TIRAMISU : FP7-Project for an integrated toolbox in Humanitarian Demining: focus on Technical Survey and Close-in-Detection

L.Marques (ISR-UC), Y.Baudoin (RMA), G.Muscato (UNICT), G.Turnbull (USTAN), D.Hoja (DLR), G.Alli (IDS) , A.Ginestet (NOVELTIS) , J.Braunstein (VALLON), M.Zoppi (DIMEC), E.Cepolina (PIERRE) and TIRAMISU consortium (www.fp7-tiramisu.eu)

Abstract

The TIRAMISU project aims at providing the foundation for a global toolbox that will cover the main mine action activities, from the survey of large areas to the actual disposal of explosive hazards, including mine risk education and training tools. After a short description of some tools, particular emphasis will be given to the topics proposed by the VALLON Workshop, namely the development of performing methodology in Technical survey and/or Close-in-Detection

1. Introduction

The modular toolbox is described on www.fp7-tiramisu.eu while the following (non exhaustive) table gives a short description of the Technical Survey and Close-in-Detection tools

TID	Product Name (partners a.o.)	Current TRL	Expected TRL	Description Notes
T3	Ground Penetrating Radar Array (IDS) Ground Penetrating Radar Array: Signal processing module for classification (NOVELTIS)	4	6-7	Within the TIRAMISU project, IDS will build a modular, densely sampled, GPR imaging array with real time software for fully automatic detection of mines. The dense sampling and relatively large scanning width (1-2 m) of the GPR array will allow imaging capabilities, which through suitable advanced signal and image processing algorithms will be crucial for discriminating real mines, especially shallower and smaller AP mines, from metal fragments, rocks, roots or other soil heterogeneities (generally termed as clutter), thus reducing the usually high false alarm rate (FAR) of GPR. Could be combined with the tool T17 and mounted on a UGV
T4	Medium stand-off Synthetic Aperture Radar (DLR)	2-3	5-6	In this project DLR HR-AS will develop a vehicle-based side-looking imaging sensor (TIRAMI-SAR) based on the synthetic aperture radar (SAR) principle for the medium range detection of mines (5-15 m). This innovative solution can in fact solve critical problems encountered by previous attempts with SAR (very large distances from hundreds of meters to kilometres) while avoiding the criticalities of the forward looking scheme. Contrary to the military requirement, a humanitarian demining tool can be used to scan a long 5-7 m wide strip on its side from a safe lane in order to provide indication of suspected items for other tools to investigate further. In this way the system will serve as a very fast area reduction tool reducing hundreds of square meters of suspected land to a few spots requiring accurate close-in checks. It should be noted that SAR imaging requires a stand-off side-looking geometry, being completely different from normal close-to-ground GPR measurements. Consequently the use of the same vehicle in parallel for SAR and GPR is not possible

T7	Chemical sensor (USTAN)	2,3	6	To complement the well-established sensor technologies, we are developing novel polymer-based sensors for detecting explosive vapours from landmines. These sensors work by detecting a change in the light emission from a semiconducting polymer film [Thomas2007]. When exposed to very dilute vapours of TNT-like compounds, the explosive molecules adhere to the film and obstruct the light emission. Fluorescence sensing has previously been studied in laboratory conditions and in the field as the Fido sensor from Flir Systems. It was recently discovered that greater sensitivity is possible using laser light from the polymer instead of fluorescence to detect explosives [Rose2005]. Most research on light-emitting polymer chemical sensors has been laboratory-based and materials oriented. The research in TIRAMISU plans to advance the use of polymer laser sensors to minefield detection conditions for the first time, and will aim to establish the feasibility for new modes of application of laser and fluorescence array sensors including Technical Surveys of suspected mine fields.
T8	Remotely controlled Inspection Platforms (ISR-CSIC-RMA+)	4-6	7-8	UGV-UAV, Stand-Off UXO Sensor's carriers; read further Proceedings of 6th IARP Workshop RISE'2012, on the TIRAMISU Website
T12	Low-cost agricultural derived assistance (DIMEC-PIERRE)	5	9	TIRAMISU intends to research breakthrough solutions for Technical Surveys based on agricultural technology, a complex of landmine absence verification assets and a new systematic methodology for the tracking and monitoring of the survey operations and for their planning. The implementation of a low-scale GIS system to collect real data on the trajectories of the assets and the area covered is a fundamental element that will complete an effective monitoring of operations and constitutes the basis for an informed land release planning.
T16	Intelligent Prodder (UNICT)	3	4 ,7	This device will be based on piezo- electric touch sensors with a simple yet effective methodology for feature selection and elaboration. Moreover, another advance will also be the integration of the prodder with other sensors such as force sensors and sensitive and highly directional electric field and magnetic field sensors. Therefore a multisensory data fusion technique will be implemented to improve the reliability of the system
T17	Innovative Metal detector Array (VALLON)	5	9	This research project focuses on a versatile and innovative multi-channel metal detector. The goal is to unify the advantages of a hand held detector (high detection performance, flexible adaption to terrain, various discrimination functions to enhance the detection capabilities by reducing the false alarm rate while keeping the probability of detection high) with the advantages of vehicle mounted multi-channel systems (large detection footprint, high search speed). This multi-channel metal detector is highly user configurable in terms of coil number, data interfaces and integration into multi sensor systems (with GPR, chemical sensors, etc .

2. Technical Survey : Agricultural Machines (LOCOSTRA, DIMEC-PIERRE)

Among the promising machines allowing dual-use applications (demining and agricultural activities), TIRAMISU entrusted the completion of the Toolbox to three partner experienced in this domain: one of the most relevant and pioneering systems is the platform LOCOSTRA, whose name stands for LOw-COst TRActor for Humanitarian Demining. LOCOSTRA is a tele-operated four wheeled machine design for technical survey. It is derived from a small agricultural tractor designed to operate in vineyards and orchards, the P796V produced by Pierre Trattori, with an hydraulic driveline and a double steering mechanism giving to the machine very high agility and controllability. This tractor is reversible (it can operate indifferently in both directions of motion); it is equipped with a standard three-points connection for the implements and it is characterized by a very high power/mass ratio allowing it to run heavy tools.

The demining version of this tractor is armoured and mounts wheels with an original design resisting blasts of antipersonnel mines. The user can tele-operate the machine from a long distance and basic operations are performed by LOCOSTRA autonomously.

The main functions supported so far are: the cut of the vegetation to prepare the minefield for technical survey, the treatment of the soil for the removal of mines, and the carry of tools for mine detection and localization. The ground engaging tools used are modifications of agricultural implements with similar functions: an armoured mulcher is used to cut the vegetation; a mine sweeper obtained from a modified potato-digger is used to harvest mines from the soil; a large loop detector is used to scan the soil. LOCOSTRA has been tested with live AP mines in Jordan with the support of the national mine action centre and NPA Jordan in February 2011 and will be further improved under TIRAMISU.

Figure 1. LOCOSTRA in test

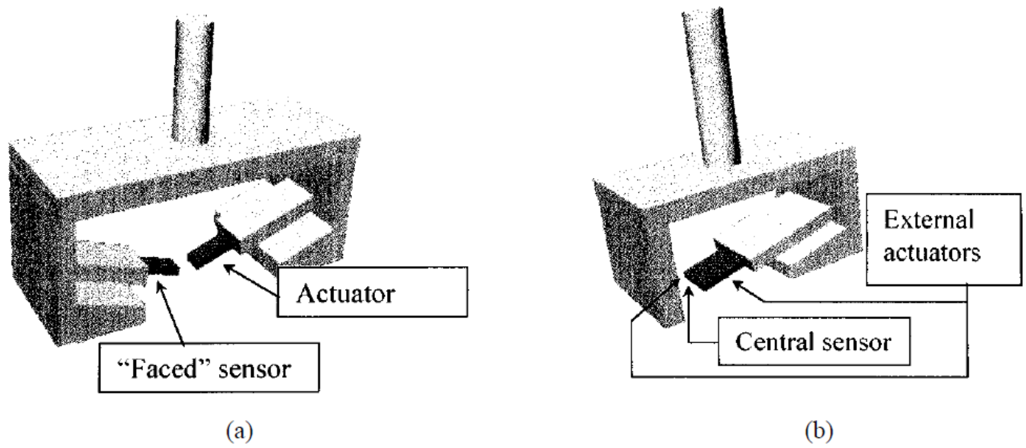
3. Technical Survey and Close-in-Detection

Some tools, particularly the ones developed by the industrial partners, are improvements to existing commercial products, so a large amount of experience in the respective field, and related results already exist. In these cases, preliminary results already obtained by this short period of time are presented.

3.1 Intelligent Prodder (UNICT)

Humanitarian demining is a very complex problem that still finds its place in many regions of the globe, with millions of mines in the area. Different devices have been designed and tested that may be useful in solving, or at least to simplify, the problem, such as metal detectors, dogs, GPR, IR or the prodder. The working methods of these devices may be different, and it is possible to distinguish 2 main classes: the class that contains the tools that use "contact" with the mine for detection and the class that contains the tools that "do not use the contact". Our study is focused on devices with some sensors that, by direct contact, can give information helping to solve the problem of humanitarian demining.

The University of Catania conducted intensive research activity in the development of tactile Measuring Systems for the Recognition of Unknown Surfaces [Baglio 2003]. In these works a novel smart tactile sensor that recognizes the nature of the surfaces was developed. The approach is based on the idea of analyzing the signal produced when the sensor touches and stimulates the surface. An "intelligent probing" system for material recognition has been developed. It is based on the use of bimorph piezo-ceramic actuators and sensors that allow the unknown surface to be stimulated and the response signal sensed.



Miniaturized sensors for E-field and B-field measurements have also been extensively investigated at the University of Catania; both of these sensors are based on the exploitation of the properties of hysteretic materials, such as ferroelectric and ferromagnetic, and on advanced methodologies to deal with bistable nonlinear dynamical systems [Baglio, 2009]

For the TIRAMISU toolbox, we will work with the goal of improving the intelligent prodder in particular by means of:

- Inserting force feedback to better understand the exerted force to the objects and to obtain reproducible contacts;
- A "multiple contact" tip will be developed and evaluated in order to both obtain information about the contact angle with the buried object. This tip will also allow to implement both active and passive readout strategies;

- The electric field [Ando2010] and magnetic field sensors [Ando2005, Baglio2009] will allow for the identification of anomalies during the approach phase, a suitable differential configuration will be developed for each sensor to have information on the “signature” of the buried object and therefore on its dimensions. The acoustic sensor will enter into play when the probe touches the buried object allowing to classify the material among plastic, glass, metal, wood, etc;
- Improving signal analysis of the objects by using for example neural networks based learning, fuzzy logic classifier and wavelet analysis;
- Using multisensory data fusion methods to fuse all information together to classify detected objects.

Results from preliminary tests

In this first year of the research activity we set up a laboratory using an available industrial manipulator that was equipped with a force/torque sensor by ATI engineering in order to allow performing repetitive trials. At the same time a preliminary probe with piezoelectric sensors and actuator in the tip was made and some preliminary classifications performed. In the following figures are shown the robotic manipulator adopted in the lab, the acquired force/torque sensor and some preliminary results of material classification.

Figure 2. Manipulator with prodder.

Figure 3. Force sensor.

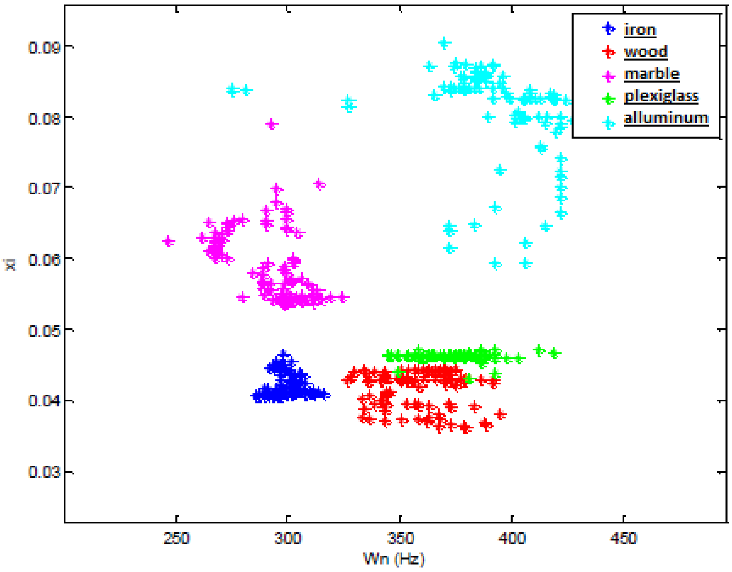


Figure 5. Preliminary classification results Amplitude/frequency for different materials.

3.2 Ground Penetrating Radars

3.2.1. GPR LUCIFER (IDS, NOVELTIS)

The objective of tool developed by IDS, is the building of a densely sampled down-looking Ground Penetrating Radar (GPR) array, named LUCIFER, for close-in detection of landmines and the development of the corresponding real-time signal processing. The array should be able to detect anti-personnel (AP) and anti-tank (AT) mines and unexploded ordnance (UXO) from distances shorter than 1 m. Subsequently the GPR array will be integrated with a partner's metal detector (MD) on a suitable autonomous vehicle (presumably the TEODor robot from RMA, Belgium) and tested in the field.

IDS' proposed solution for the vehicle-based GPR system will have an overall architecture (Figure 6) similar to that of commercial IDS ground-coupled systems such as STREAM X (Figure 7), except for the mechanical integration of the GPR array that will be modified in order to keep the array suspended in air at a distance of ~40 cm from the ground.

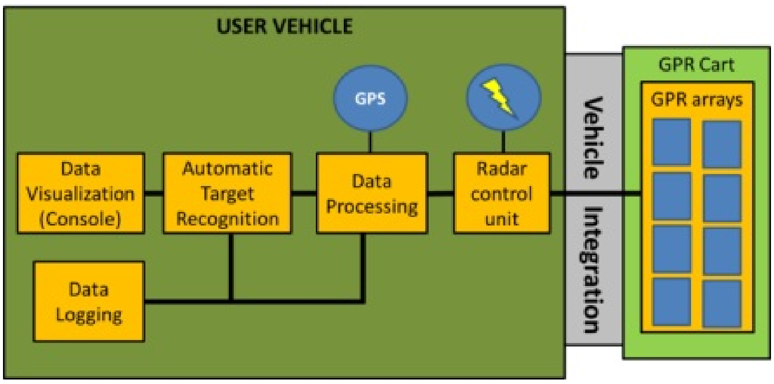


Figure 6. Schematic drawing of the GPR system for mine detection.

Figure 7. IDS' commercial GC GPR system STREAM-X (600 MHz) with different mechanical frames.

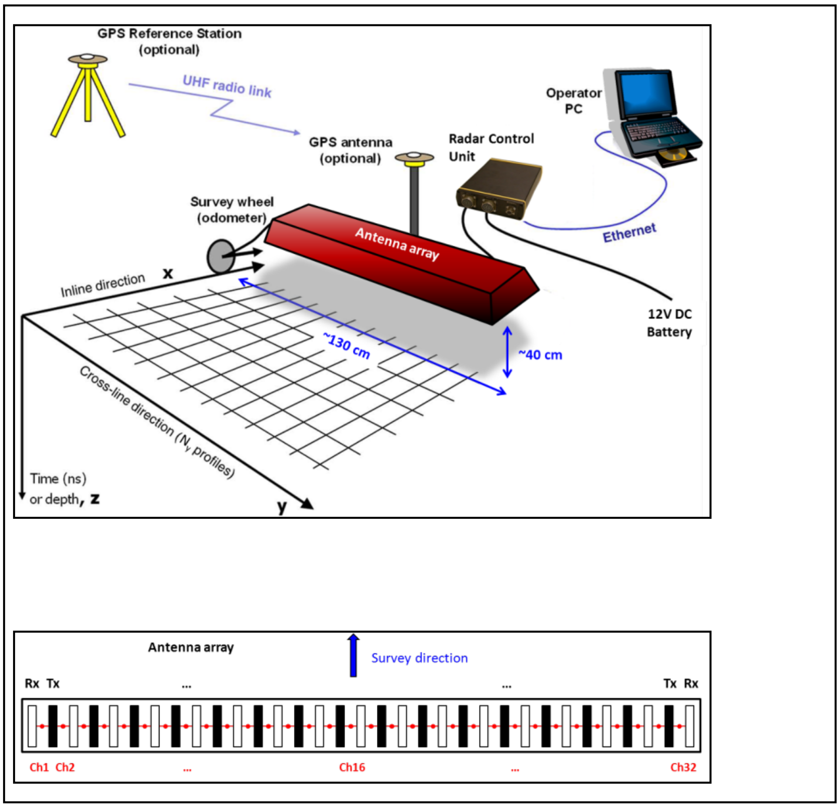


Figure 8. IDS' proposed AL GPR system (top) with scheme of transmitter and receiver antennas in a 32-channel, 1D antenna array (bottom).

The tool developed at NOVELTIS will use pre-processed data, which means without the clutter (notably without ground reflection), from the LUCIFER array and will give a classification of the detected target to know if they are deterministic (e.g. mines or sub-munitions) or random (e.g. rocks).
It is made up of three modules:

1. Time-frequency analysis module;
2. Targets detection module;
3. Targets classification module.

3.2.2. GPR TIRAMISAR (DLR)

In comparison with a down-looking, close range (60-100 cm) GPR sensor, it would be highly desirable to be able to detect mines and UXO from a safe stand-off distance (ideally 10 m to 20 m). To this end numerous research prototype radars have been developed and tested in the past 15-20 years by military organizations. Due to the specific military requirement of detecting devices in front of a vehicle (e.g. on a road) to assure the safety of an ensuing convoy, all these systems have been designed to be forward looking (i.e. the radar is mounted on top of the vehicle pointing forward). Based on this acquisition geometry, the resolution transversal to the direction of movement of the vehicle has always been gravely insufficient due to the practical limitations to the width of the array (i.e. 2-3 m at most). Consequently no such system was ever developed beyond the level of research prototype while the less desirable GPR solution has begun being used in the field.
In this project DLR HR-AS will develop a vehicle-based side-looking imaging sensor (TIRAMI-SAR) based on the synthetic aperture radar (SAR) principle for the medium range detection of mines (5-15 m). This innovative solution can in fact solve critical problems encountered by previous attempts with SAR (very large distances from hundreds of meters to kilometers) while avoiding the criticalities of the forward looking scheme. Contrary to the military requirement, a humanitarian demining tool can be used to scan a long 5-7 m wide strip on its side from a safe lane in order to provide indication of suspected items for other tools to investigate further. In this way the system will serve as a very fast area reduction tool reducing hundreds of square meters of suspected land to a few spots requiring accurate close-in checks. It should be noted that SAR imaging requires a stand-off side-looking geometry, being completely different from normal close-to-ground GPR measurements.
The development shall concentrate on the investigation of suitable processing algorithms to be used for close-in stand-off ground penetrating radar to be installed on a moving vehicle as shown in figure 7-1 The construction shall concentrate on the identification of the required hardware based on existing DLR concepts, and on the assembly and optimization of the required sub-systems according to suitable modifications of the concepts with respect to the special imaging geometry (air-soil, side-looking) and antenna array structure. Finally the implementation of the developed algorithms and extensive laboratory tests and a field trial shall complete the work.

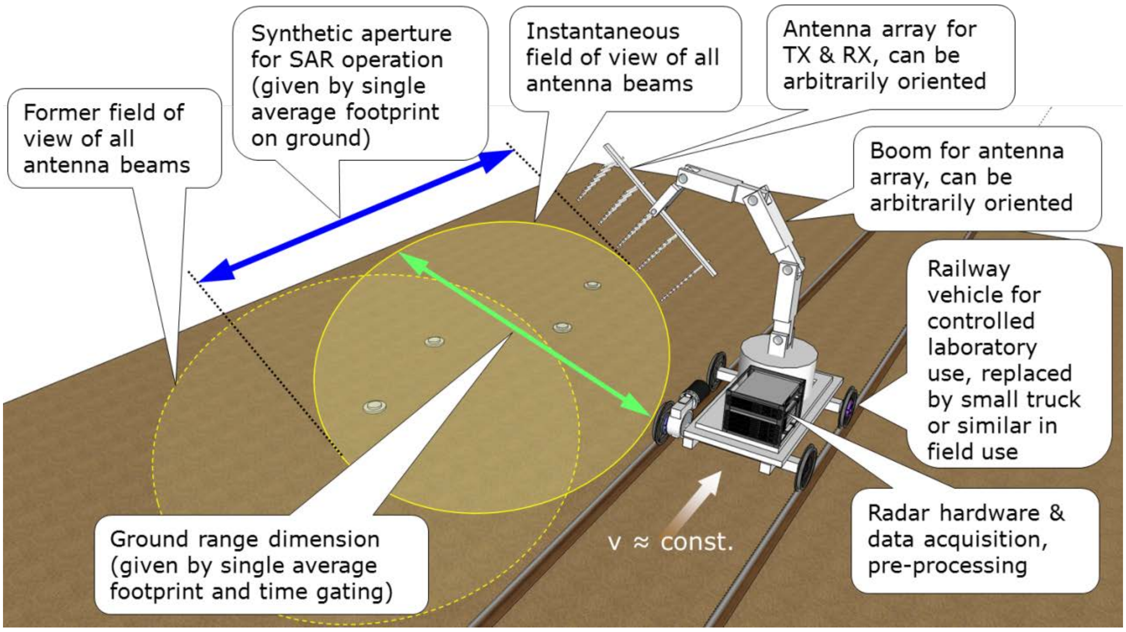


Figure 9. Data collection principle of the intended SAR system for the medium range detection of buried and unburied suspicious objects.

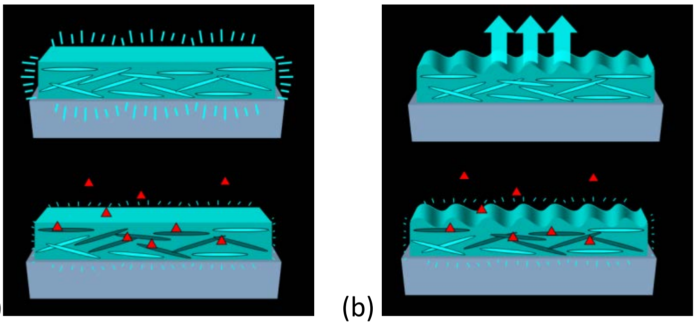
3.3. Explosives Vapour Detector (USTAN)

The explosives vapour detector tool is envisaged to be used in two different scenarios: for close-in detection of individual mines, and for wide-area technical survey in combination with REST sampling. For these applications it may be necessary to design two slightly different versions of the same tool, tailored to each application.

The basic tool will consist of the following elements:

- A thin-film polymer sensing element deposited on a glass/plastic substrate;
- A laser (or possibly LED) excitation source that will illuminate the luminescent polymer film;
- A light-detection module that will spectrally select the light emission from the polymer and monitor the intensity of the light emission;
- An input stage to draw the vapours across the sensing element;
- Control electronics/software for the light source and detector.

The next figure illustrates the basic principles of the detector



(a) (b)

Figure 10. (a) concept of explosive vapour sensing using fluorescent polymer films (a) and polymer lasers (b). (a)Top panel shows blue fluorescence from a film of polymer molecules (blue rods). Bottom panel shows effect of TNT vapour exposure- when the TNT molecules (red triangles) come into contact with the polymer chains they switch off much of the light emission. (b) Top panel shows a blue laser beam emitted from a corrugated film of.Bottom panel shows effect of TNT vapour exposure, switching off the laser emission, leaving only weak fluorescence**.**

3.4. Advanced Lightweight Detecting System (ISR-UC, RMA)

The state of the art in handheld mine detection devices uses a metal detector (MD) and a ground penetrating radar (GPR) to perform the task. The goal of this work package is to develop an advanced lightweight detecting system for humanitarian demining purposes consisting of an integration of three different sensors, a MD, a GPR and an explosives vapour detector (EVD). In this project ISR-UC will develop the sensor fusion algorithms required to achieve this goal, thus pushing the field of mine detection forward. The final prototype will consist of a handheld/vehicle-based device capable of detecting explosive devices (ED) with a higher clearance rate than that of the current level of technology.

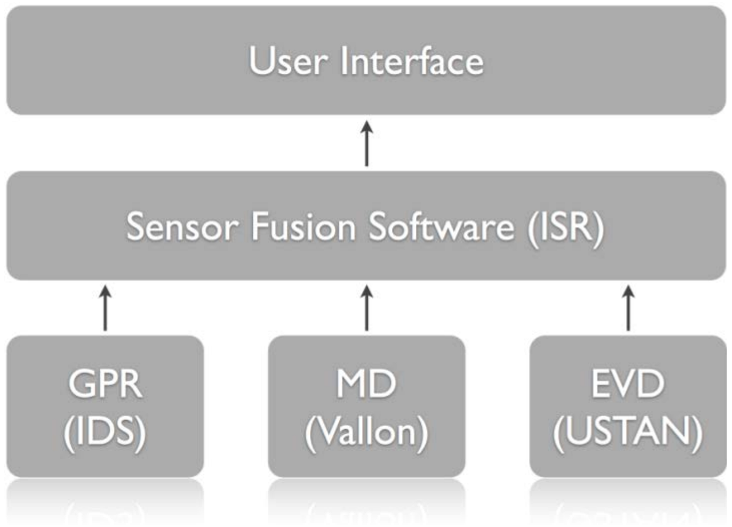
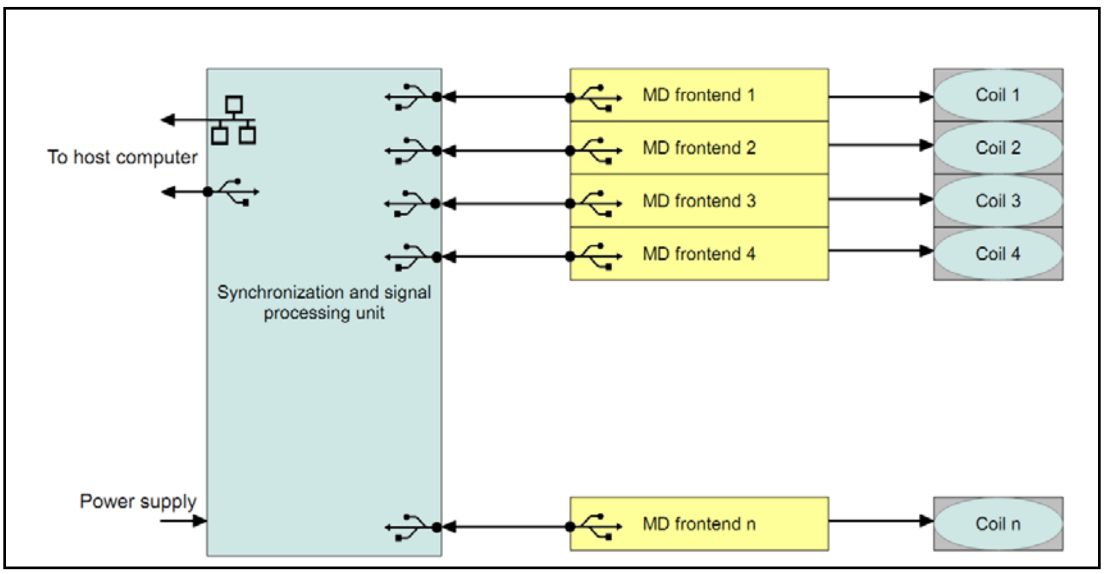


Figure 11. Overview of the advanced lightweight detecting system.

The autonomous navigation of the detecting platform will be entrusted to the partners focusing on Robotics (CSIC, ISR-UC and RMA) [Y.Yvinec, 2012]

3.5. Multichannel Metal Detector (VALLON)

This research project focuses on a versatile and innovative multi-channel metal detector. The goal is to unify the advantages of a hand held detector (high detection performance, flexible adaption to terrain, various discrimination functions to enhance the detection capabilities by reducing the false alarm rate while keeping the probability of detection high) with the advantages of vehicle mounted multi-channel systems (large detection footprint, high search speed).
This multi-channel metal detector is highly user configurable in terms of coil number, data interfaces and integration into multi sensor systems (with GPR, chemical sensors, etc).
Figure 12 shows the block diagram of the envisaged multi-channel metal detector and **the modular concept of the system. The signal-processing unit can handle up to 32** detection channels.



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5. Acknowledgement

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