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# A Pipeline for an Automatic Autonomous Observatory: Application to TAROT

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**Abstract.** We have developed a data processing pipeline for the automatic TAROT observatory. It is composed of a scheduler (MAJORDOME), a telescope control and a data processing software (TAITAR). Details of the MAJORDOME and classification softwares are given in companion contributions (Boër et al. 2000; Bringer & Boër 2000). In this paper, we present the overall architecture of the pipeline, and the interactions between the various modules.

## 1. Introduction

The Télescope à Action Rapide pour les Objets Transitoires (TAROT, Boër et al. 1999), in operation at the Calern Observatory (France) has for primary objective the realtime detection of Cosmic Gamma-Ray Bursts (hereafter GRBs). However, this goal uses only about 10% of the available time, hence several routine programs, mainly connected with the study of celestial variability are currently running.

The users for the routine program submit remotely their observation requests to the MAJORDOME. If selected by the scheduler, the request will be processed by the telescope and the corresponding frame will then go through the data processing software in near real time in order to generate a catalogue of the different objects including their properties. If an alert occurs (e.g., to observe a GRB source location given by the GCN), the corresponding position is immediately sent to the telescope, and the images are processed straight afterwards, delaying the processing of routine observations. With this software suite, TAROT is now fully autonomous, i.e., there is no human intervention on the telescope, nor on the processing. Results may then be used to search for new or variables objects, as it is the case for optical counterparts of GRBs.

## 2. The Pipeline Architecture

The TAROT observatory (Calern, France) running for a year now is composed of different modules linked to each other according to Figure 1.

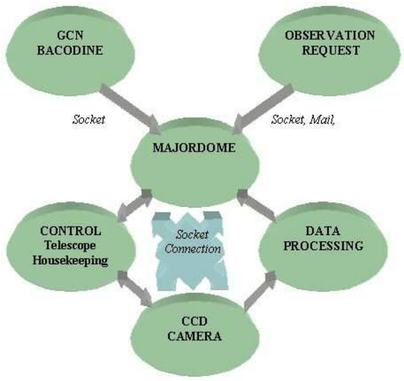


Figure 1. Overview of the TAROT pipeline modules.

- The OBSERVATION REQUEST is the module that enables anyone to send an observation proposal to TAROT. The request will then join the request database.
- The GCN-BACODINE module is simply a TCP-IP connection with the NASA center that is collecting all the satellite GRB event positions and sends those in real time to automatic observatories (Barthelmy 1999).
- The MAJORDOME is a software that is able to optimally schedule observations considering different parameters such as the Moon position, the transit date and other constraints eventually given by the OBSERVATION REQUEST. One of the particularity of TAROT is its reactivity to unprogrammed events. The MAJORDOME is though able to consider what we call an **alert request** (GRB in our case) and to reschedule in a short time (less than a minute) the timetable for the rest of the night.
- The CONTROL is the module in charge of the telescope drives and the housekeeping. It is able to detect rain, dew, and other conditions that need a special action. It then inform the MAJORDOME that reacts to these events.
- The DATA PROCESSING software is composed of TAITAR, the image processing software that detects the objects on the frame, as well as new or variable stars. We have also developed a cloud algorithm based on flux measurement of reference sources evenly spaced over the sky. The last feature of the DATA PROCESSING software is an automatic satellite detection based on the Hough Transform.

## 3. Example on a GRB BATSE Detection

The MAJORDOME receives the GRB location through the GCN connection and instantly stops what it was doing. He generates another timetable for the rest of the night and starts sending to the CONTROL the requested positions. The CONTROL does quite a basic work. Whenever it receives an order, it executes it, hence the system intelligence lies in the MAJORDOME

Let's go through our pipeline with the 1st Frame. As soon as the first frame is written on the hard disk, TAITAR starts analyzing it. First of all, TAITAR

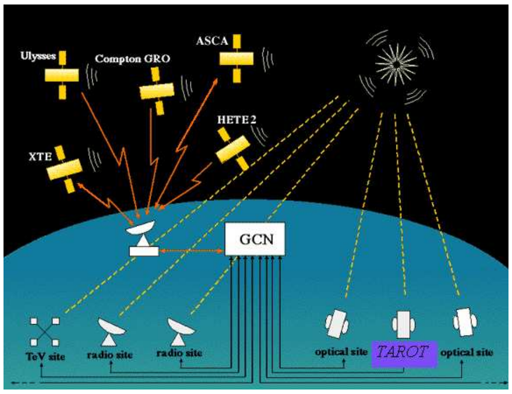


Figure 2. TAROT receiving an alert from GCN.

evaluates if there were clouds on the frame. If it is the case, the frame is not completely analyzed and the CONTROL and the MAJORDOME are informed of partially sky coverage. The MAJORDOME can decide to launch a complete cloud detection procedure, in order to select regions of the request database whose coordinates correspond to clear sky areas. If the Frame seems normal, the analysis starts. The complete analysis of a frame is done in 4 steps (Irwin 1985, Bertin & Arnouts 1996): estimation of the Sky Background, thresholding, deblending and finally astrometric and photometric calibration.

At the end of the analysis, TAITAR generates two output catalogues. One that contains all the sources of the frame, and another that contains the objects that weren't on the reference catalogues. Those objects are possible optical counterparts of GRB or variables objects.

## 4. The Pipeline Performances

Our system is completely autonomous and doesn't need any human intervention excepted once a week in order to change the archive DAT.

### 4.1. The MAJORDOME Performances

Our Scheduler is able to deal with a request database of 1500 requests in less than a minute. This is done every day at noon for the next night, or after each interruption due to rain or cloud detection. Table 1 gives an example of the various possible requests, as well as the results of the MAJORDOME scheduling.

The efficiency $\xi$ of the system is defined as the ratio of the effective observing time by the total night time (Here 6h 19 06).
For our example here, we have obtained $\xi = 88.59\%$.

### 4.2. The Data Processing Performances

TAITAR fully process a 1280x1024 frame in 90 seconds. The extraction of objects lasts 15 to 20 seconds. The rest of the time is used to calibrate the frame with the USNO catalogue. We are looking forward to generating our own

Table 1. The Request Database

| Type | Total $N^0$ | Cumulate Time | $N^0$ of scheduled | Cumulate Time |
|---|---|---|---|---|
| Total Request | 500 | 24h 36 23 | – | – |
| Visible | 435 | 21h 41 23 | 121 | 5h 38 51 |
| Periodic Non Constraint | 41 | 3h 53 12 | 12 | 0h 46 01 |
| Non Constraint | 359 | 16h 14 01 | 74 | 3h 10 40 |
| Constraint | 35 | 1h 34 10 | 35 | 1h 34 10 |

catalogue in order to optimize the astrometric and photometric calibration.
*Astrometric Accuracy*: Our objects location average error is 1 arcsec.
*Photometric Accuracy*: Our differential magnitude accuracy is 0.03 mag.

### 4.3. General Performances

TAROT produces about 300 frames per night, which represents $300 * 2 * 1280 * 1024 = 750MB$. Our system analyzes these frames in 7.5 hours.

## 5. Conclusions and Perspectives

We have developed a fully autonomous pipeline in order to run the TAROT observatory. Our system is composed of different modules that interact with each other. We are now looking forward to developing a second version of our scheduler that will be able to schedule observations even in bad conditions and on a period of several months. Shortly, we will use on line our classification algorithm based on Kohonen networks and our satellite detection algorithms which detect in less than 10 seconds all the satellite or plane tracks on the frame.

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## References

Barthelmy, S. 1999, information available at http://gcn.gsfc.nasa.gov/gcn/
Bertin, E. & Arnouts, S. 1996, ApJS, 117, 393
Boër et al. 1999, A&AS, 138, 579
Boër, M. et al. 2000, this volume, 115
Bringer, M. & Boër, M. 2000, this volume, 642
Irwin, J. 1985, MNRAS, 214, 575