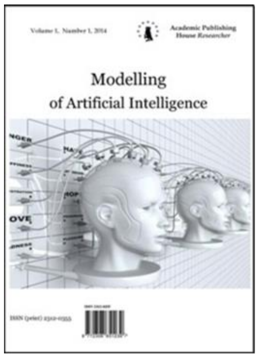
Published in the Russian Federation
Modeling of Artificial Intelligence
Has been issued since 2014.
ISSN: 2312-0355
E-ISSN: 2413-7200
2017, 4(2): 96-101

DOI: 10.13187/mai.2017.2.96
www.ejournal11.com



Application of Monte Carlo Method for Calculation of the Comets' Area by the Photographic Pictures

V.Ya. Tsvetkov [a, *]

[a] Research and Design Institute of design information, automation and communication on railway transport, Russian Federation

Abstract

The article describes application of statistical method for definition of cross-sectional area of comets and other moving astronomical bodies. Application conditions of this method are described. The simulation modeling which form the basis of this method, is defined. Spatial restrictions which are imposed on the application of this method, are described. The article describes technical implementation of the method. Analysis of method errors is provided. Fields of method application are described. The method is applicable for areal objects estimate by means of thermal pictures and radar images.

Keywords: space researches, comets, celestial bodies, statistical computations, Monte Carlo method, cross-sectional area.

1. Introduction

Comet research represents an important field of space researches (Anders, 1989, Weissman, 2002, Bryant, 2014). One of characteristics of small celestial bodies, meteorites and comets is their cross-sectional area (Jenniskens, 1997). This characteristic is conditional considering that the cross section is defined by choice of the cross-sectional plane. The cross section is defined by the observation point. In the event of using the camera the cross section is determined by the position of the camera view point and obliquity of the principal optical axis in relation to direction towards the object. However, for all its disadvantages, the cross section provides quite complete information on the size and weight of the object. From the perspective of space geoinformatics (Bondur, 2015) the cross section of the comet represents an areal object. Areal is commonly referred to as a certain space domain which has an area.

The main toolkit for areal objects identification is space monitoring (Black, 2002). The main toolkit for research of the objects which has a cross section are space images (Aldrich, 1971). During last decades analogue photographic pictures were replaced by digital ones (Vislotskii, 2000). Digital pictures are inferior to analogue ones when imaging of high-speed processes and bodies traveling at high speed. However, the simple acquisition and the promptness of the data transfer have determined a migration to digital imaging of the astronomical objects. The remote sensing allows acquisition of various images – photogrammetric, thermal, and radar ones. The suggested method makes it possible to process images obtained in different spectrums of electromagnetic waves: optical, infra-red, ultra-violet, radar and X-ray one. This actualizes the development of

* Corresponding author
E-mail addresses: cvj2@mail.ru (V.Ya. Tsvetkov)

methods for area determination of arbitrary shaped objects according to the photographic pictures and models.

2. Material and methods of the research

The existing works in the field of Solar system structure and works in the field of the units of measurement were used as material. The statistical and correlation analysis were used as a research methodology.

3. Results

The method is based on using of the well-known Monte Carlo model (Mooney, 1997, Robert, 2004, Earl, 2008) for the statistical analysis. The source material is obtained on the basis of the remote sensing. Proposed method comprises of conditions and limitations. The basis of the method is an availability of the space picture containing two images of one moving astronomical object, obtained at time interval T. In this case the background on which the moving object is depicted is not considered for calculations. The other version is an availability of two comparable images. In this event the background or the background image is of importance for images identification.

Let us consider the first version according to which there are two pictures of one moving objects are depicted on one image at different time points (Fig. 1).

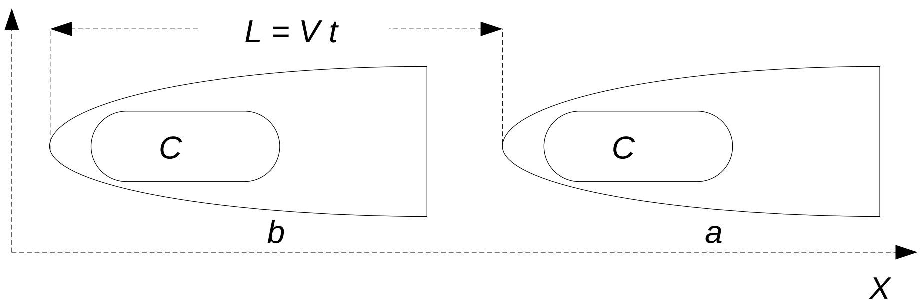


Fig. 1. Information situation (Tsvetkov, 2012) of the object movement

The underlying situation of the object (comet) fixation is identified with the letter *a* at Fig. 1. In time interval *t* the repetitive imaging is carried out and object is fixed in a position which is marked with letter *b*. The speed of an object *V* is considered to be known. Besides, the boundaries of the object should be recognized. From the perspective of the comet it is a core (*C*) and an exterior contour. The conventional coordinate system *XY* is set on the image.

Considering the known speed *V* and time interval *t* between the imaging it is possible to gauge the distance *L* which the object has covered during the imaging.

$$L= Vt.(1)$$

The value *L* is descriptive of the actual distance. The distance at the model *l* which can be measured according to the coordinates of the image will correspond to the actual distance. Thus the scale of the imaging m_x can be determined along *X* axis as

$$m_x= L / l.(2)$$

Parameters of the camera for scale determination are not to be considered inasmuch as during imaging of the moving objects the anamorphic images are obtained. The anamorphic images are images which scale along X-axis – m_x and scale along Y-axis – m_Y are different.

$$m_x \neq m_Y.$$

Fig. 2 shows auxiliary geometric constructions, which provide the basis for the future calculations. The condition of the geometric constructions is fixation of the object (comet) boundaries at the image. It is quite complicated condition for the comets which contour changes its shape. However, if the time interval between two imagings is not long the comet contour is not reshaped considerably and the boundaries of two situations of object fixation can be compared.

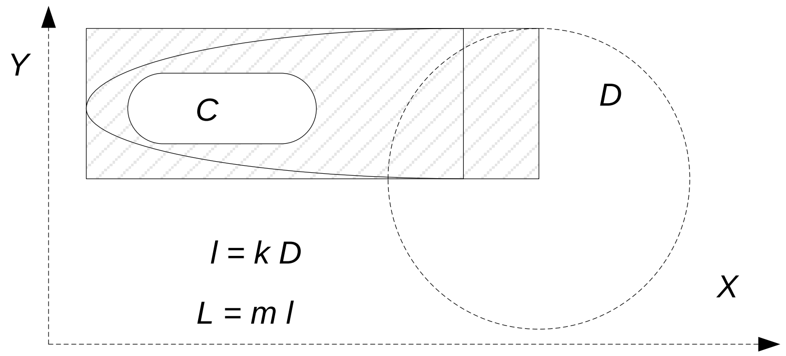


Fig. 2. Information situation of geometric constructions

According to the image the particular size *D* is selected, which characterizes cross-sectional dimension of the object along *Y*-axis. This value can be measured by using the image and is known. The particular rectangle is selected at the image (indicated by crosshatch at Fig. 2). One side of the rectangle is set by cross sectional dimension *D* at the object image (Fig. 2). The second side of the rectangle is set by *l* parameter, which is also measured according to the image as the distance between two positions of the object (Fig. 1, Fig. 2).

The picture of boundary points at the image should be sharp to make it possible to form the correct geometric area using numerical intervals.

The condition of area calculation comprises of using random number generator with homogeneous distribution which covers the set interval of the rectangle of the geometric field. The rectangular area is necessary for simple setting of the rate for the random number generator based along two coordinates. The situation of modeling and area calculation is shown at Fig. 3. The particular rectangle $l \times D$ is indicated by crosshatch on which the object researched is laid *BA (BigArea)*. Instead of *BA* comet core *C* can be researched.

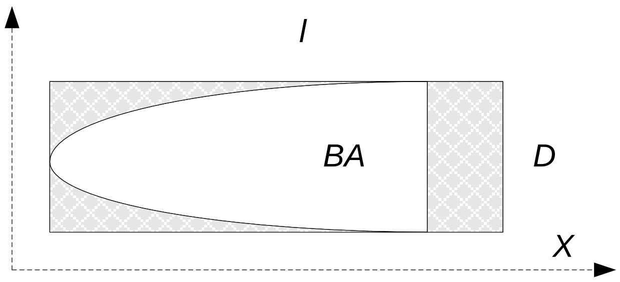


Fig. 3. Information situation of the area calculation

This method applies the simulation modeling, according to which "point" with "random" coordinates is "dropped" on the picture of a rectangular area in accordance with Monte Carlo method. The field of dropping is set by the boundaries of the particular rectangle $l \times D$. Along *X* axis the interval of random numbers is set by the value *l*. Along *Y* axis the interval of random numbers is set by the value *D*.

The essence of Monte Carlo method application is generating coordinates x_m, y_m, in a random manner which set the random point $M(x_m,y_m)$ at the known rectangle – standard *A*. In the event of ramdom dropping $M(x_m,y_m)$ *always* falls into the area of the standard. This provides reasons to introduce the first relation – the relation of the actual standard area to the number of random dots on it. As this takes place the number of points at the standard is always proportional to its area, but depending on the point density the relation will be different. The point density is determined by the number of droppings. The larger is the number of droppings the higher is the density.

Another areal *BA* which area at the planet is unknown is situated in the standard areal *A* (cross section of the moving object with sharp boundaries). In case of random dropping the point $M(x_m,y_m)$ *in some cases* falls into the object area on the image. During series of droppings a part of points fall into the object area *BA* meanwhile the part fall outside the object. But every point falls on the standard. In the event of large number of tests the number of points on object area *BA* becomes proportional to its area. It's possible to introduce the second relation – actual area of the object (area on the surface) to the number of random points on it. In accordance with the law of large numbers, as the number of tests is increased the limits of two marked relation of the area to the number of point become equal.

The following parameters are used for the calculation. S_A is standard A area in the field, S_{PA} is the model area (the pictures are in image) of the standard A in image, S_{BA} is object *O* area in the field, S_{PBA} is area of the object model *BA* in image, *N* is a total number of points during tests, N_{BA} is a number of points fallen into the zone of the object *BA* on model, N_E is a number of points outside the object on standard *A* model. In the initial state the point counters

$$N=N_{BA}=N_E = 0.$$

As a result of modeling

$$N\neq 0,\ N_{BA}\neq 0,\ N_E\neq 0,$$
$$N= N_{BA} + N_E.$$

Every point $M(x,y)$ has random coordinates x_m,y_m according to which it is determined whether this point is situated in the field of an object or outside of it. Mathematically boundaries of the object *BA* at the model is defined by two conditions depending on the selected Information situation. The conditions are read as follows: "above – below" are vertical boundaries and "left – right" are horizontal boundaries.

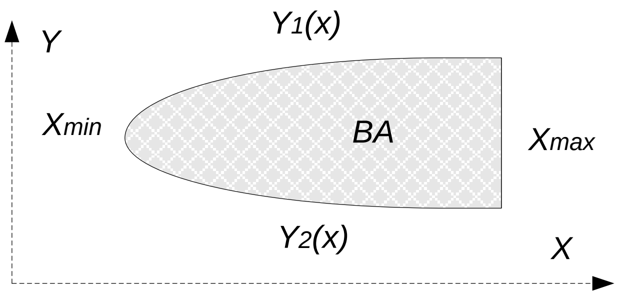


Fig. 4. Information situation of boundaries definition of the object researched

For information situation on fig. 4 the boundaries are defined as follows: The condition "above – below".

$$Y_1(x)>Y_m(x_m)>Y_2(x) \quad (3).$$

Condition "left – right"

$$x_{min}<x_m<x_{max}(4).$$

The functions $Y_1(x),Y_2(x)$ are determined on the basis of the boundary approximation *BA*. The values x_{min}, x_{max} are determined on the basis of the image measuring. If a random point falls into *BA*

$$N_{BA}= N_{BA}+1$$

If for random "dropping" and obtaining coordinates of the points x_m,y_m at least one of conditions (3) и (4) is not met or both of them are not met, the point is outside the object. In this situation the point counter outside the object area increases by one.

$$N_E= N_E+1$$

In the event of every test

$$N= N + 1.$$

During the process of modeling $N = N_{BA} + N_E > 1000$ tests are carried out. Modern computers are able to perform this operation in several seconds. After tests completion the weight or "conventional area" is determined. It is estimated on assumption that

$$S_A \sim S_{PA} \sim N \quad (5)$$

The area of the standard *A* on the surface of the comet which is proportional to the area of the standard in image and also proportional to the total number of points which were used for modeling. In addition to the expression (5) another proportionality exists.

$$S_{BA} \sim S_{PBA} \sim N_{BA} \qquad (6)$$

The value α in the event of large numbers *N* is a constant for two relations.

$$\alpha = S_A / N_A = S_O / N_{AO} \ (7)$$

It is called the weight of point during random test and/or "point area". It follows from here that unknown area of the object *BA* will be determined as follows

$$S_{BA} = \alpha N_{BA} \ (8)$$

Let us estimate the deviation of the method. The method is iterative, therefore its deviation is associated with the notion of convergence. For estimate of the calculation deviation it is required to perform additional $K << N_A$ tests. It is possible to determine the difference between estimated area of the object $S_{BA}(N)$ in the event of tests number *N* of points and the object area $S_{BA}(N+K)$ in case of tests number $N + K$ of points.

$$\delta S_O = [S_{BA} - S_{BA}(N+K)] \ (9)$$

In addition, a part of points K_{OA} fall into area of the object. Simple arithmetic calculations using expressions (7), (8), (9) provide the formula of relative error λ which is calculated by means of formula

$$\lambda = \{(N_{BA}K - NK_{BA})/(N[N_{BA} + K_{BA}])\} \ (10)$$

A numerical illustration

1) The number of tests N_A=1000, the number of points fallen into the object N_{AO}= 500. The number of additional tests K=20, the number of additional points fallen into the object K_O= 10. λ= 0.

2) The number of tests N_A=1000, the number of points fallen into the object N_{AO}= 500. The number of additional tests K=20, the number of additional points fallen into the object K_O = 5. Relative deviation λ= 0.009 or 0.9 % of the measured object's area (but not a standard object).

The value N_A can be increased by times, but the basis should be formed by a reasonable sufficiency. Provided that the accuracy/deviation does not exceed the tolerance calculations can be stopped and a series can be ceased.

4. Discussion

This method is conditional but in a number of instances it is the only one that allows obtaining of the result. An idea of comet's cross section construction is related to the estimation method of the middle section (Wang, 2002) of an arbitrary shaped body well-known in ballistics. The essence of the method is that if we find an arbitrary shaped object (meteorite fragment, bomb or shell splinter), three of its mutually perpendicular diameters are measured. According to them the volume and a specific weight of the body is conventionally measured. By means of them the penetrative impact of the object is estimated. Therefore this method can be considered as middle section estimate of the comet in plane of parallel plane of the photographic picture.

5. Conclusion

An offered method makes it possible to determine the cross-sectional area of moving objects by means of different images. The main condition is the presence of the object contour at the background of the other bodies or outer space. It can be used for estimation of areals' areas by thermal pictures and radar images. Considering the simplicity of an algorithm, it is possible to build it in any software system for calculations of the areas.

References

Aldrich, 1971 – *Aldrich, R.C.* (1971). Space photos for land use and forestry (Space photos for land use and forestry, considering IR color photographs from Apollo 9 flight). Photogrammetric Engineering, 37, 389-401.

Anders, 1989 – *Anders, E.* (1989). Pre-biotic organic matter from comets and asteroids. *Nature*, *342*(6247), 255-257.

Black, 2002 – Black, C., Amrhein, N. (2002). U.S. Patent Application No. 10/309,093.

Bondur, 2015 – *Bondur V.G., Tsvetkov V.Ya.* (2015). New Scientific Direction of Space Geoinformatics // *European Journal of Technology and Design*, 4 10(4), 118-126.

Bryant, 2014 – *Bryant, E.* (2014). Comets and Asteroids. In *Tsunami*. Springer International Publishing, pp. 169-194.

Earl, 2008 – *Earl, D. J., Deem, M.W.* (2008). Monte Carlo simulations. *Molecular modeling of proteins*, 25-36.

Jenniskens, 1997 – *Jenniskens, P., Van Leeuwen, G. D.* (1997). The α-Monocerotids meteor outburst: the cross section of a comet dust trail. *Planetary and space science*, *45*(12), 1649-1652.

Mooney, 1997 – *Mooney, C. Z.* (1997). Monte carlo simulation (Vol. 116). Sage Publications.

Robert, 2004 – *Robert, C. P.* (2004). Monte carlo methods. John Wiley & Sons, Ltd.

Tsvetkov, 2012 – *Tsvetkov, V.Y.* (2012). Information Situation and Information Position as a Management Tool. // *European Researcher*. *Series A*. *36*(12-1), 2166-2170.

Vislotskii, 2000 – *Vislotskii, A.I., Vintaev, V.N., Konstantinov, I.S., & Ushakova, N.N.* (2000). Key Issues of the Problem of Correction of Space Photos Resolution by Digital Afterprocessing. In Proc. IV Int. Scientific-Practical Conf." Manned Space Activities, 169-170.

Wang, 2002 – *Wang, G.* (2002). Species diversity of plant communities along an altitudinal gradient in the middle section of northern slopes of Qilian Mountains, Zhangye, Gansu, China. // *Chinese Biodiversity*, *10*(1), 7-14.

Weissman, 2002 – *Weissman, P.R., Bottke, W.F., Levison, H.F.* (2002). Evolution of comets into asteroids. *Asteroids III*, *1*, 669-686.