Journal of Applied Sciences

ISSN 1812-5654

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http://ansinet.com

Journal of Applied Sciences 6 (8): 1631-1634, 2006
ISSN 1812-5654

Monte Carlo Modeling for Gamma Rays Bursts Detection Monitoring Algorithms

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Abstract: In this study an efficiency comparison was made for three different monitoring algorithms in order to simulate the response of rotating monitoring systems. Burst-events counting on a spherical surface were simulated as a system, with a one or more detectors located on the center of a sphere. The burst-events direction was randomly changed at steps analogous to the monitoring period and the monitoring was simulated in Monte Carlo calculations for three separate models: In the first model, the random direction, the detection vector was randomly changed after each step using two isotropic distributed random variables. In the second model, the sphere stripping the detection vector was pointed to the upper latitude. The whole sphere was scanned through a full monitoring period. In the second model, the quadrantic stripping, four quadrants were defined for each hemisphere, in the step-by-step completion of the whole segment angular detection vector ranges. This method was set to present an equivalent of a bundled detectors array and has an enhancing monitoring ability. It may be applied on galactic oriented objects, distributed along the galactic sphere Equator. The 10^6 steps scored events from each of the three algorithms in very similar probabilities. Only after increasing the number of events from 10^6 to 10^7, the random model showed an improved scoring algorithm compared to the other two patterned monitoring algorithms. The sphere-stripping algorithm was proven to be 25% more efficient compared to the quadrantic algorithm, and is therefore the preferred patterned monitoring algorithm.

Key words: BASTE, detectors, Gamma rays, GRB, modeling, Monte Carlo, random, X-rays

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INTRODUCTION

The cosmic γ-ray burst phenomenon (Klebesadel *et al.*, 1973) was discovered in the late 1960's while monitoring the Earth surface, looking for evidence of clandestine nuclear tests. Before the launch of the Compton Observatory in 1991 (Gehrels *et al.*, 1993), a complete Gamma Ray Bursts (GRB) mapping was performed. The Compton Observatory (CGRO) covered gamma rays detection of several objects: the Sun, compact companion in stars binaries, supernova remnants, interstellar medium, galaxies, quasars, pulsars, supernovae and gamma ray burst sources (Schönfelder, 2001) and established the gamma ray astronomy. A space shuttle was used for the Compton Observatory which was the largest satellite (17 ton) ever placed in orbit.

One of the four instruments abroad CGRO, the BASTE (Schönfelder, 2001), was used to detect Gamma Ray Bursts roughly once per day on the average with a typical 5° spatial accuracy. Since 1991 until 1996 more than 2,000 bursts were detected and found to be isotropicaly distributed on the galactic coordinates sphere surface, as shown in Fig. 1 (Paciesas *et al.*, 1999).

GRBs and supernovae are probable gamma-ray sources short period events. The GRB duration in the BASTE GRB database showed a distribution of a 0.01 sec up to 8 min with a higher probability in the shorter duration (Meegan, 2001) (duration of 10 sec or less occurred in more than 50% of the events). The duration information and the typical angular resolution led to a higher probability of observing a single event in an order of 2 10^{-4} per angular-opening. Ten seconds duration was assumed for a given event indicating that a typical event would be taking place in a portion of 10^{-4} of the total observation time, which would add an angular motion to the detection system and may lead to an improved detection.

The X-ray satellite Beppo-SAX was set out in 1996 with two position-sensitive detectors acting as telescopes for low energy x-ray (0.1-10 keV) objects. A HPGSPC spectrometer was also included, with two wide field proportional counters and a collimated Phoswich Detector System in order to monitor 60-600 keV gamma ray bursts with a temporal resolution of about 1 ms. An attitude orbital control system was added to ensure a 1' pointing accuracy of source observations and a 10° per min slew rate maneuvers (Boella *et al.*, 1997).

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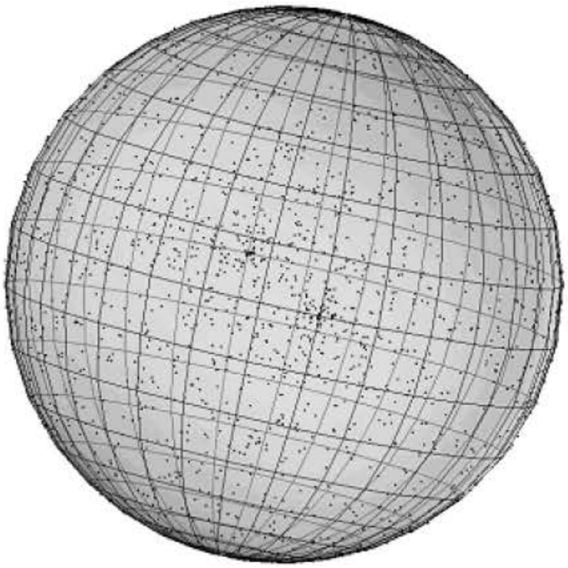

Fig. 1: The 1600 GRB objects catalog, measured by BASTE in a galactic coordinates system (data points taken from http://www. batse. msfc. nasa. gov/batse/grb/catalog/current/)

Suitable for Randomly distributed gamma rays detection systems are very limited due to the restricted ability to support missions such as Beppo-SAX or Compton Observatory.

A new way of exploring the gamma ray sources is suggested in order to collect and group raw-data from all gamma burst events monitoring satellites and to transmit the mapped signals. An analyzing computer located on a communication satellite will transmit the mapped signals to a mission station on Earth.

MATERIALS AND METHODS

General parameters were defined to simulate GRB emission in order to compare different sensing algorithm performances. A simulated Burst-events counts system on a spherical surface, including a detector, was placed in the center of a sphere. The detecting point was defined as a 5° opening-angle from the origin cone's vertex, for counting burst-events on a sphere. Only in cases when an event occurred within a certain distance from the detecting cone, the detector responded. The distance was defined by the angle between two vectors, the center of the sphere to the burst-event point and the detector's direction vector (Fig. 2). The burst-events were defined as an array of b vectors; each vector containing longitude and latitude as components. Two random variables were generated in order to fill up the burst-events positions into the array. The detector was allowed to monitor four times only the whole sphere, using 10,000 steps, for each burst-events set. Assuming a 10 sec counting time at each step will result a period of 28 h between each burst-events repositioning, similar to the natural occurrence timing of GRB.

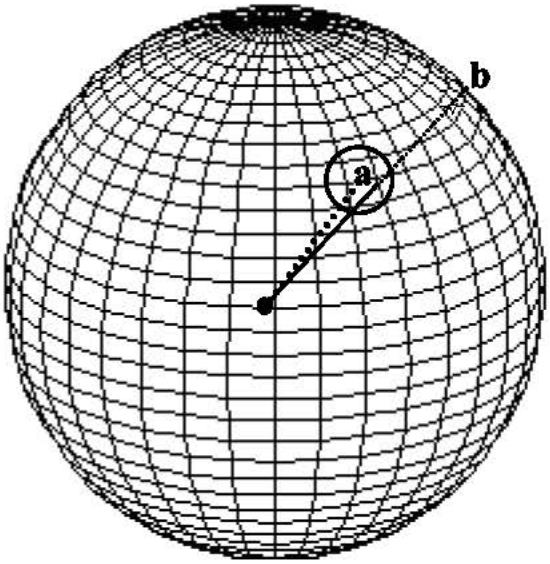

Fig. 2: The 5° opening-angle detecting point from the origin cone's vertex vector (a) and the burst-event vector (b)

Three different monitoring algorithms were simulated in order to compare each of the monitoring algorithms by computing their efficiency. The burst-events monitoring was computed using Monte Carlo calculations in three separate modules (computer codes written with Fortran 90), describing selected cases of detector angular translations. All the modules were written based on spherical coordinates with two vectoric-transformation subroutines from spherical to Cartesian presentation and vice versa. A different subroutine was included in each module to calculate the angle between two vectors: the burst-event location and the detection direction unit-vector. For every step, the subroutine calculated the angular distance in order to determine burst-events occurrence inside the 5° detector view range using Eq. 1.

$$\cos\alpha = \frac{\vec{a}\cdot\vec{b}}{|\vec{a}|\cdot|\vec{b}|} \tag{1}$$

The monitoring algorithms description

Random: The detection vector was randomly changed after each step using two isotropic distributed random variables. The detection vector slew duration was defined as zero, for any step independent on the angular distance between the previous orientations to the next.

Sphere stripping: The detection vector was pointed to the upper latitude and the longitude was given a 5° change for every step. After a complete circle, the latitude was reduced by 5° and the next longitude was scanned until the whole sphere was scanned through a full monitoring period.

Quadrantic stripping: For each hemisphere, four quadrants were defined in the step-by-step completion of the whole segment angular detection vector ranges. The steps were contributed correspondently to each of the spherical quadrants. This method was set to present an equivalent of a bundled detectors array. This algorithm has an enhancing monitoring ability, since the detection vector is pointing four times on the Polar Regions and twice on the Equator for each sequence. This method may be applied to galactic oriented objects, distributed along the galactic sphere Equator.

RESULTS

The same parameters were chosen to test the results of the three algorithms. Figure 3 showed isotropic distribution of 200 computed burst-events, with a single event (circled) detected by one of the algorithms. Small opening detection system reduced the probability to detect GRBs, therefore, a factor of ten variance reduction was performed by enhancing the burst-events population. Table 1 summarizes the simulations results for each monitoring algorithm.

The simulations results showed no apparent difference between the three algorithms for 200 bursts in 4×10^{3} periods (10^6 steps). After enhancing the burst-events population, the random monitoring algorism showed a better yield compared to the other two algorithms that provided similar yields. The quadrantic stripping algorithm was found to be an inferior monitoring method under 4×10^{5} period simulations.

Table 1: The three monitoring algorithms results for different burst-events, with different period lengths. The total events results with standard deviations are presented for each case

	200 Burst-Events		2000 Burst-Events		
Monitoring Alogrithm	4×10^{3} Periods	4×10^{4} Periods	4×10^{3} Periods	4×10^{4} Periods	4×10^{5} Periods
Random	10±3	133±12	140±12	1330±36	13357±116
Sphere stripping	9±3	53±7	40±6	415±20	4653±68
Quadrantic stripping	8±3	37±6	60±8	388±20	3636±60

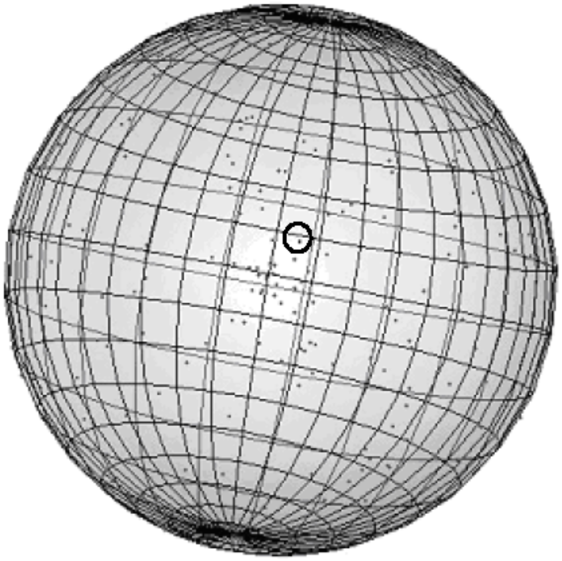

Fig. 3: A computed 200 burst-events example set with a circled one detected event. The burst-events were isotropic distributed, as shown

CONCLUSIONS

We could predict the highest yields from the random monitoring algorithm due to the GRBs spatial distribution isotropic nature. The comparison between the methods was done to compare the random monitoring algorithm exact ratio of yields to other patterned monitoring methods. The random monitoring was three times more efficient than the quadrantic and the sphere-stripping algorithms. The sphere-stripping algorithm, the most common used tool for monitoring, read about 25% more events compared to the quadrantic algorithm and therefore should be taken as the better patterned algorithm.

The quadrantic-stripping algorithm structure could be suitable for non-isotropic sources, such as galactic phenomena where most of the events are concentrated in a given space. Monitoring efficiency for a group of detection satellites should be evaluated in the future using Monte-Carlo simulations.

The Monte Carlo method was found to be a very convenient tool, applicable to assist in monitoring assessments. The computing recorded timing was less than 14 h for 10^8 steps on a Pentium - 4 PC with 1.8 GHz Intel processor.

REFERENCES

Klebesadel, R.W., I.B. Strong and R.A. Olson, 1973. Observations of gamma-ray bursts of cosmic origin. Astrophys. J., 182: L85.

Gehrels, N., C.E. Fichtel, G.J. Fishman, J.D. Kurfess and V. Schönfelder, 1993. The compton Gamma ray observatory. Sci. Am., 93: 38.

Schönfelder, V., Ed., 2001. The Universe in Gamma Rays. Springer-Verlag Berlin Heidelberg, pp: 1-7, 87-89.

Paciesas, W. *et al*., 1999. The Fourth BATSE Gamma-Ray Burst Catalog (Revised). APJS, 122: 465.

Meegan, C.A. *et al*., 2001. Current BATSE Gamma-Ray Burst Catalog, on the Internet. http://www.batse.msfc.nasa.gov/data/grb/catalog/

Boella, G., R.C. Butler, G.C. Perola, L. Piro, L. Scarsi and J.A.M. Bleeker, 1997. BeppoSAX, the wide band mission for X-ray astronomy. A and AS, 122: 299B.