An Automatic Infrared Sensor System to Observe Unusual Animal Behavior

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Abstract. Automatic observation systems for unusual animal behavior, which has been told as an earthquake precursor in folklores and retrospectively reported by citizens, have been constructed using infrared sensors and a CCD camera. The systems to quantify the activities of genetically controlled mice and aquatic catfish famous in folklores were developed using a digitalization algorithm to study the influence of the electromagnetic waves on their daily biological rhythms. Data acquisition for different animals and different individuals at multi-sites was made and the data was transferred through the Internet. Environmental electromagnetic noises can simultaneously be monitored using antennas to bind the correlation with animal behavior and to find seismic electromagnetic signals (SEMS) before earthquakes.

Keywords: unusual animal behavior, infrared sensor, seismic electromagnetic signals(SEMS)

1. Introduction and background

Unusual animal behavior before large earthquakes has repeatedly been reported by citizens especially in Asia. Unusual phenomena observed by human senses are called macro-anomaly (Rikitake, 2001). For example, earthworms appeared and aligned in one direction crawling out of the soil a week before the 921-Earthquake in Taiwan in 1999. More than 1500 reports on macro-anomaly prior to the Southern Hyogo Prefecture Earthquake in 1995, Japan, were collected retrospectively (Wadatsumi, 1995). Similar reports were also collected after the Izmit Earthquake in Turkey in 1999. Other macro-anomalies except unusual animal behavior include lightning (Ikeya and Takaki, 1996), clouds (Teramoto and Ikeya, 2000) and underground water anomaly. An episode before the Ansei Earthquake in Japan in 1854 that nails clinging to a magnet dropped from the magnet implies a certain kind of electromagnetic anomaly presumably caused by the electric field of ULF waves rather than the change of the earth's magnetic field (Ikeya, 1999).

An old legend in Japan tells us that catfish move violently before large earthquakes and many scientists have studied the relation between catfish behavior and earthquakes. Hatai and Abe (1932) suggested that catfish might sense earth currents, as a precursor phenomenon for earthquakes. Mulilis and White (1986) attempted to specify typical behavior of catfish prior to earthquakes by detailed observation. The correlation of unusual behavior of catfish with felt earthquakes in Tokyo was found by Egawa (1991) at the Tokyo Metropolitan Fishers Experiment Station.

Asano (1998) studied in detail the electrosensory organs of catfish, and argued that its specific ability should be considered in this connection. Catfish have extraordinarily sensitive electrosensory organs all over their skin. The organs are the most sensitive to oscillating electric fields at frequencies from a few Hz to about 100 Hz, and can detect even 5 mV/m in water in this frequency range. The sensitivity is more than a million times as sensitive as that of carp or gibel. The intensity of the electric field is 50 – 60 mV/m at a distance of 10 cm from the

(a) (b)

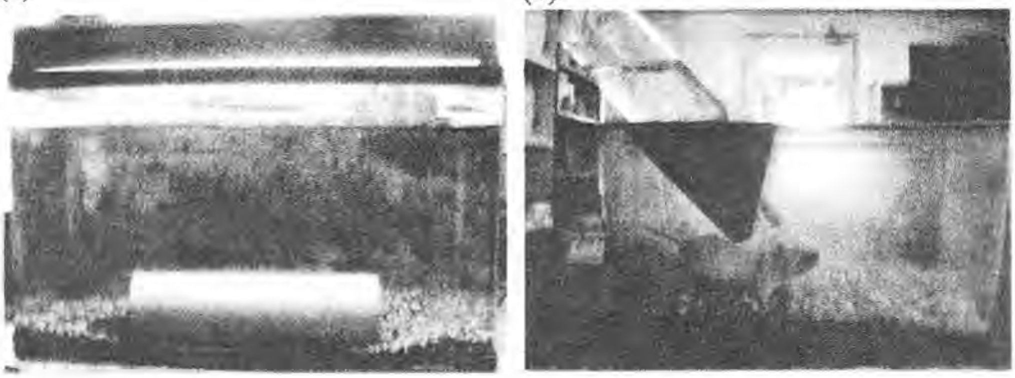


Fig. 1: Living environments of (a) a catfish hiding in a polyvinyl chloride pipe in an aquarium and (b) a mouse kept in a cage with an automatic feeding apparatus.

gills. These organs are used as a tool for catching prey by catfish living in a murky habitat where optical senses are of little use.

Animal activities showing cycling with an approximate 24 hours period are called circadian rhythms (e.g., rhythm of sleeping contrasted with active phase) (Nakagawa and Nagai, 1991). When the surrounding environment of light is changed periodically, the rhythm is controlled by the light cycle. However, the autonomous biological rhythm is not lost even under constant conditions. Generally, a mouse is active in the dark time, while it is less active at the illuminated time. If animals are stimulated stressfully at a certain time, the phase of the rhythm sometimes subsequently shifts. This phenomenon was actually observed before the Southern Hyogo Prefecture Earthquake in 1995 during research on circadian rhythms at the Institute for Protein Research, Osaka University (Yokoi et al, 2002).

Unusual animal behavior and intense electromagnetic (EM) pulses were detected simultaneously during compression of granitic rocks (Ikeya et al, 2000). Although many efforts have been made to observe SEMS (seismic electromagnetic signals) from DC to VHF bands using appropriate antennas of new design (Nagao, 2001), the properties of SEMS have not been definitively established yet. Therefore, behavioral observation of animals having sensitive electrosensory organs as a supersensitive antenna is as important as the geophysical measurements. Simultaneous observation with EM fields may give evidence that catfish and mice are sensing EM pulses.

In this paper, the activity of animals has been quantified using our new observation system. Movements of mice and catfish were automatically detected by infrared sensors and photographed by a CCD camera. Their daily circadian rhythms were obtained and can be checked through the Internet. This system would be useful for check a short-term earthquake prediction using unusual animal behavior is possible or not.

2. System configurations

2.1. Animal living environments

Japanese catfish in our laboratory was kept as shown in figure 1-(a). The length of catfish was about 30 cm in an aquarium with a size of 60 cm × 30 cm × 35 cm. The floor was covered by gravel with a thickness of about 3 cm above which freshwater was circulated by a pump.

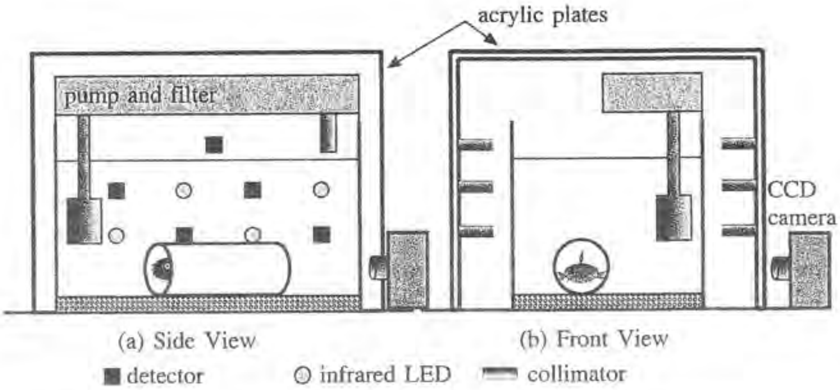


Fig. 2: Sensor locations of (a) side view and (b) front view for automatic observation of catfish behavior. The CCD camera photographed the behavior but stored the data in a PC only when there is a movement.

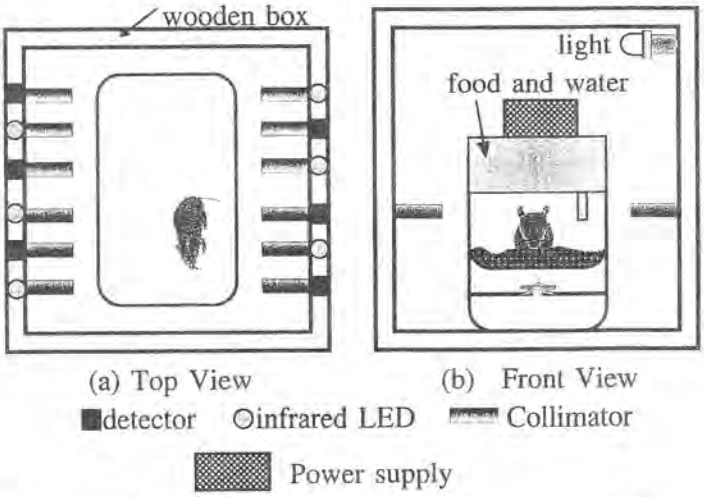


Fig. 3: Mouse activity monitoring system of (a) top view and (b) front view. The locations of detectors and infrared LEDs are shown. Electromagnetic pulses were generated in the downside box. The power supply was placed on the top.

The catfish stayed most of the day in a polyvinyl chloride pipe of 8 cm diameter on the gravel. Filleted fish was given to the catfish as food regularly once a week.

Figure 1-(b) shows the living environment of a mouse. The mouse was about 15 weeks old and weighed 25 grams at the start time of the observation. Wooden chips covered the bottom of the plastic case with a size of 22 cm × 15 cm × 12 cm. Chips, water and food were changed once each seven day period.

2.2. Observation system using infrared sensors (IR system)

Figure 2 shows the observation system, which monitors catfish activity using infrared sensors. This system detects the catfish if out of its "nest." Acrylic plates covered the sides and top of the aquarium and the sensors were attached to both sides of the plates. Nine commercial pairs of infrared LEDs and detectors (ELEKIT, PS-3051) were used whose circuit diagram is shown in Appendix A: eight pairs covered the area under water, and the other covered a part above the water surface to detect floating movements as shown in figure 2. The LEDs and detectors were connected to the driving electric circuits using balanced type shielded wires. The infrared signal was transmitted from each LED at 0.25 second intervals and each detector responded only to its appropriate infrared LED so infrared light from outside did not affect this system. Collimators were attached to each LED and its detector ensured no inter-influence by neighboring LEDs.

Output signals from the nine sensors were transferred as shown in Appendix B to a PC through a nine channel analog/digital board (Interface, PCI-3133) with a sampling frequency of 10 Hz. Photocouplers were inserted in each signal line in order to prevent switching noises from the A/D board. When the creature intercepted the infrared light, the output signal was low-level (≈0V), while signal at high-level (≈1.3V) was obtained if there was no interception.

<u>Data treatment procedure</u>

(i) Treatment of A/D converted signals

Each channel obtained ten data in one second because of the sampling frequency. Existence or nonexistence of animal positioning at a certain second was decided by the following criterion.

If $$\sum_{i=1}^{10} V_i \geq 5, \qquad E(T) = 1 \quad \text{Existence,}$$

while $$\sum_{i=1}^{10} V_i < 5, \qquad E(T) = 0 \quad \text{NonExistence}$$

V_i : ith ($1 \leq i \leq 10$) A/D converted signal (defined as high-level(H) = 0 and low-level(L) = 1)

$E(T)$: representing data at time T[s]

For example, when A/D converted signal at time T_n[s] was "LLLHHLLLLL", i.e. $\sum_{i=1}^{10} V_i = 8$, therefore $E(T_n)$=1 was obtained. This idea was introduced in order to prevent noise with pulse-like characteristics during data acquisition. These data were recorded continuously with time codes and automatically saved to a file every ten minutes. Therefore, 144 data files were created over a day.

(ii) Calculation of daily activity

Checking through the 144 files, we can determine the catfish activity at one-second resolution. The daily activity was calculated at the fixed time once a day from the 144 files. To characterize daily catfish activity, the data pattern of nine channels was compared every second. If the patterns were different at the next second (meaning that the catfish shifted its position), we set the "activity" at the second to be 1, while the value was counted as zero when the patterns were the same. Thus the activity indicators of 1 or 0 were created and saved as 144 files a day. (The data acquisition software using the A/D board and the software for calculating the active periods can be downloaded from our Web site: http://pumice.ess.sci.osaka-u.ac.jp/~catfish/index.html.)

2.3. Observation system for mouse

The monitoring system for mouse activity using infrared sensors was similar to that for catfish activity as shown in figure 3. A plastic confinement box was surrounded with another box made of wood. Day and night could be altered artificially by controlling the light inside the box. Six pairs of sensors were fixed on each side of the wall of the wooden box. This system was designed to monitor plural mice at one time in order to compare the effects on the circadian diagrams of mice due to exposures to electromagnetic pulses.

2.4. Observation using CCD camera

The catfish movements were continuously monitored using a monochrome CCD camera. Images were captured at one second intervals and transferred through a video capture board to a PC. The obtained image was compared with the previous image by the free software program, MoDeCa v1.3 (created by Muse Ishikawa). Images were saved when a difference was sensed from the previous image. The numbers of saved images were summed and were posted on the Internet in the form of a bar graph.

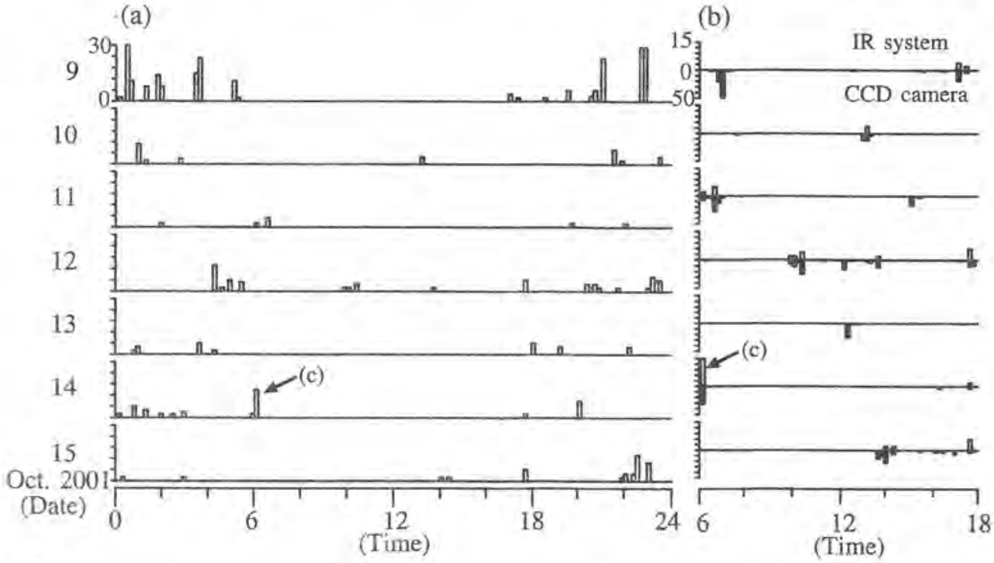
2.5. Data communication system

A data acquisition system using the Internet was developed. An FTP server was set up at Osaka University and the data at remote locations are transferred to the server at fixed intervals once a day by a batch program. The data may be used to correlate with seismic accidents.

3. Observation results

3.1. Catfish

Figure 4 shows catfish activity monitored by infrared sensors and by the CCD camera. Figure 4-(b) is the result only for daytime (6 – 18 h), because the CCD camera cannot monitor at night (18 – 24 h, 0 – 6 h) in the absence of light. The catfish abstained from food during the indicated period. The characteristic activity pattern is clearly nocturnal as shown in figure 4-



(c)


Fig. 4: Observed results of catfish activity (October 9 0:00 – 16 0:00, 2001). (a) Whole day activity observed every ten minutes by the IR system. (b) The IR data during illuminated time (white bars) compared with the CCD camera (black bars). (c) Catfish movement at 6:02:57 on October 14, 2001 as arrowed in (a) and (b).

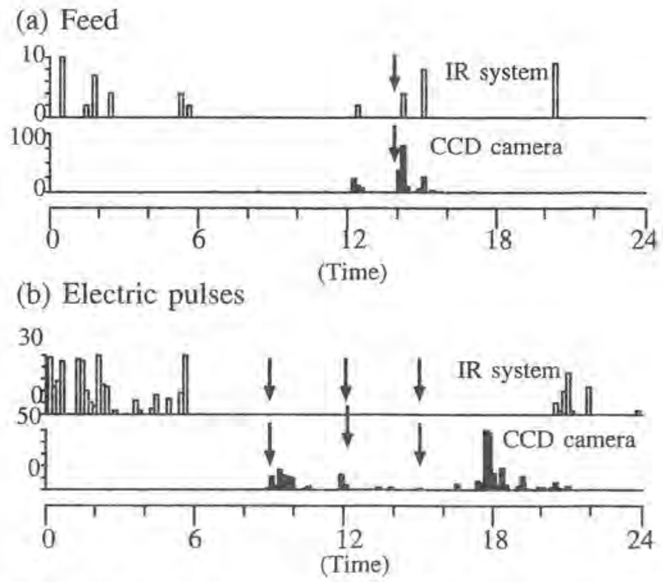


Fig. 5: The activity data of catfish response to (a) feed and (b) electric pulses indicated by arrows. The IR system detected catfish movements outside of the pipe, while the CCD camera detected all movements.

(a). The observation results by IR system did not always synchronize with those by the CCD camera because these two systems monitored at different areas: the CCD camera monitored one end of the pipe, while infrared sensors covered mainly the area over the pipe (shown in figure 2). Catfish movements were detected by both systems at 6:02 on October 14 and also recorded by the CCD camera as shown in figure 4-(c) when the catfish moved outside of the pipe.

Catfish response to feed

The pattern of catfish activity after being fed is shown in figure 5-(a). Feed pellets which sinks to the bottom of the aquarium is given to the catfish. The catfish comes out from the pipe and feeds about a few minutes after the feed reaches the bottom (14:00). In this experiment, the catfish moved about three minutes after the feed was given, then fed intermittently until 15:46.

Catfish response to electric current

Another experiment for activity of catfish to electric current was performed. Electric pulses were given to the catfish at 9 h, 12 h and 15 h, in order to examine the response to electric pulses. Ten rectangular pulses with 5.0 milliseconds width and with field intensity of 5.6 V/m in the aquarium were given at one second intervals each time. Catfish response to the pulses is shown in figure 5-(b). The catfish moved violently at the moment of electric stimulation. Catfish activity was not detected by the IR system because the catfish did not come out from the "nest" when electric pulses were applied. Catfish movements after 18 h may not be directly connected with the electric stimulations.

3.2. Mouse

Typical results of the mouse activity are shown in figure 6. The dark time was set from 8 h to 20 h, while the illuminated time was the remainder. This system records the period of time when a mouse runs around, so that the sleeping/active pattern of a mouse is continuously monitored and reveals the mouse's inherent nocturnal nature as shown in figure 6. If electromag-

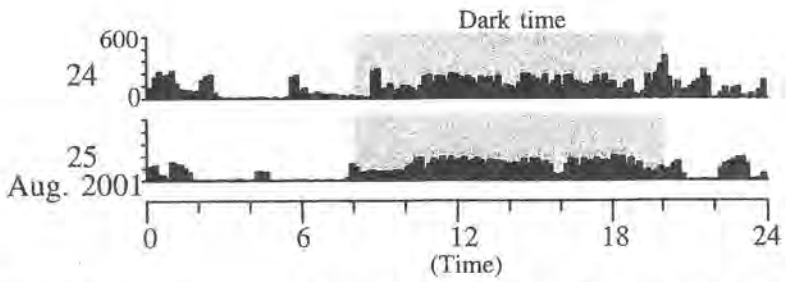


Fig. 6: A typical mouse activity during blight and dark periods. Dark period was set from 8 h to 20 h, while light period was set in the remaining period.

netic waves change mouse circadian rhythms in some way (e.g., phase shift), it can detect the alteration. An experiment is under way in which mice are stimulated by electromagnetic waves.

4. Discussion

Advantages and disadvantages of monitoring systems:

The time of catfish movement is recorded by an economically built IR system, which is adequate to observe daily rhythms but is difficult to follow the intensity of movements. An expensive electromyogram system, which measures electric fields generated by muscular movements, allows the observation of both frequency and intensity of movements when electrodes are attached to the pipe in which a catfish lives. However, the movements cannot be monitored when the catfish is outside of the pipe. Catfish movements outside of the pipe were observed when the camera was set to monitor the whole aquarium. Its movements in the pipe were monitored with another CCD camera at the end of the pipe. It is necessary to use a camera having sensitivity to infrared light and infrared lighting, since observation during the dark period is impossible using a CCD camera having sensitivity only to visible light. Another sensors to catch the sound of violent movements of catfish would be useful.

Our automated and continuous observation systems can be built economically and used for many observation sites over the long term. Conventional behavior observation of living creatures contains some subjectivity. Very few studies deal with unusual animal behavior quantified and correlated with seismic activities and seismic electromagnetic signals before earthquakes. Animal behavior has individual differences and random elements, which is why scientists have refused to correlate behavior with earthquakes. However the attitude of discarding such relationships without careful consideration is blameworthy. It is natural that creatures have individual differences but this can be allowed for by many simultaneous observations on many experimental subjects. The present results have already shown that the systems are useful for monitoring many animals in order to study the responses biologically. Certainly, earthquake prediction may not be possible only by observation of animal behavior, but the simultaneous observation for a long period with SEMS and background EM noises including those caused by lightning and magnetic storms.

5. Summary

Observation systems of unusual animal behavior have been developed using infrared sensors and a CCD camera. Original points of the system are the digitalization algorithm of animal activity and the data acquisition system using computer networks. Catfish movements response to external stimulations such as feed and electric current are clearly monitored. Advantages and disadvantages of various observation systems are discussed. It is shown that the IR system operates successfully to observe daily rhythms of animal and is well suited to studying the influence of electromagnetic waves on daily rhythms. It will be widely accepted that unusual animal behavior precedes some kinds of earthquakes, when quantitative phase shifts of the rhythms are recreated in experiments and their biological origins are found.

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Appendix A. Circuit diagram

Figure A1 shows the circuit diagram of driving electric circuits using PS-3051 (by courtesy of EK JAPAN). Some modifications were made to the original circuit. Information about PS-3051 is presented on the WWW site (http://www.elekit.co.jp/index_US.html).

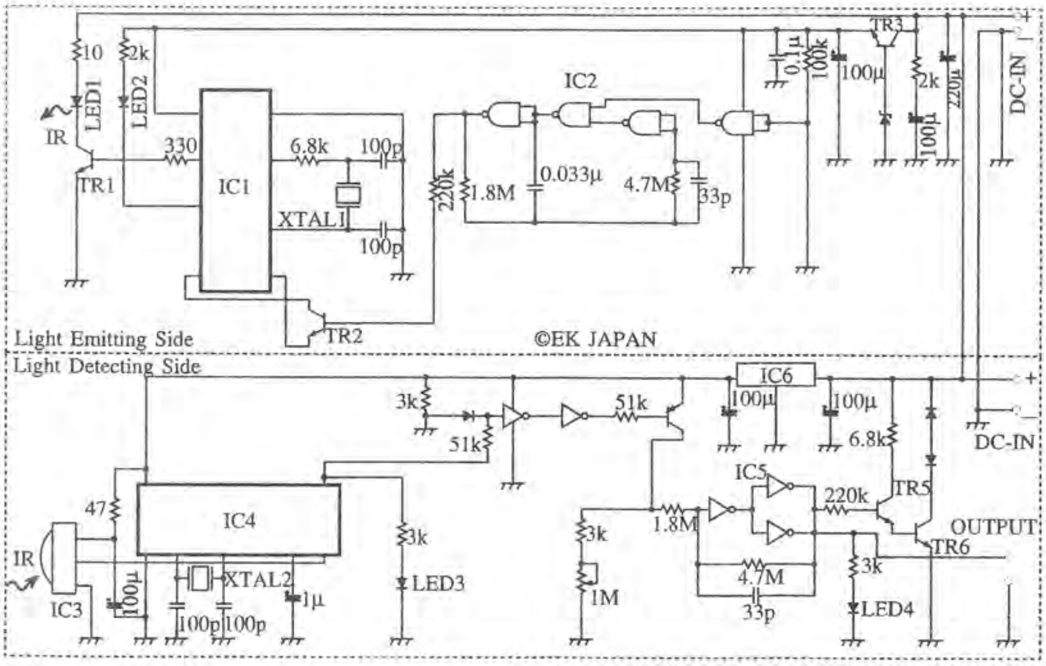
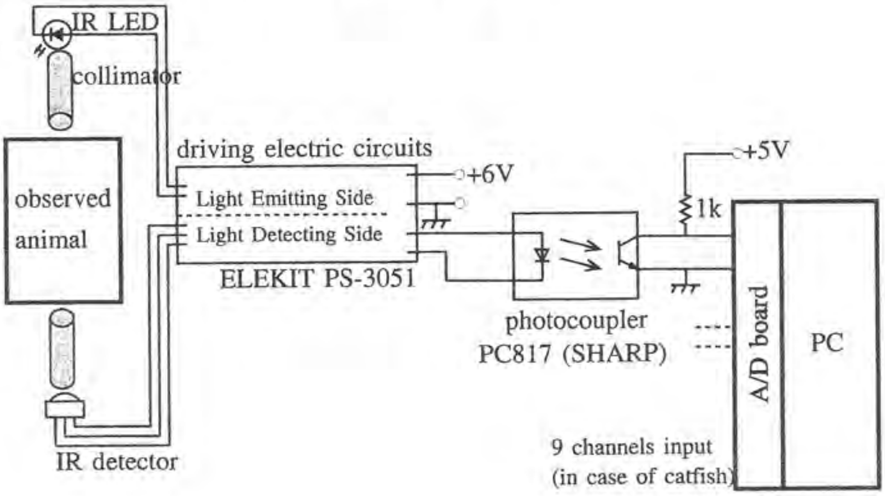


Fig. A1

Table: Devices used in driving circuits.

device	index	model number
IC	IC1	TC9243P (TOSHIBA)
	IC2	74HC00AP
	IC3	IR detector
	IC4	TC9244P (TOSHIBA)
	IC5	TC4069UBP
	IC6	AN8005
Transistor	TR1,TR6	2SD734
	TR2,TR3,TR5	2SC945
	TR4	2SA733
Seramic Transducer	XTAL1,XTAL2	SCB455E (Murata)
LED	LED1	IR
	LED2,LED3	red
	LED4	green

Appendix B. The connection of IR sensors to PC



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