STEREOSCOPIC IMAGE PROCESSING USING A DIGITAL PHOTOGRAMMETRIC SYSTEM

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ABSTRACT:

Stereoscopic image processing software has been developed on a digital photogrammetric system, and some experimental applications with this system have been carried out.
The main processor of the digital photogrammetric system is a personal computer (PC) and has a special three-dimensional (3D) display module which can display stereoscopic drawings together with stereoscopic images. By using this 3D display module, the positions of stereo conjugate points can be passed to the computer before stereo matching, and the errors in stereo matching can be corrected afterward.
Some general-purpose stereoscopic image-processing programs have been developed on the digital photogrammetric system. Because updated DEM can be extracted easily by the system, orthoimages of any place can be changed to stereoscopic images of any B/H ratio freely, and be analyzed on the 3D display module by observing the stereoscopic models of the stereoscopic images on it.
Application experiments have already been carried out in some fields, such as route selection, earth resource exploration, etc. In the field of route selection for microwave communication, stereoscopic images overlaid with other information are very useful. The most suitable route can be selected by considering various kinds of conditions. In the field of earth resource exploration, the B/H ratio of stereoscopic images is very important. The changes in extractive lineaments are sensitive to the B/H ratio. It seems that this new kind of system has high application potential in many fields.

1. INTRODUCTION

Topographic information is very important in some application fields, and a stereoscopic image processing system having a 3D display is very useful in these fields. However, there are few such systems with sufficient stereoscopic image processing programs. One big problem with this kind of system is that it is very hard to get appropriate DEMs for each application. The DEM is used to produce stereoscopic images from an orthoimage. In order to get appropriate DEMs, a digital photogrammetric system is also necessary. Another problem in this digital photogrammetric system, however, is that, the accuracy of the DEM extracted by a digital photogrammetric system is not good. Generally speaking, the errors in stereo matching are a very serious problem for automatic DEM extraction with a computer, because it is impossible to get rid of such errors completely by present computer techniques. Many methods have already been proposed, but they all need to be improved. It seems that the best way is to get human help at appropriate stages. In order to get human help, a man-machine interface is necessary.
In this research, stereoscopic image processing software has been developed on a PC-based digital photogrammetric system to get appropriate DEMs freely for each application, and special man-machine interface functions have also been developed to extract precise DEMs and to analyze stereoscopic images effectively.

2. DEVELOPMENT OF A DIGITAL PHOTOGRAMMETRIC SYSTEM

2.1 Hardware for the digital photogrammetric system

In this work, a digital photogrammetric system was developed first, then stereoscopic image processing software was developed on the system, and then some application experiments were carried out using both of them. Because there was a paper written about the digital photogrammetric system already (Mori, 1992), the explanation about the system will be made briefly here.
The main processor of the digital photogrammetric system is a PC made by NEC, which has a special 3D display module. The components of the system are a PC, floppy disk drives, magnetic disk drives, a mouse, three additional boards and liquid crystal shutter glasses. The liquid crystal shutter glasses are parts of the 3D display module.

The 3D display module can display stereoscopic drawings together with stereoscopic images. Stereoscopic images are memorized in two frame memories. Stereoscopic drawings, such as stereoscopic points, lines and circles, can be drawn in Video Random Access Memories (VRAM) using 3D graphic software which has been newly developed using two-dimensional graphic software provided in the PC operating system. The left image and drawing, and the right image and drawing, are overlaid respectively and displayed alternately. The observer can see a stereoscopic model by using liquid crystal shutter glasses, which are synchronized with the display. Photo 1 is the overview of the system. The most significant feature of this system is that the total cost of the system is lower and the size is smaller because recent excellent digital equipment is employed in the system.

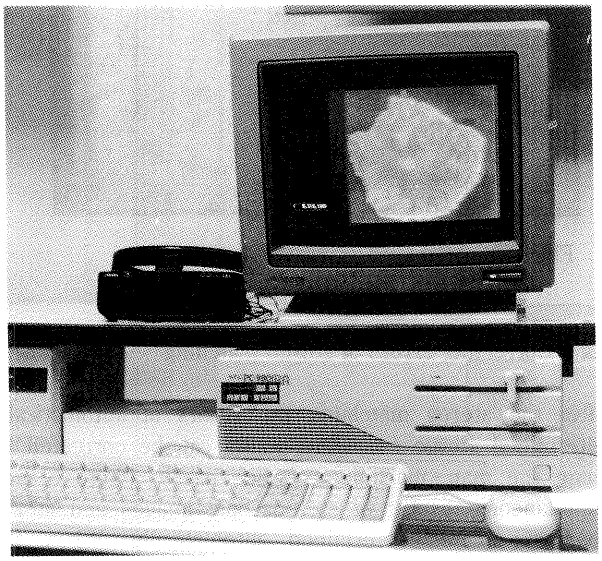

Photo 1 The overview of the digital photogrammetric system

2.2 Software for the digital photogrammetric system

This system can extract DEMs of any spatial resolution from digital stereoscopic images and can draw contour lines of any interval by using the DEM. The stereo conjugate points in stereoscopic images are determined automatically by stereo matching, using an image correlation method. Because errors in stereo matching can be corrected easily by using the 3D display module, precise DEMs can be extracted from digital stereoscopic images. The details of this function will be explained in the next chapter. Photo 2 shows an orthoimage and overlaid contour lines, which are produced from stereoscopic images by this system.

2.3 Stereoscopic image processing software

A stereoscopic image processing system must be very useful in fields which need topographic information, especially when it has a man-machine interface as mentioned above. Now there are scarcely any stereoscopic image processing systems which have these

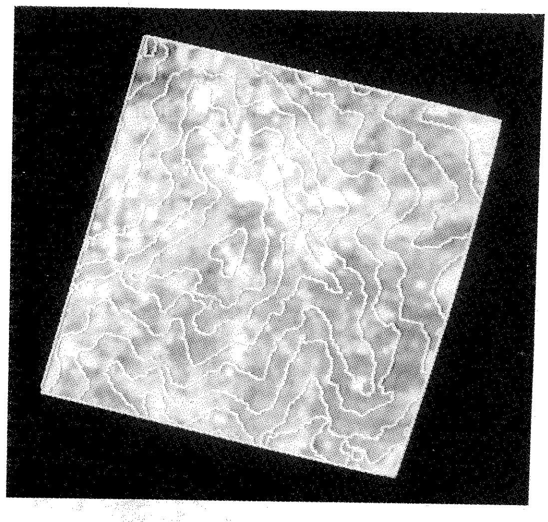

Photo 2 An orthoimage overlaid by contour lines.

abilities. Therefore development of the stereoscopic image processing programs on this digital photogrammetric system was attempted. The functions of the programs are as follows: enlargement and reduction, brightness enhancement, affine transformation, calculation between images, cutting out and displaying a part of a big image, etc. A program has also been developed to produce stereoscopic images of any B/H ratio from a digital orthoimage using DEM. This system has the functions of both a digital photogrammetric system and a stereoscopic image processing system.

3. PRECISE DEM EXTRACTION BY USING THE 3D DISPLAY MODULE

3.1 Inputting positions of stereo conjugate points

Generally speaking, image recognition is very difficult for a computer because there is too much information in images to be analyzed. It is also true in the case of stereo matching, which is one technique to determine stereo conjugate points automatically with digital photogrametric systems. Now the errors in stereo matching are a very serious problem for automatic DEM extraction. It seems that the best way is to get human help at appropriate stages. In order to get human help, a man-machine interface is necessary. The 3D display module of this system can provide the man-machine interface. In automatic stereo matching, the man-machine interface can be used to reduce matching errors at two stages, before and after the stereo matching.

Before the stereo matching, some stereo conjugate points can be provided to a computer by using the 3D display module. Because this module can display stereoscopic images together with stereoscopic drawings of points, the height of the points can be easily adjusted to the surface elevation of the stereoscopic model by using a mouse device. When adjusted, the positions of the stereoscopic points indicate the positions of stereo conjugate points in the stereoscopic images. Photo 3 is one example. In this case, 25 stereo conjugate points are determined manually using the 3D display module and are then provided to the computer.

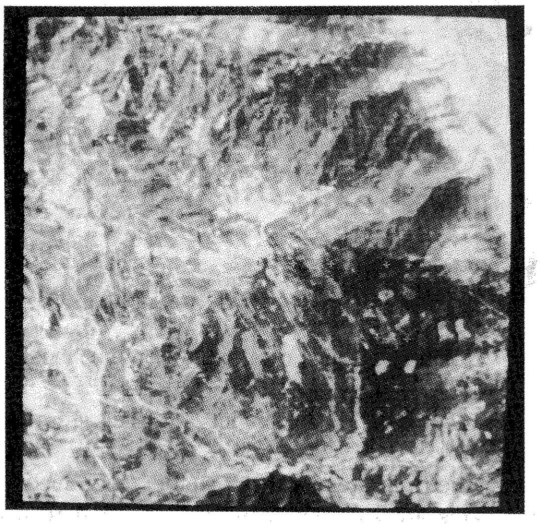

Photo 3 Manually determined stereo conjugate points

In another case, it is also possible to identify stereo conjugate lines instead of stereo conjugate points. Photo 4 is one example of this case. These lines are drawn one by one along surfaces such as valleys and ridges, with a mouse looking at the stereoscopic model through liquid crystal shutter glasses. The steps for drawing these lines are as follow.

1)First draw one line of a stereopair along a valley or a ridge on one (left or right) image.
2)Next draw the second line in exactly the same position on the other image.
3)Repeat these two steps.

These lines are very useful for automatic stereo matching because the accuracy of stereo matching is usually bad where valleys and ridges, when an image correlation method is used.

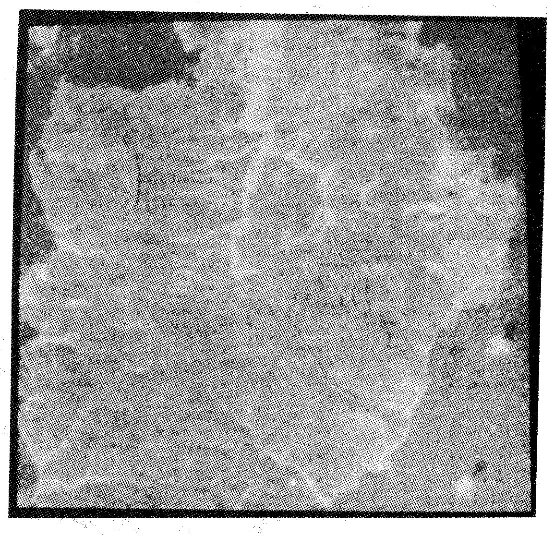

Photo 4 Manually drawn stereopair lines

3.2 Correcting errors of stereo matching

After the stereo matching, the errors of automatically determined stereo conjugate points can be corrected by using the man−machine interface easily. Photo 5 is a simultaneous display of stereoscopic images and stereo conjugate points determined automatically. When the stereoscopic model from the stereoscopic images is observed, correct points are positioned on the surface of the model and error points are above or below the true surface. These error points can be corrected easily by the mouse, and a precise DEM can be extracted after these corrections.

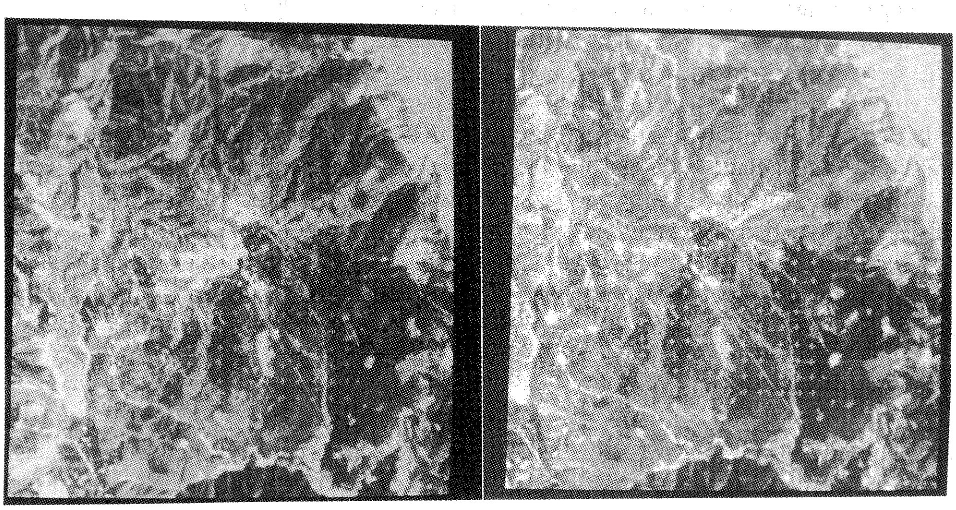

Photo 5 Simultaneous display of stereoscopic images and stereo conjugate points

4. APPLICATION TO ROUTE SELECTION

4.1 Production of stereoscopic images overlaid with other useful information

This digital photogrammetric system with stereoscopic image processing software can be used effectively in many fields, such as earth resource exploration, route selection, dam construction, regional development, etc. Experimental applications of this system have already been made in some fields, and two of them will be explained here.

One of the applications is in the field of route selection, such as for roads, pipelines, microwave communication routes and high-voltage electric wires. Here, as one application example, route selection for microwave communication will be shown. In this case, some information which is useful for the work is at first written on an orthoimage using the calculation program developed in this system, and then transformed to stereoscopic images. By looking at these stereoscopic images with liquid crystal shutter glasses, an operator can get precise topographic information together with images and other useful information.

Photo 6 shows the stereoscopic images displayed alternately. In this photo, two images are taken as if overlaid. Two kinds of information are overlaid on these images, the faults, shown here by bright broken lines, and the active faults, shown by dark broken lines. An operator can see a stereoscopic model by looking at the alternative display through liquid crystal shutter glasses. The information gotten from the model is as follow:

(1) Locations of lakes, roads, villages, etc., which are taken in the images.
(2) Locations of overlaid faults and active faults.
(3) Topographic information obtained by observing the stereoscopic model.

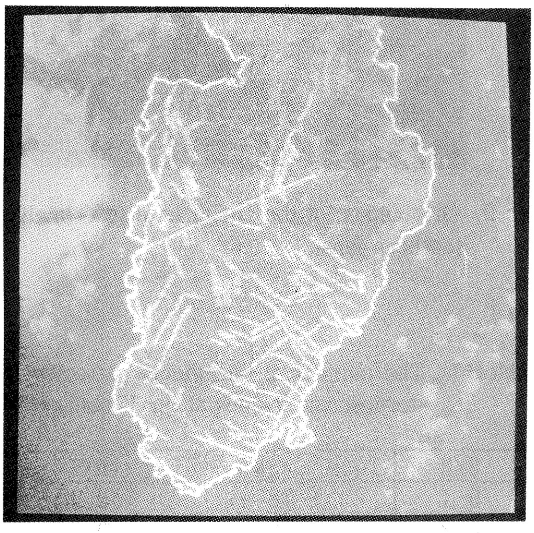

Photo 6 Stereoscopic images overlaid with other useful information

4.2 Route selection using the 3D display module

Photo 7 shows one example of analysis using these overlaid stereoscopic images. The steps for selecting a route for microwave communication are as follow:

(1) An operator, by observing the stereoscopic model, examines the conditions of the areas where parabolic antennas for microwave communication are planned to be constructed.
(2) The operator indicates two points on the model which seem to be good locations for antenna construction. In the photo, these points are shown by two pairs of cross points.
(3) The computer automatically ties the two pairs of points by a pair of lines on the stereoscopic images, then outputs a cross-section of the earth's surface under the line, which can be drawn using the DEM extracted beforehand; it then calculates the quality of the microwave communication between the two points using the cross-section produced. The cross-section is shown in the photo by a wavy line. The scale of the wavy line is shown by 5x5 crossed lines.
(4) The operator at first checks the area surrounding the route for microwave communication by observing the line and the image near the line on the stereoscopic model; he then inspects the quality of the microwave communication by using both the surface cross-section and the calculated value of microwave communication quality.

By using this method, much field work can be replaced by computer work, and time and money can be reduced drastically.

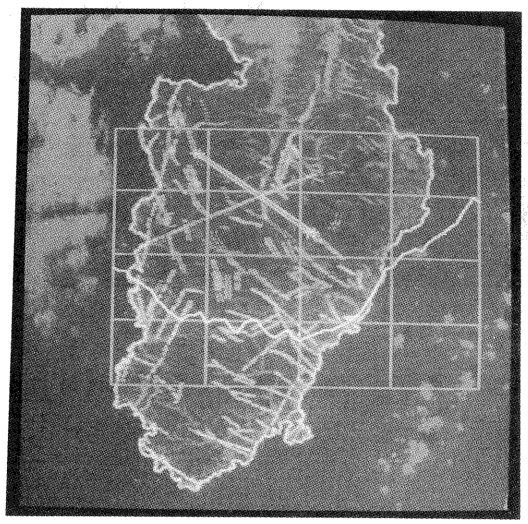

Photo 7 Route selection for microwave communication

5. APPLICATION TO EARTH RESOURCE EXPLORATION

5.1 Relationship between B/H ratio and extractive lineaments

Another application, to earth resource exploration, will be explained next. In the field of resource exploration, features extracted from the shape of the earth surface are very important. One of them is a lineament which looks like a straight line on the earth surface. Lineaments often indicate the existence of faults. It is very important to extract as many lineaments as possible for the effective analysis. One experiment has been carried out to examine the relationship between B/H ratio of stereoscopic images and extractive lineaments. The experiment has been carried out at two test areas. One is the Izu peninsula in central Japan and the other is at Hishikari district in Kyusyu, southern Japan.

Photo 8 and photo 9 are orthoimages of the Izu peninsula and the Hishikari district. Stereoscopic images of several B/H ratios have been made from these orthoimages using DEMs, and the experimental lineament extraction has been carried out using these stereoscopic images. Table 10 and table 11 show the number of lineaments extracted from the stereoscopic images of different B/H ratios. From these tables, some results can be extracted as follow:

(1) The number of lineaments extracted differ greatly with the different B/H ratios of the stereoscopic images. Two times as many lineaments can be extracted in the best case as in the worst case.

(2) The best B/H ratio for lineament extraction is not fixed. It seems to change according to the steepness of the earth surface. The mountains are very steep in the Izu peninsula but very gentle in the Hishikari district.

It can be said from this experiment that the B/H ratio of stereoscopic images is very important for image analysis, and the most suitable B/H ratio changes with the landform of the area. It is a big advantage of this kind of system that stereoscopic images of any B/H ratio can be made easily and used effectiveiy in image analysis.

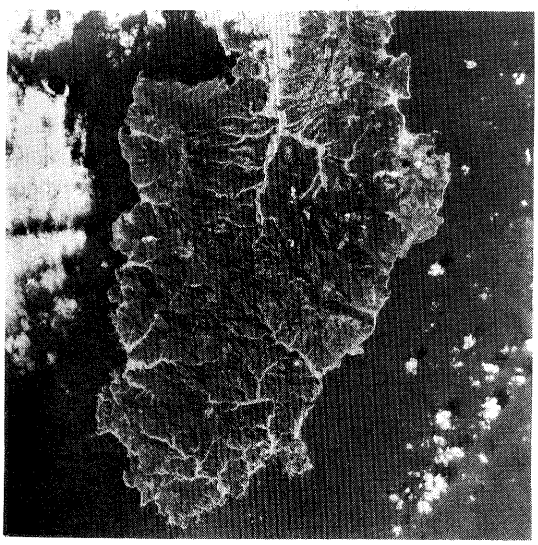

Photo 8 Orthoimage of the Izu peninsula in Japan

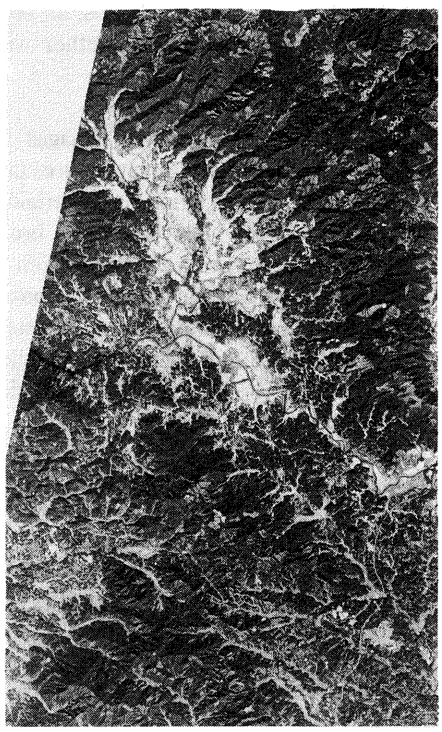

Photo 9 Orthoimage of the Hishikari district in Kyusyu, southern Japan

Table 10 The number of lineaments extracted from stereoscopic images of the Izu peninsula

B/H	Total number	Length (km)
0.1	135	305.86
0.3	284	594.13
0.5	330	730.10
1.0	262	610.36

Table 11 The number of lineaments extracted from stereoscopic images of the Hishikari district

B/H	Total number	Length (km)
0.1	78	152.18
0.3	76	189.18
0.5	103	249.43
1.0	164	309.58

5.2 Stereoscopic image analysis in the field of earth resource exploration

As mentioned above, the B/H ratio of stereoscopic images is very important in the field of earth resouce exploration. The reason is supposed to be that very small changes in the shape of the earth surface are important and cannot be ignored. So, for effective analysis, the B/H ratio of stereoscopic images must be considered in the field.

Photo 12 shows an application in the field of earth resource exploration. In this photo, broken lines are faults, filled dots are hot springs, and small marks like eyes are veins of mineral. This information was written on an orthoimage using the calculation program developed in this system and then transformed to stereoscopic images. The B/H ratio of these stereoscopic images is 0.5, which is the most suitable value in this area. Looking at these stereoscopic images with liquid crystal shutter glasses, we can get precise topographic information together with information in images and overlaid information. The man-machine interface is also available, which makes it possible for the operator to draw dots and lines on these stereoscopic images to indicate the results of image analysis.

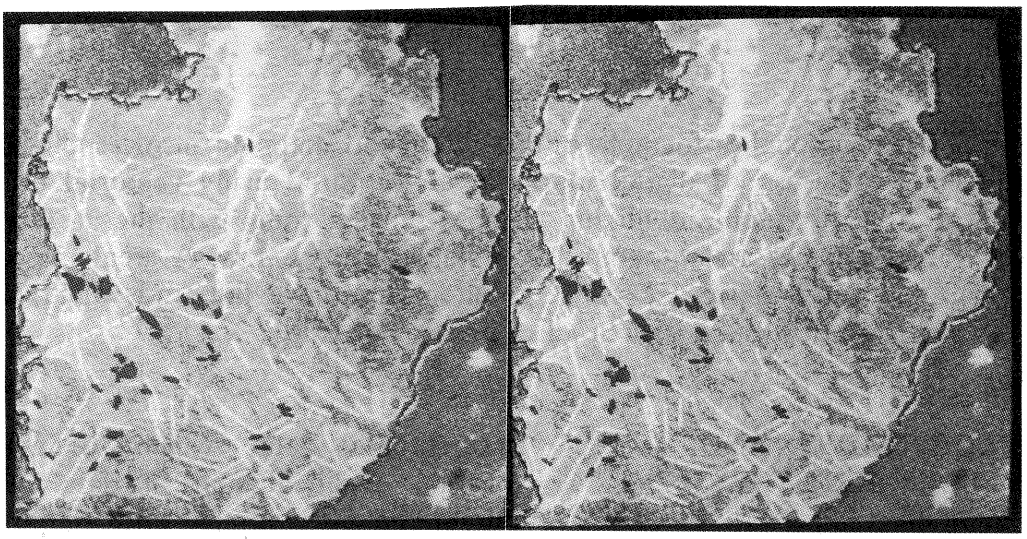

Photo 12 Application example in the field of earth resource exploration

6. CONCLUSION

Stereoscopic image processing software has been developed on a digital photogrammetric system. By using this system with stereoscopic image processing software, updated precise DEMs of any place can be extracted easily from digital stereoscopic images with the help of a man-machine interface of the 3D display module. Overlaid stereoscopic images of any B/H ratio can be produced from orthoimages using the DEM and the stereoscopic image processing software, and effective analysis can be carried out in many application fields by using the stereoscopic model of overlaid stereoscopic images and the functions of the man-machine interface.

The most significant features of this system are as follow:
1) Because this system has a special man-machine interface, precise DEMs can be extracted from digital stereoscopic images using human inputs.
2) Because precise DEMs can easily be obtained at any place, stereoscopic images of any B/H ratio can be easily produced from an orthoimage.
3) Because this system has many stereoscopic image processing programs and a special 3D display module, analysis and designs using stereoscopic images can be carried out effectively.
It can be said that this system has high application potential in many fields.

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