decision is made to the maximum of membership degrees.

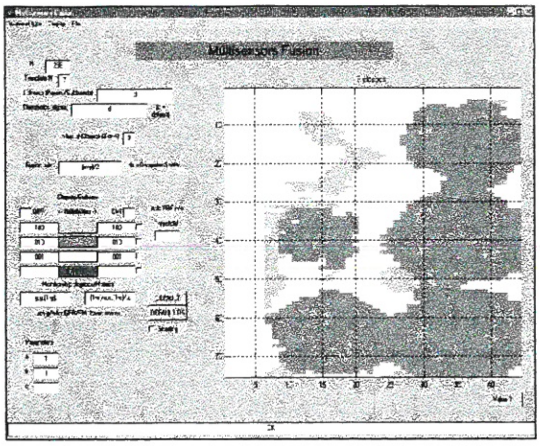

Figure 22. Three Classes Example. Here, white means "No object", light grey means "Non-metallic object" and dark grey means "Metallic object". This example shows class memberships of dwells from 75 scans in the case of a MACADAM file.

More options are available such as :

- Assign a reliability level (a value between 0 and 1) to the sensors (Figure 20a), which will be multiplied to the sensors basic detection scores (default value is 1).
- Add complementary information from PRFs (Figure 20a). Even if these sensors are not part of the fusion process, information about the detection depth (surface or buried) can be added this way (Figure 23).

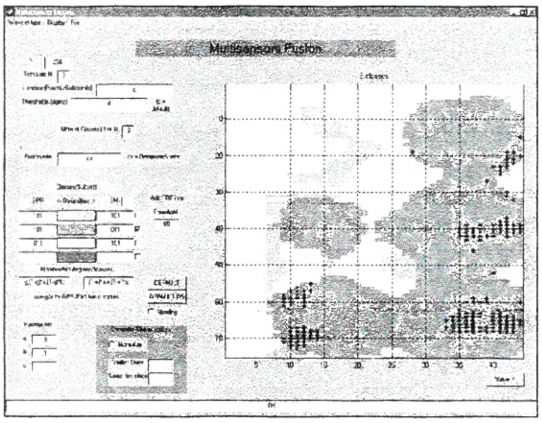

Figure 23. Addition of PRFs Depth Information. An asterisk means a PRF detection, that is, a surface detection.

- Display membership level (Figure 24).

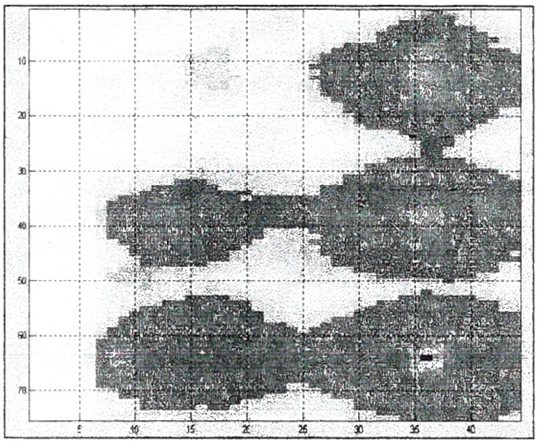

Figure 24. Shading Option : the darker the colour is, the weaker the membership to the corresponding class is.

- Display information issued from the DS theory (Figure 25).

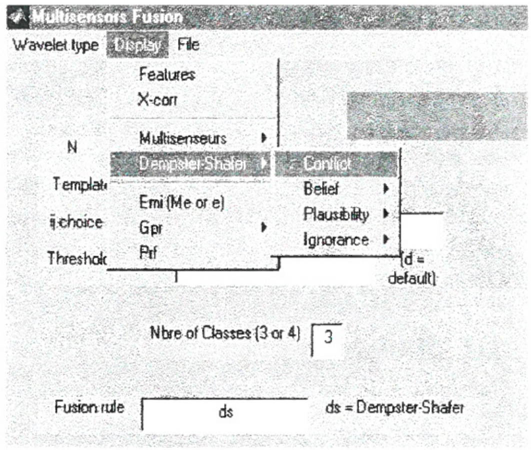

Figure 25. Optional DS Theory Functions : Conflict, Plausibility, Belief and Ignorance

Plausibility and belief (and ignorance, as ignorance is the difference between plausibility and belief) are computed only for a given subset, which is chosen by the user, and for a given sensor. Selecting one of these functions will open a new window for the choice of the subset (Figure 26).

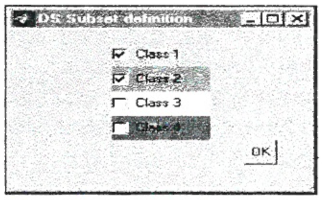

Figure 26. Choice of the Subset. The Subset is the Union of Checked Individual Classes.

Then, as shown in Figure 27, the selected function is displayed.

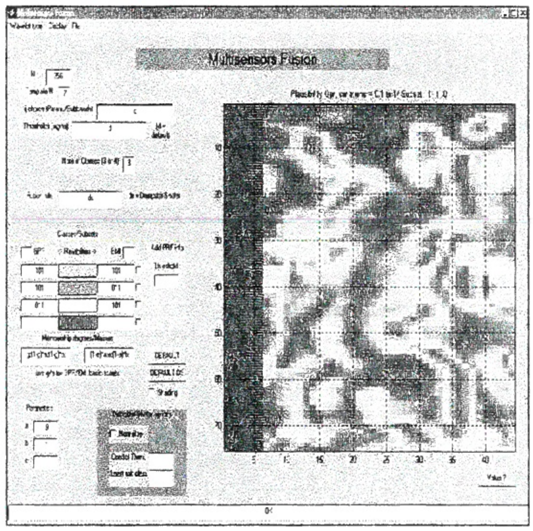

Figure 27. Plausibility of A subset Composed of the Two First Classes (see Figure 26), for GPR Data

The DS theory frame makes available another decision tool. By writing 'pl' (respectively 'be') in the 'Fusion Rule' box, decision is made, to the maximum of plausibility (belief). In these cases, plausibility (belief) is computed for each individual class and decision on class membership of a dwell, is made to the maximum of plausibility (belief).

4. Conclusions

The QLF tool proved its usefulness and convenience during the numerous trials which the multisensor handheld system was subject to. Its main destination was double: roughly, in-the-field tuning of algorithms and data perusal in order to determine performances in terms of detection and false alarms rejection. Also it was meant for testing some modified algorithms, upon users' request.

The other main aspect of the QLF, that is the multisensor fusion tool, was designed in order to be the les specific and the more evolutionary it could. That means, the fusion tool itself can be used with detection scores issued from other features extraction methods and can be easily upgraded. More classes or sensors can be added, for example.

It allows use of a lot of different kinds of fusion rules and flexibility in the class definition and the membership degrees allocation. Working in the evidence theory frame is quite easy and a lot of specific DS theory functions can be computed and displayed.

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