VIEW-FINDER : ROBOTICS ASSISTANCE TO FIRE-FIGHTING SERVICES AND CRISIS MANAGEMENT

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Abstract
In the event of an emergency due to a fire or other crisis, a necessary but time consuming pre-requisite, that could delay the real rescue operation, is to establish whether the ground or area can be entered safely by human emergency workers. The objective of the VIEW-FINDER project is to develop robots which have the primary task of gathering data. The robots are equipped with sensors that detect the presence of chemicals and, in parallel, image data is collected and forwarded to an advanced Control station (COC). The robots will be equipped with a wide array of chemical sensors, on-board cameras, Laser and other sensors to enhance scene understanding and reconstruction. At the Base Station (BS) the data is processed and combined with geographical information originating from a web of sources; thus providing the personnel leading the operation with in-situ processed data that can improve decision making. This paper will focus on the Crisis Management Information System that has been developed for improving a Disaster Management Action Plan and for linking the Control Station with a out-site Crisis Management Centre, and on the software tools implemented on the mobile robot gathering data in the outdoor area of the crisis.

Keywords**:** crisis management, robotics, VSLAM, 3D modeling

I. THE BASE STATION (BS) AND THE CRISIS MANAGEMENT INFORMATION SYSTEM (CMIS) [1,2,3]

The architecture of the CMIS is composed of two high level conceptual entities communicating with each other: the appliances (robots) performing their mission inside the crisis area and the combination of the base station (BS) and the Crisis Management Information System (CMIS), located close (if not at the same place) to the Control Operation Center (COC). The Base Station is in charge of managing the robots. The CMIS takes the information produced by the robots and the sensors they carry, and relayed through the BS, and provide an interface to this information for the crisis managers.

A. The Base Station

Developed by SAS, the following picture depicts the components of the system and the relationship between them:

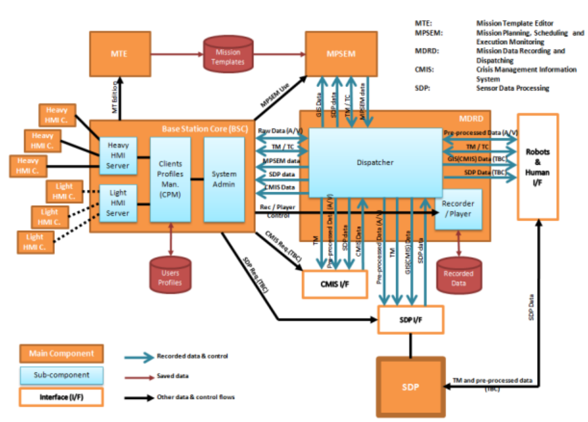

Fig.1. View-Finder base station functional architecture overview

The following components have been identified as

necessary in the base station:
- Base Station Core (BSC)
- Mission Template Editor (MTE)
- Mission Planner, Scheduler and Execution Monitoring (MPSEM)
- Mission Data Recorder & Dispatcher (MDRD)
- Human Machine Interface (HMI) Clients
- Sensor Data Processing (SDP)

The Base Station is quite central in the system: it provides management means for the overall system, including users administration, system elements health status and testing, software maintenance (updating software components...), etc. It also has two different HMI servers: one related to Heavy HMI service (as a gateway for data from and to the connected Heavy HMI), and the other one related to Lightweight HMI service (as a web server, for access through the internet). The BSC accepts connections with clients HMI, either remotely (lightweight client through internet) or on-site (heavy, full-featured client). These servers allow using the different base station components features (MTE, MPSEM, MDRD...), in addition to enabling monitoring and control interfaces for robots operations.

B. The Crisis Management Information System

Proposed by RMA, the CMIS has been developed using a laptop Dell Latitude D830 and has been developed following the open source principles and tested in Debian based operating system, specifically in Ubuntu (versions 6.06 and Higher)

There are several reasons that convince us to employ Ubuntu as development and testing platform: Ubuntu is a very stable operating system based in the Debian distribution; it is also very popular and gaining momentum. The popularity of Ubuntu suggests that there will be research opportunities for those who are interested in deploying the CMIS. Popularity of Ubuntu also demonstrates that the distribution will be around for a while so the instructions done in this guide will still be valid for future tests and implementations of the CMIS.

Moreover the philosophy of the distribution is such that Ubuntu is committed to using up to date drivers and cutting edge technology and it is a main requirement of the proposed system.

The choice of Apache as Web-server is quite logical, we need a powerful, flexible, well known and manageable web server to serve subsystems of the CMIS. Additionally the tools used for very important pars of the systems, as the GIS, were developed and tested with this web server

Concerning the implementation of the GIS module in the CMIS, we used several technologies together in order to make the system work. The web container *Tomcat* is used to make our server side applications (servlets) run. It's the heart of the GIS subsystem since the tools used are servlets which need a container to be deployed and executed.

The GIS tools is based on the use of the following applications and frameworks:

– GeoServer, a geographical data server, which stores and serves raster maps

– GeoMajas, a framework which consumes and presents the maps served by Geoserver enriching them with layers which present the sensors' data

– The sensors data are collected from the base station with a tool written by the RMA researchers, the CMI.jar application.

– All the data are stored in a spatial database using PostGis, a spatial extension built on top of the open source PostgreSQL database

The next picture illustrates the on-site Crisis Management Information Team, directly related to the above described Base Station, through a wireless (Hard/Soft) Internet connection set up between the crisis site and the Crisis Management Centre.

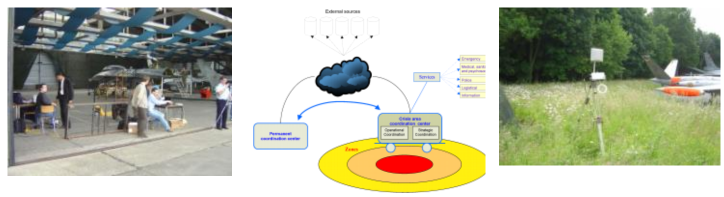

Fig.2. On-site deployment and Inter-level Transmission

II. THE ROBOTS

A. Scenario

On site of the incident, the Control Operational Centre will be deployed if the situation implies it (decision of the Fire-Fighting Operation and/or Incident Officer) and for so far the Robotics assistance fits the next basic requirements: Improvement of the Security/Safety of the Intervention Team, Rapid Deployment of Intervention Team, Operation in Contaminated Environments, Implementation of Reliable Chemical Detection means, Hazard Prediction Modelling (Mapping/Training), Secure visual Data (environment, victims, etc). A typical scenario has consequently been proposed by/with the support of the End-Users: the crash of an airplane on/near a military/civilian zone and the post aircraft crash management by three management levels (on site, province and state)

B. Indoor and outdoor Robotics systems

A ARTVJr autonomous mobile robot has been improved for the ViewFinder Application from the software architecture and autonomous navigation point of view. The main goal of increased performance is achieved by combining State of the Art Player/Stage driver for the RFLEX–ATRV Jr onboard real time controller with the ViewFinder system based on CORBA/CoRoBa/Mailman communication technologies [4,14]. The usage of player's driver determines independence of the ViewFinder System from indoor autonomous mobile platform. It means the robot is seen by the ViewFinder System as a set of functionalities, therefore another robot with respective functionalities can be used. Player server provides access to the robot basic functionality given by RFLEX real time OS, which consists of sensors: sonars, odometry, battery status, ptz camera, laser and compass.

The ATRv Junior (PIAP) The ROBUDEM (RMA)

Fig 3. The robots in the View-Finder Project

The ROBUDEM is equipped with odometric sensors, a vision system consisting of a Bumblebee2 vision system consisting of 2 digital cameras, an RTK DGPS with three antennas, INS and ultrasonic sensors which give distance measurements to obstacles in front of the robot and before the wheels. All sensors and actuators are managed under the RMA developed CoRoBa [5] framework

III. THE MISSION PLANNING AND RELATED COMMAND-CONTROL OF THE ROBOTS

The next chapters will focus on the outdoor scenario (Robudem) implying the continuous localisation of the robot and the surrounded environmental features (airplane's fragments, victims, gas (Hydrazine) leakages or tanks, etc) and, obviously, his mission related navigation

A. Vision-based Simultaneous Localization and Mapping [6]

In the outdoor application the robot ROBUDEM uses a single monocular camera to extract natural features in the scene. These features are used as landmarks in the built map. The SLAM problem is tackled as a stochastic problem using an Extended Kalman Filtering to maintain a state vector, **X**, consisting of the robot state, $\mathbf{y_R}$, and map feature states, $\mathbf{x_{Li}}$. It also maintains a covariance matrix, **P**, which includes the uncertainties in the various states as well as correlations between the states.
A world coordinate frame W is defined such that its X and Z axes lie in the ground plane, and its Y axis point vertically upwards. The system state vector $\mathbf{y_R}$ in this case is defined with the 3D position vector (y_1,y_2,y_3) of the gravity center of the robot in the world frame coordinates and the robot's orientation roll, pitch and yaw about the *Z, X,* and *Y* axes, respectively $(\gamma, \theta, \varphi)$.
The dynamic model or motion model is the relationship between the robot's paste state, $\mathbf{y}_R^{t-1}$, and its current state, $\mathbf{y}_R^t$, given a control input u^t

$$\mathbf{y}_R^t = \begin{bmatrix} y_1^t \\ y_2^t \\ y_3^t \\ \gamma^t \\ \theta^t \\ \varphi^t \end{bmatrix} = \begin{bmatrix} y_1^{t-1} + (\mathbf{v}^{t-1} + \mathbf{V})\cos(\gamma^{t-1})\Delta t \\ y_2^{t-1} + (\mathbf{v}^{t-1} + \mathbf{V})\sin(\gamma^{t-1})\Delta t \\ y_3^{t-1} \\ \gamma^{t-1} + (\omega^{t-1} + \mathbf{\Omega})\Delta t \\ \theta^{t-1} \\ \varphi^{t-1} \end{bmatrix}$$

Where **f** is a function representing the mobility, kinematics and dynamics of the robot (transition function). **v** and w are a random vector describing the unmodelled aspects of the vehicle (process noise such as wheel sleep or odometry error).
v and ω are the linear and the angular velocities, respectively.
V and **Ω** are the Gaussian distributed perturbations to the camera's linear and angular velocity.
Feature are selected using SIFT algorithm and are represented by their 3D position vectors. When a feature is first detected, measurement from a single camera position provides good information on its direction relative to the camera, but its depth is initially unknown. In our application, to estimate the 3D position of the detected features, we use an approach based on *epipolar geometry*. This geometry represents the geometric relationship between multiple viewpoints of a rigid body and it depends on the internal parameters and relative positions of the camera. Features are not deleted from the map when they leave the field of view, but remain in the map and can be re-observed when the camera moves back and they become visible again. In some cases it is necessary to delete features which are not being reliably matched on a regular basis: some features detected will be frequently occluded or may contain parts of objects at very different depths. These features will lead to failed correlation attempts and can be removed from the map automatically.
To avoid using outlier features, the moving object mask detected by the motion segmentation procedure introduced in [8] is used. Subsequently, during map building, the detected features on the moving parts are excluded.
For feature matching we used a measurement test based on the discrepancy between a predicted measurement that each feature would generate and an actual sensor measurement and the mahalanobis distance between features descriptors. The epipolar constraint is also taken into account in our application for feature matching.
The main open problem of the current state of the art SLAM approaches and particularly vision based approaches is mapping large-scale areas. Relevant shortcomings of this problem are, on the one hand, the computational burden, which limits the applicability of the EKF-based SLAM in large-scale real time applications and, on the other hand, the use of linearized solutions which compromises the consistency of the estimation process. To overcome these limitations, we proposed an approach to build a global representation of the environment based on several size

limited local maps built using the previously described approach.

On site (BBN) Intervention	SLAM on CMIS Station

Fig 4. Intervention and localisation of the ROBUDEM

Two methods for local map joining are proposed, the first method consists in transforming each local map into a global frame before to start building a new local map. While in the second method, the global map consists only in a set of robot positions where new local maps started (i.e. the base references of the local maps). In both methods, the base frame for the global map is the robot position at instant t_0. The obtained map can be superimposed to a satellite image of the navigated area by matching the GPS data corresponding to frame coordinates of the local maps.

B. Behaviour based navigation [9]

The control architecture describes the strategy to combine the three main capabilities of an intelligent mobile agent: sensing, reasoning and actuation. These three capabilities have to be integrated in a coherent framework in order for the mobile agent to perform a certain task adequately. To combine the advantages of purely reactive and planner-based approaches, our research work aims at implementing a hybrid control strategy which fuses a behaviour-based controller for autonomous navigation with automation aspects for gas-detection.

The performance of the behaviour-based controller depends on the implementation of the individual behaviours as well as on the method chosen to solve the behaviour fusion or action selection problem. The action selection problem can be formulated as a multiple objective decision making (MODM) problem.

Mathematically, a multi-objective decision problem can be represented in the following way:

$$\arg\max_{\mathbf{x}} \left[o_1(\mathbf{x}), \ldots, o_n(\mathbf{x}) \right]$$

Where $o_1(\mathbf{x}), \ldots, o_n(\mathbf{x})$ are a set of system objectives, tasks or criteria (fig.5) and where $\mathbf{x} = (x_1, \ldots, x_n) \in R^n$ is a n-dimensional decision variable vector. The degree of attainment of a particular alternative $\boldsymbol{x}$, with respect to the k^{th} objective is given by $o_k(\mathbf{x})$. $X \subseteq R^n$ defines the set of feasible alternatives. This problem is in the literature often known as the Vector Optimization Problem (VOP). In summary, the degree of relevance or activity is calculated by observing the history of the output of each behaviour. This history-analysis is performed by comparing the current output to a running average of previous outputs, which leads to a standard deviation, which is then normalized). It is obvious that this method increases the numerical complexity of finding a solution to the VOP, but this does not necessarily leads to increased processing time, as the search interval can be further reduced by incorporating constraints from both data sources.

As the Robudem is equipped with multiple sensors with very different spectral properties, various types obstacles can be perceived: the modules of the architecture of fig.5 have thus been developed

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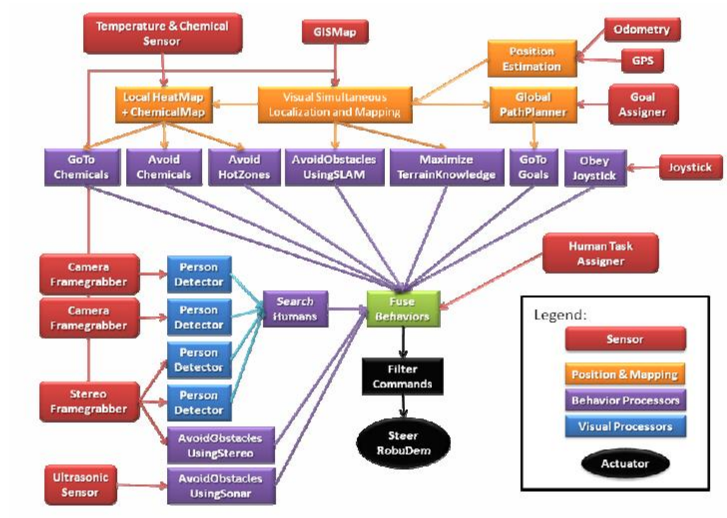

Fig.5. Behaviour based Navigation

C. Victim Detection

In a first attempt at victim detection, we used the standard Viola-Jones [13] detector for face and upper body detection. The first tests were executed on indoor and good quality images. These tests were very successful, 90% of the faces and 80% of the upper bodies were detected. However, the target hardware, the RobuDem, is going to operate in outdoor environment where the background is various and the illumination is unpredictable. So, outdoor experiments were strongly suggested. Although, the results were better than expected, the false alarm was increased dramatically while the hit rate was decreased to 70% for the upper body and to 30% for the face detection. The conclusion from these tests is that in outdoor environment the face detection based person detection is not viable. Usually it only consumes the computation time without giving any results or any correct results. If the detection was more detailed, the system became too slow with minor success. If the detection was tuned to be faster, the hit rate decreased under 10%. The upper body detection is more robust, it adopts itself to different illuminations much better. However, it gives much more false alarms. A further issue would consist into the integration of other sensing capabilities, such as Infra-red and audio signals.

D. Traversability Analysis

Detecting obstacles from stereo vision images may seem simple, as the stereo vision system can provide rich depth information [15]. However, from the depth image, it is not evident to distinguish the traversable from the non-traversable terrain, especially in outdoor conditions, where the terrain roughness and the robot mobility parameters must be taken into account. The RMA-DUTH approach is based on the construction and subsequent processing of the *v-disparity* image [12], which provides a robust representation of the geometric content of road scenes. The v-disparity image is constructed by calculating a horizontal histogram of the disparity stereo image. Consider 2 stereo frames and the computed disparity image, as shown in Figure 6. Then, the v-disparity image can be constructed by accumulating the points with the same disparity that occur on a horizontal line in the image.

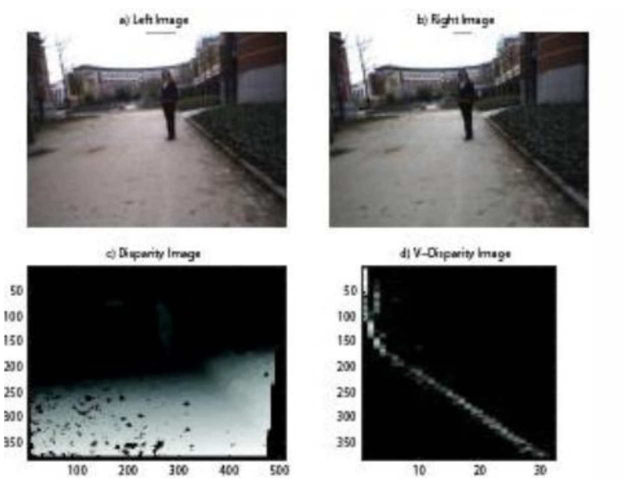

Fig.7. Disparity, V-Disparity Image

The classification of the terrain in traversable and non-traversable areas goes out from the assumption that the majority of the image pixels are related to traversable terrain of the ground plane. The projection of this ground plane in the v-disparity image is a straight line, from the top left to the bottom right of the v-disparity image. Any deviations from this projection of the ground plane are likely obstacles or other non-traversable terrain items. As such, the processing of the v-disparity image comes down to estimating the equation of the line segment in the v-disparity image, corresponding to the ground plane. This is done by performing a Hough transform on the v-disparity image and searching for the longest line segment. Then, one must choose a single parameter which accounts for the maximum terrain roughness. As this parameter depends only on the robot characteristics, it only needs to be set once. This parameter sets the maximum offset in v-disparity space to be considered part of the ground plane. Any outliers are regarded as obstacles, which enables to compile an obstacle image

IV. Conclusion

The very essence of the VIEW-FINDER Intelligent Information System is to integrate disparate elements involved in a crisis situation into an info-structure that will allow information to be exchanged readily between all of those elements: crisis centres, relevant forces dealing with the crisis (fire fighters, de-bombing squads, police, etc.), robotics platforms and sensors. This paper introduced some results of the major outdoor tasks entrusted to the partners of the View-Finder project.
The next steps of this work will consist into the reconstruction of the 3D environment, based on the structure from motion [11] and the intensive test of the Visual SLAM [6], combining the DGPS, the INS (Inertial Sensor) and Camera signals of the Robot in order to optimize the autonomous navigation of the ROBUDEM and the efficiency of the visual information transmitted to the Fire-Fighters.

Acknowledgement

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