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A simple integrated circuit device for measuring distances traveled and determining speed in open-field environments

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Abstract

An easily constructed and inexpensive device for measuring distance and determining mean speed, which utilizes an integrated circuit (IC) photosensor system, is described. It was designed for evaluating activity of small animals in open-field environments, being used in conjunction with a video-recording system. The horizontal locomotor path of the animal is manually tracked directly from the video monitor image or from a tracing made of the image.

Keywords: Locomotor activity; Distance; Speed; Open field; Water maze

1. Introduction

Analysis of locomotor activity is frequently of interest in behavioral research, most often in open field-type paradigms — either as a primary focus of the research or as a control needed to evaluate the functional integrity of motor systems. The current paper describes a simple and reliable device developed to measure distance traveled and to determine swim speed in a Morris-type water maze (Czech et al., 2000), based on the principle of the instrument (planimeter) used, e.g., by cartographers in measuring distances on maps and by real estate surveyors. While several excellent monitoring systems capable of evaluating a broad range of behavioral features are commercially available, their cost is often prohibitive for smaller labs and their extensive capability is often not exploited. These include the popular Poly-Track (San Diego Instruments) (Lindner et al., 1997; Prendergast et al., 1997) and the HVS 2020 Plus (HVS Image) (Niittykoski et al., 1997) video-tracking systems. Customized video-tracking systems have also been developed, sometimes to also meet unique requirements (Kaminsky and Krekule, 1997; Vatine et al., 1998). Construction of these systems can, however, require considerable time and technical skill. In contrast, the herein described device is inexpensive, easily constructed with limited skills or tools required, and with readily available components.

2. Functional system description

Component parts of the system are shown in Fig. 1. A simple fork (a) is constructed of three pieces of clear Plexiglas; one piece serves both as a handle and as a spacer to provide an appropriate opening to accommodate a wheel (e.g., an opaque plastic pulley). (b) A rubber O-ring can be inserted into the grove at the edge of the pulley to provide good, nonslip contact with the surface to be measured. Two or more small holes (No. 53 drill bit) (c) drilled through the wheel provide a light path between the emitter (E) and sensor (S) sections of a photodetector system that monitors increments of wheel rotation. Owing in part to its use in other applications, we found it convenient to split the S and E sections of an interrupter (slot) module (HOA2001-001; Optoelectronics Section, Honeywell, Richardson, TX) rather than purchasing the S and E units separately. The two sections are aligned and bonded to the outer surfaces of the fork in line with the light path holes. The integrated circuit (IC) sensor module contains a photodiode, differential amplifier, voltage regulator, Schmidt trigger, and output stage — thus eliminating the need for external photodetector circuitry. This IC

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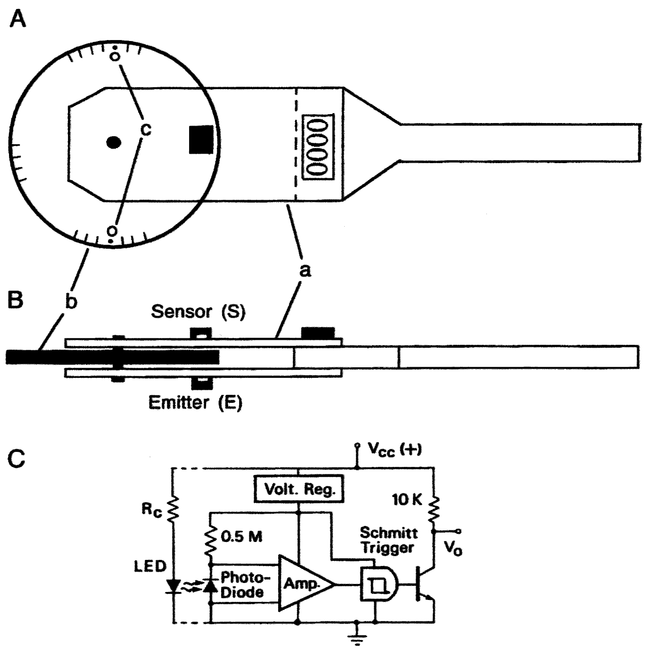

Fig. 1. Side (A) and top (B) views of unit, along with the photosensing system circuitry (C). Lower case letters designate component parts as referred to in the text. One side of the wheel is painted black to block any stray light from activating the sensor unit and arbitrary scale unit ticks are marked on its perimeter. R_c is a 100-Ω external current limiting resistor for the LED (E). All electrical components except R_c and LED are contained in the sensor unit. The IC optosensor with Schmidt trigger output provided a distinct advantage both in mounting space required and time needed for construction. We have used this module in a number of devices, including a drinkometer (Czech, 1982) and suspension system activity monitor (Czech, 1984).

sensor unit can be used with infrared or visible light and is available in several packages. With incident light above threshold level, the output voltage (V_o) of the sensor is high (TTL logic "1") and approximately equal to the supply voltage (V_{cc}); interruption of the emitter light beam drives it low. The unit operates over a supply voltage range of from 4.5 to 12.0 V DC and its output is thus compatible with both TTL and CMOS logic. We are operating the unit at 5.0 V DC, and coupling the output to a TTL monostable multivibrator (74121) for signal conditioning. The 74121 output is used to activate a normally open reed switch/relay with contact closure incrementing a miniature self-powered LCD counter (e.g., 4 digit model 7016; Radio Shack). All external circuitry, along with counter module and reset switch, is conveniently mounted on the outer surfaces of the fork. The conditioning circuitry was first wired on PC board. Power supply leads are connected to an off-board 5.0 V DC source; alternatively, the system could be powered by an on-board battery.

Wheel diameter and selected number of equally spaced holes will determine number of counts per complete wheel revolution. To calibrate, distance traveled per count can be determined simply by rolling the device out over a fixed distance, starting at any one of the tick marks and determining the number of counts, plus any partial (i.e., distance traveled prior to the first hole encounter registered and past the last hole registered). Unless a preselected unit of travel (e.g., a centimeter) per count is desired, there is no need to use any particular diameter wheel and/or number of equally spaced holes. We found it convenient to simply use two holes in a 5.5-cm diameter pulley found in a store selling surplus science supplies; they can also be obtained in many hobby stores. One side of the wheel was painted black as a precaution to block stray light.

We found it convenient to first project the videotaped activity from a swim trial onto a large sheet of easel paper, with projected image actual size of pool dimensions, and to trace the swim path pattern of the animal by hand with pen or pencil onto the projected image over the duration of the trial. A different projected image size could, of course, be used with correction; too small an image area could, however, sometimes make it difficult to maintain continuity of the swim path in a complex pattern (e.g., overlapping of tracing in some path segments could make it difficult to determine the correct continuation of the traced line). The paper was then laid on a table and the pattern tracked with the device; mean swim speed was calculated from distance and time (duration of trial in seconds) data. Analyses could be carried out for selected regions (e.g., quadrants) as well. This would, however, require that time spent in each of the selected regions also be measured independently if mean swim speeds for regions are desired. While available in sophisticated tracking systems, the current system does not permit determining instantaneous speed at any point in the swim path.

Several alternatives to using a video projection system are also available and have been shown to be effective in our laboratory tests. One could, e.g., track the swimming animal directly on the video monitor screen with the device during the actual trial, either with or without videotaping the trial. In the latter case, however, a hard copy of the swim pattern would not then be available for possible further analysis and/or presentation. As another alternative, one could manually trace the swim path on a piece of thin transparent film (readily available from office supply stores) positioned on the video monitor screen, either during the actual trial or upon later playing the tape. The swim path could subsequently be tracked. If tracking from a tracing, it is recommended (as noted earlier) that screen size be large enough to permit accurate determination of swim path continuity in the event of extensive overlapping. Screen size is not a concern if tracking directly on the monitor image since there is no tracing of the path.

3. Discussion

A principal advantage of the present system is that it can be easily and inexpensively constructed with readily available materials. We built the unit as described for under

US$30.00. All electrical/electronic components can be obtained from well-known distributors, such as Newark Electronics (Chicago, IL) and Radio Shack. More importantly, the automatic tally of wheel revolutions feature eliminates counting errors and frees the user to focus attention on other demands. Moreover, it is very easy to use. We originally attempted using a standard small diameter wheel planimeter, but found it extremely difficult, typically requiring multiple attempts, to effectively trace the often complex swim pattern of the animal while at the same time attempting to keep count of wheel revolutions; tracking a moving target was virtually impossible. This was our experience irrespective of procedure used. Our search for a suitable commercially available unit with either mechanical or electronic counting was unsuccessful; they simply were not available. Modifying existing commercially available planimeters in order to produce an instrument with the advantages/characteristics we desired was deemed to be neither practical nor cost-effective.

The device is quite flexible and can be used in a number of situations. For example, in the absence of sophisticated tracking electronics and software, investigators often track locomotor activity in open-field paradigms, including water mazes, by counting movements across elements/lines of a grid pattern or other guide (Klapdor and Van Der Staay, 1998; Mogensen et al., 1995; Watanabe and Satoh, 1995). Tracking subject movements with the device herein described provides a simple alternative procedure, and where actual distance traveled is measured. Determination of distance is thus not differentially influenced by criteria used for determining what movements within the grid pattern are to be counted as distinct crossings. While this paper focused primarily on use in the water maze environment, I would expect investigators would find other applications as well, some of whom would also likely suggest useful modifications of the device.

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