The Institute of Space and Astronautical Science
Report SP No. 15, March 2003

Development of the Linux-based video observation system for meteors

By

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(1 September 2002)

Abstract: We report on the development of the video meteor observation system that runs under the Linux operating system on x86 processor based personal computers. The system has three high sensitive CCD video cameras. Two of the cameras have a field of view of $31^\circ.2\times23^\circ.6$ with a limiting magnitude of 5.5, and the rest has a wider field of view of $56^\circ.7 \times 43^\circ.4$ with a limiting magnitude of 3.5. NTSC video outputs from the cameras are digitized into either 640×480 or 320×240 8bit gray scale frames with a rate of 30fps and stored to hard drives. After the observation, the analysis software detects the meteors from the captured frames. The detection limit of meteors is about 1.5 magnitude brighter than the limiting magnitude of stars.

We observed the 2001 Leonid shower with our system from 15^h00^m UT to 21^h00^m UT on 2001 November 18, and detected about 1100 meteors.

1. INTRODUCTION

Video observation is the latest and the most powerful observational technique in meteor science, because the time resolved imaging is essential to study the transient events. Frame rates of video are 30fps for NTSC and 25fps for PAL and SECAM, thus the time resolution is an order of magnitude shorter than the duration time of meteors. By analyzing the video data, we can determine the time of the appearance, the light curve, the path position, the angular velocity, and the train duration of meteors. These parameters can be also obtained with visual observation, however the errors are much larger than those obtained with video observation.

Video observation has become popular in the last few years. Many groups have used video cameras to observe the recent activity of the Leonids (e.g. Watanabe, et al. 1999; Watanabe, et al. 2002; Shigeno et al. 2002). This is because the high sensitive CCD video cameras have recently come onto the market with low price. These cameras have enough sensitivity to observe meteors, so that the expensive image intensifiers are not required except the deep observation.

The main problem of video observation is the data analysis, in particular the meteor search process. It is tedious work to detect meteors by inspecting the video manually, and it takes

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much longer time than the observation. To process a large amount of video data, a computer based system is required. MetRec is the most widely used automatic meteor analysis system on personal computers (PCs) (Molau 1994; Molau and Nitschke 1996), however, MetRec is the Dos based system that can't use the full power of modern hardware, and it works only on the PC with the Matrox frame grabber card. It is necessary to develop a new system on a modern operating system for future observations.

2. VIDEO OBSERVATION SYSTEM

The goal of our development is to construct a meteor observation network of the remote video systems that are controlled through the Internet. The network capability is, therefore, required for the system. Another requirement is the flexibility to support new hardware, because the product life cycle of hardware is very short. We decided to develop the video system on the x86based Linux PCs. Linux is a free Unix-like operating system that has the built-in network capability and supports a wide variety of hardware originally developed for MS Windows. Furthermore, many developmet tools and astronomical applications are available.

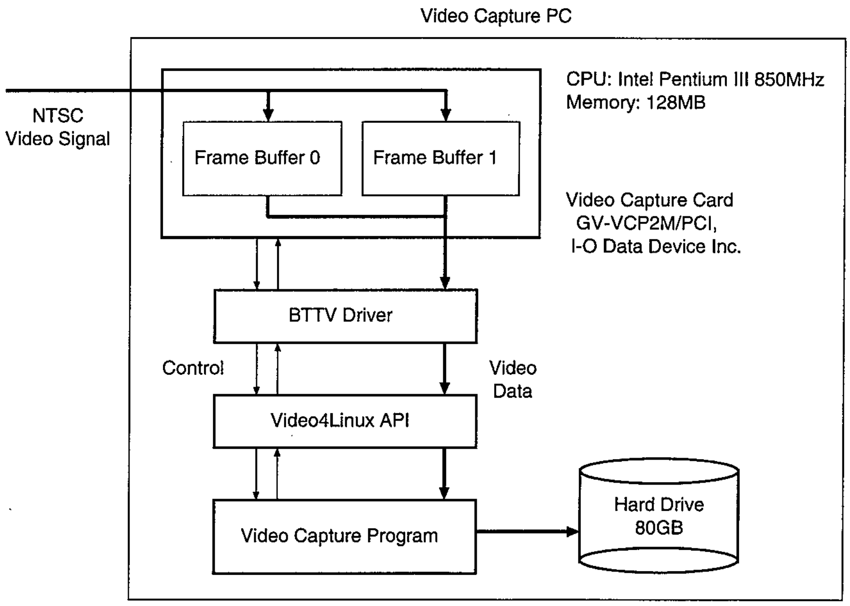

Fig. 1: The block diagram of the video capture system.

We have developed a PC based video capture system for automatic observation. The block diagram is shown in Fig. 1. The PC we used was an Intel Pentium III 850MHz processor system with 128MB memory, 80GB hard drive, and a video capture card (GV-VCP2M/PCI, I-O Data Device Inc.). To handle the video capture card, we used the Video4Linux API. The API acts as a layer between the device driver and the application program, so that the application program using the API works on any video capture card whose device driver supports the API. The bttv (http://bytesex.org/bttv/) is a device driver following the Video4Linux. It supports video capture cards with the Conexant Bt8x8 chips, including GV-VCP2M/PCI. The NTSC video signal was digitized by the video capture card into 8bit gray scale frames with either 640×480

or 320 × 240 resolution and the digitized frames were stored to two frame buffers alternately. While the capture card stores a frame to the frame buffer, the capture program read the other frame buffer and stored it to the hard drive. In this way, we recorded the video with a frame rate of 30fps. The recording data rate was 2.3MB/s for 320 × 240 resolution and 9.2MB/s for 640 × 480 resolution.

To test the performance of our video capturing system, as well as to observe the 2001 Leonid shower, we made the video observation system shown in Fig. 2 We used three video cameras, C1, C2, and C3. Each camera consisted of a ultra-fast CS-mount lens and a high-sensitive 1/2" monochrome CCD video sensor (WAT-100N, WATEC Co.). Two 12mm F/0.8 lens (HG1208AFCS-HSP, CBC Co.) were attached to C1 and C2, whose field of view was 31°.2 × 23°.6 with a limiting magnitude of 5.5. While, a 6mm F/0.8 lens (HG0608AFCS-HSP, CBC Co.) was attached to C3, whose field of view was 56°.7 × 43°.4 with a limiting magnitude of 3.5. The video outputs from the cameras were digitally recorded to hard drives in PCs. For comparison, we used the traditional recording system with video cassette recorders(VCRs) that recorded the video and the time signals of the radio simultaniousely. The TV monitor was used for real-time monitoring to focus the camera and to adjust the alignment of three cameras.

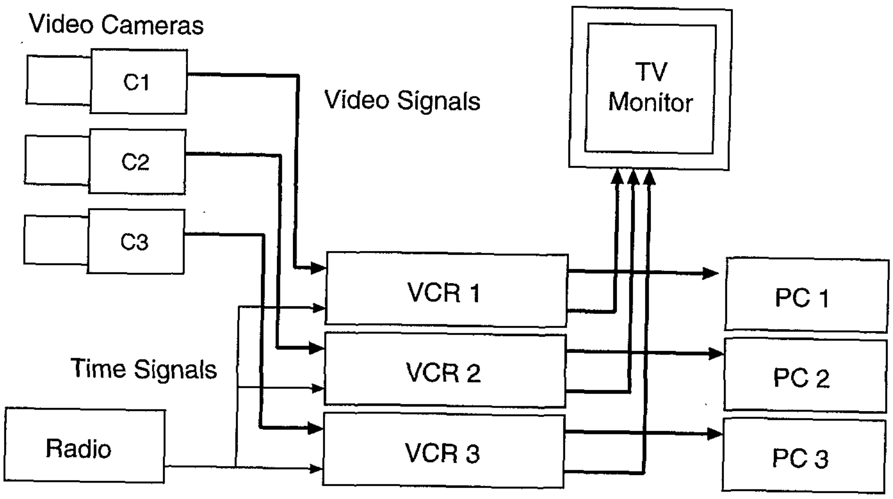

Fig. 2: The block diagram of the video observation system.

3. METEOR SEARCH

We have developed a meteor search program as a part of the automatic meteor analysis system. We used simple algorithm to reduce the processing time. The meteors change their position and luminosity during their short duration time, while the stars are approximately stationary in short time intervals. Thus, the light spot of the meteors should remain in the difference image between two successive frames. We searched the maximum pixel of a difference image between two successive frames and recorded the frame number, the pixel value, and the pixel position. Fig. 3 shows a plot of the maximum pixel value against the frame number. The spiky peaks in the plot are candidates of the meteors. However, the high background about 100 obscure the lower peaks: the faint meteors are not detectable.

Since the main source of the background was scintillation of stars, we masked stars of the

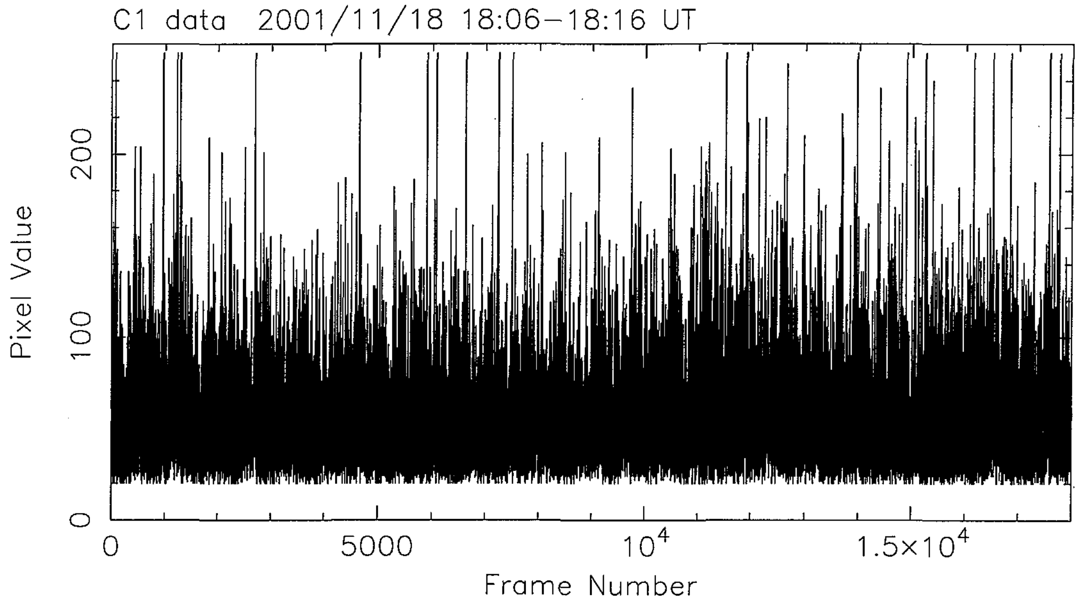

Fig. 3: Maximum pixel value of the difference images of the C1 camera plotted against the frame number. The background level is 100 that is about a half of the dynamic range of the camera.

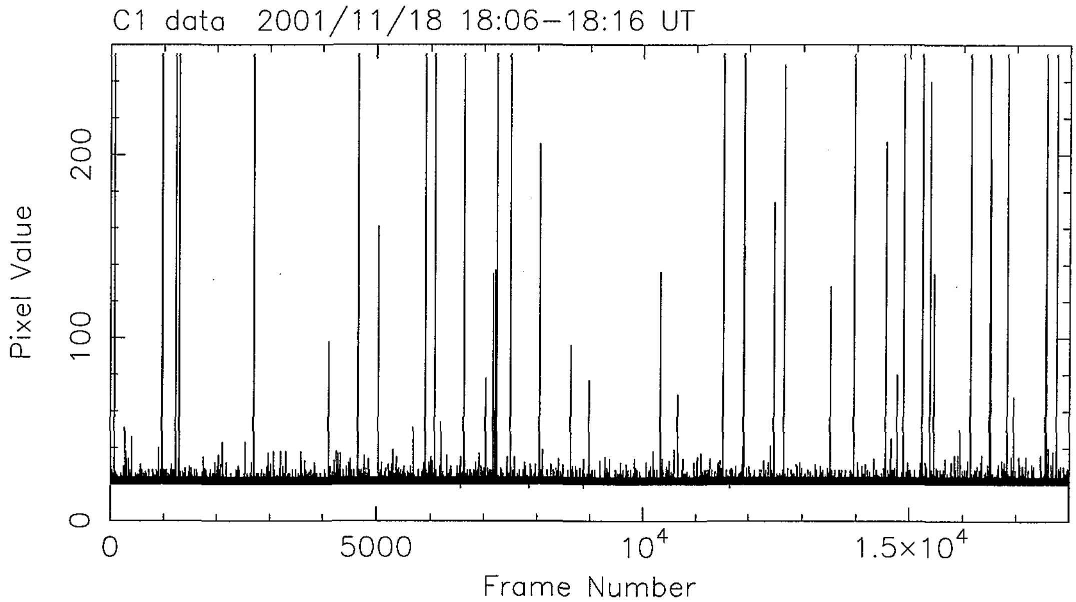

Fig. 4: Same as Fig. 3 except that star pixels of difference images are masked. The background level reduces to 30.

images to reduce the background. We extracted the stars by applying the threshold operation to the mean image averaged over 10s. Contribution of the meteors to the mean image is negligible small because of their short duration time. Fig. 4 is the plot obtained from the masked images. The background level decreased to 30 and many lower peaks appeared.

The peaks in the plot are not only the meteors but also the cosmic rays and the electric noises of the camera. We used the duration time to select the meteors, because the cosmic rays and the electric noises are the 1frame(1/30s) events whose duration time is shorter than that of the meteors. The selection criterion was that the peak width at some threshold level was longer than 0.1s.

4. OBSERVATION

The 2001 Leonid shower was observed with our video system at Miyazaki University (31°49′30″N, 131°24′50″E). Three video cameras, C1, C2, and C3, were arranged to cover a rectangular filed of view of 56°.7 × 74°.6 and pointed to 20°south from the zenith. C1, C2, and C3 covered the SE, NE, and W part of the filed of view, respectively. The observation started from 14^h50^m UT through 20^h50^m on 2001 November 18. Due to the computer trouble, video capture of C3 started from 16^h50^m UT. Video outputs were recorded with 320 × 240 resolution to reduce the disk space.

5. ANALYSIS AND RESULTS

In general, the pixel value of video is not proportional to the brightness of the object. In order to establish the relationship, we measured the pixel values of stars. We obtained the pixel values of stars from the 10s averaged images subtracting the local background. Fig. 5 shows the pixel values of stars observed with C1, C2, and C3. The figure shows the linear relation between logarithm of pixel value and visual magnitude in the pixel value range from 0 to 256. The best-fit line of each camera was $\log(PIX) = 3.6 - 0.49M_v$, $\log(PIX) = 4.4 - 0.67M_v$, and $\log(PIX) = 2.8 - 0.50M_v$, respectively.

We processed all the captured data with our meteor search program. The adapted parameters are shown in Tab. 1. The numbers of detected meteors of C1, C2, and C3 were 359, 222, and 528, respectively. The time variation of the number of Leonid meteors is shown in Fig. 6. The Leonid counts increased rapidly and peaked at 18^h30^m UT, then decreased gradually.

To verify the performance of the meteor search program, we compaired the detected meteors to those detected by inspecting the videotapes. We used the data observed from 16^h50^m UT to 18^h50^m. Tab. 2 shows the magnitude distribution of the detected meteors. The magnitude of each meteors was estimated to compare the brightest meteor spot to field stars. The detection limit of meteors for the program was about 4 mag for C1 and C2, and 2mag for C3. The magnitude differences between the detection limit of meteors and the limiting magnitude of stars were about 1.5 mag for the program and 0.5-1.0 mag for the naked eye.

Table 1: Parameters for meteor search.

Camera (lens)	C1 (12mmF/0.8)	C2 (12mmF/0.8)	C3 (6mmF/0.8)
threshhold of masking	4	3	5
threshhold of meteor search	30 (4.3 mag)	30 (4.4 mag)	40 (2.4 mag)
duration time [s]	0.1	0.1	0.1

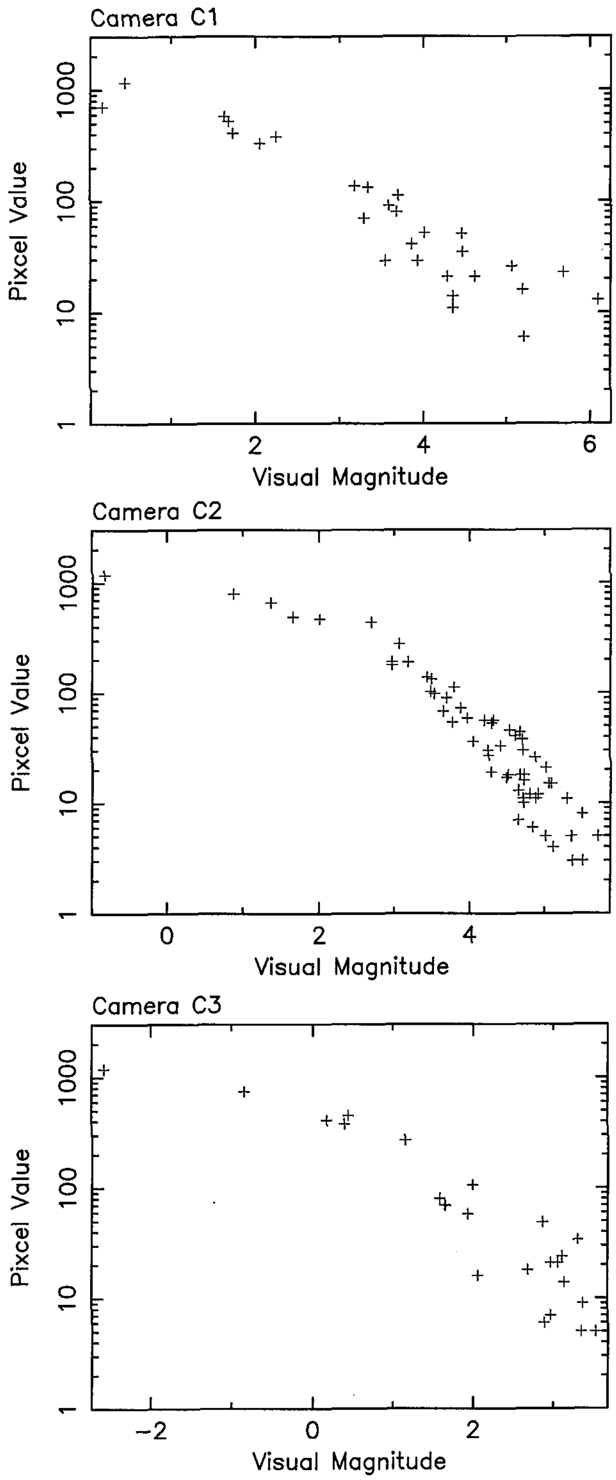

Fig. 5: Pixel values of stars plotted vs. their visual magnitude. The upper, middle, and lower figures show C1, C2, and C3 data, respectively.

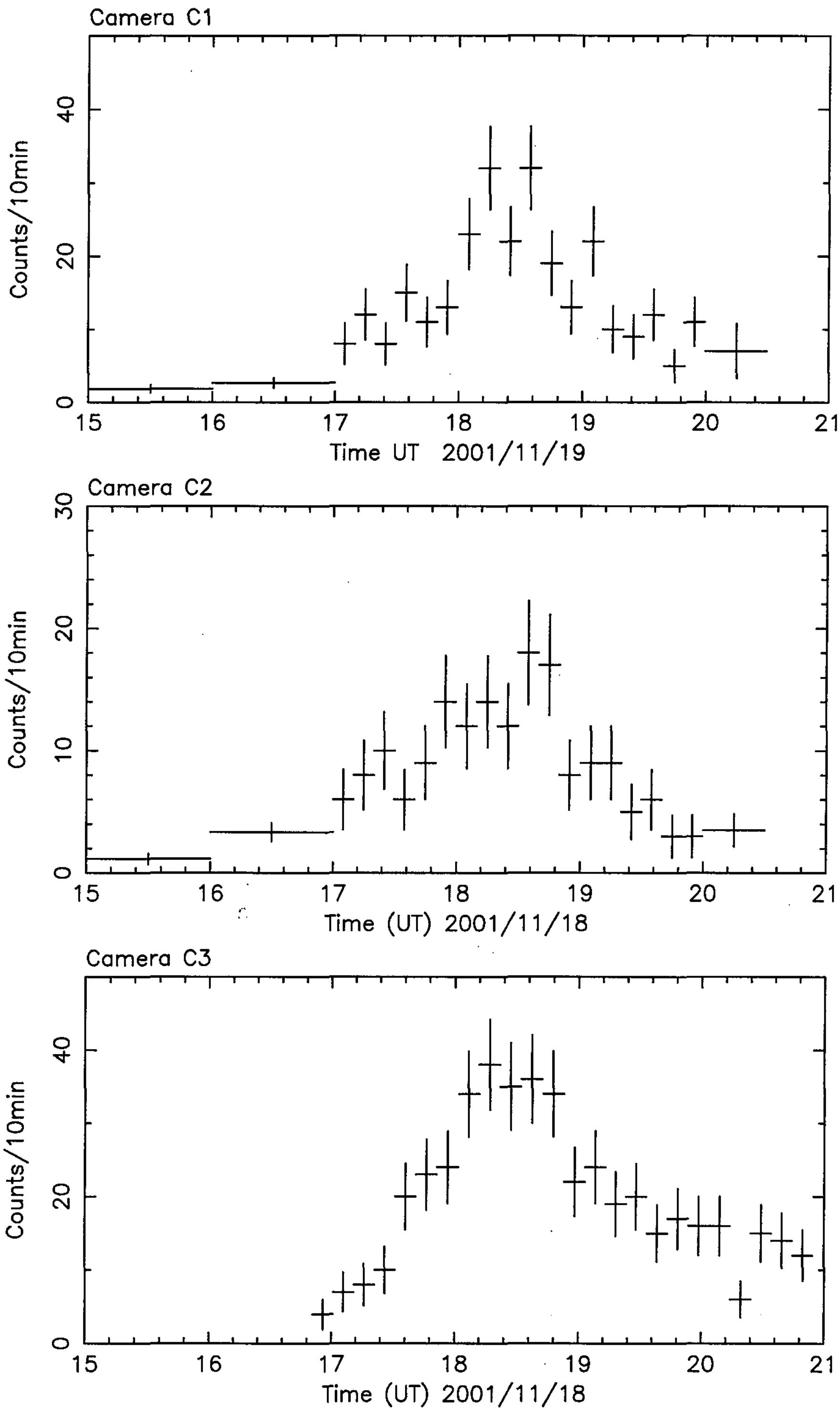

Fig. 6: The time variation of the number of Leonid meteors. The crosses show 1σ errors. The upper, middle, and lower figures show C1, C2, and C3 data, respectively.

Table 2: Magnitude distribution of the detected meteors.

Camera (lens)	C1 (12mmF/0.8)		C2 (12mmF/0.8)		C3 (6mmF/0.8)	
limiting magnitude	5.5		5.5		3.5	
method	naked-eye	program	naked-eye	program	naked-eye	program
>-3 mag	10	10	9	9	22	22
-2 mag	3	3	11	11	19	19
-1 mag	7	7	13	13	26	26
0 mag	20	20	12	12	47	47
1 mag	26	26	17	17	95	94
2 mag	24	24	26	26	105	57
3 mag	35	34	13	12	19	9
4 mag	40	37	28	22	0	0
5 mag	4	1	14	3	0	0

6. CONCLUSION AND FUTURE PLAN

We have developed the Linux-based video capture system that records video at 30fps with 8bit 640×480 resolution. The system was used with three video cameras to observe the 2001 Leonid shower. It worked fine to record video for 6 hours. We have also developed the meteor search program, which detects the meteors 1.5 magnitudes brighter than the limiting magnitude of stars.

The goal of our development is to construct a meteor observation network with the remote video stations controlled through to the Internet. The station requires the capability of the video capture, the automatic meteor search, and the automatic meteor analysis. We have developed first two items and start developing the third item that measures the time, the brightness and the coordinates of each meteor spots in the frame.

ACKNOWLEDGMENTS

We thank Takeshi Ura, Sayaka Funakura and Youko Matsumoto for their help by inspecting the videotapes. This research was partly supported by the educational reform grant of Miyazaki University.

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