INSTRUMENTATION & TECHNIQUES

Design of a remotely controlled "locomotory" platform useful in ethological studies

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A platform capable of movement from one point to another under remote control has been designed for use in behavior studies. Electrical and mechanical design criterion for the platform are discussed, and schematics and engineering drawings are included. The primary application was to study communication between Glaucous-winged gulls. Other applications for the platform (as in predator-prey studies and dispersal of birds from aerodromes) are suggested.

Early studies of animal models by Lack (1940a, 1940b) used tufts of feathers as a partial reproduction of a live subject, Tinbergen (1953) used two-dimensional models of cardboard, and Dilger (1956) and Kruuk (1964) used complete taxidermic reproductions to produce three-dimensional models. Tinbergen (1962) noted that only part of an animal is often as effective a stimulus as the complete animal and is usually much easier to prepare. Stout and Brass (1969) used this concept to develop and test a model of the Glaucous-winged gull (*Larus glaucescens*) consisting of a feathered head, neck, and wings mounted on a wooden body.

Galusha and Stout (in press) and Hayward, Gillett, and Stout (in press) used taxidermic models of gulls outfitted with a servo system that allowed remote-controlled movement of the head and neck. They found that orientation between interacting gulls and sequences of behavior were important aspects of the communicative schemes of the gulls. The need for a remote-controlled locomotory platform on which to mount model gulls became evident from this research. Locomotor movement allows features of communication to

be studied in greater detail than was previously possible with static models and also allows duplication of normal behavioral sequences.

Our design objectives were threefold: (1) to produce a platform that was small in size with a low profile, (2) to develop a drive train that was structurally strong and powered sufficiently to enable the platform to traverse rocky irregular terrain while carrying a 7.0-kg load, and (3) to devise a control system that would allow the operator to remotely control the speed and directional movement of the platform, along with remote movement of head-neck position.

DESIGN METHODS

There were two phases in the design of the locomotory platform. The first was to design an electrical control system that would be stable under conditions of severe mechanical shock in an environment of radio frequency (RF) fields generated by the motor. The system also had to control large currents. The second phase entailed the design of a mechanical system consisting of a gear box that could withstand high torque under heavy loading and at a relatively high drive. Drive trains had to withstand abrasion from rough terrain and yet allow fine control over platform movements.

Electrical Design

To minimize cost we used a commercially available radio-controlled servo system with five digital proportional radio channels (Heath GD-19, Note 1). Of the three available channels, two were used for the control of the transitory platform tracks (the left and right tracks were controlled separately); and the third channel controlled a servo system in the taxidermic bird mounted on top of the platform. In the body of the taxidermic mount, a Heath servo (GDA-19-4) was fitted and connected by chain gears which allowed vertical movement of the head-neck between up-right and horizontal levels (on an axis with a fulcrum point at the base of the neck).

Figure 1 and Table 1 show the schematic drawing of the electronics and parts designed to accept the digital proportional signals of the Heath radio control system and to convert these signals into usable dc drive current for the platform

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Table 1
Electronic Parts for Transitory Platform Model 2-B

Figures 1 and 3 Legend	Quantity	Part Name	Manufacturer	Value	Model Number
R1	1	Resistor—fixed	Ohmite	¼ W, 330	
R2	1	Resistor—trimmer	Helitrim	1K	82PR1K (Hx)
R3	2	Resistor—fixed	Ohmite	¼ W, 1.5K	
R4	1	Resistor—fixed	Ohmite	½ W, 1K	
R5	2	Resistor—trimmer	Helitrim	50K	89WR50K
R6	4	Resistor—fixed	Ohmite	¼ W, 4.7K	
R7	4	Resistor—fixed	Ohmite	¼ W, 3.3K	
R8	8	Resistor—fixed	Ohmite	¼ W, 10K	
R9	4	Resistor—fixed	Ohmite	¼ W, 22K	
C1	1	Capacitor—electrolytic	Sprague	12 V dc, 200 mF	WH11D
C2	2	Capacitor—tab	Sprague	50 V, .05 mF	
C3	4	Capacitor—electrolytic	Sprague	12 V dc, 100 mF	WH11D
C4	1	Capacitor—tab	Sprague	24 V, .1 mF	
C5	1	Capacitor—electrolytic	Sprague	12 V dc, 10 mF	WH11D
T1	4	Transistor	Motorola	PNP	HEP 254
T2	6	Transistor	Motorola	NPN	HEP 714
T3	4	Transistor	Motorola	NPN	MJE 3055
T4	4	Transistor	Motorola	PNP	MJE 2955
Z1	1	Zener diode	General Electric	Z = 7.5 V	GEZD 7.5
Z2	4	Zener diode	General Electric	Z = 20.0 V	GEZD 20
IC1	2	Integrated circuit	Texas Instruments	Monostable	SN74121
IC2	1	Integrated circuit	Texas Instruments	Schmitt trigger	SN7413
IC3	1	Integrated circuit	Texas Instruments	Open collector NAND	SN7426
IC4	1	Integrated circuit	Texas Instruments	Inverter	SN7404
IC4	2	dc motor	Barber-Colman*	12 V dc, 5400 rpm, .017 hp, cont. duty, 2A	BYLM 72800-51
IC4	2	Connector	Amphenol	22 contact	Series 143

Table 1 Continued

B1	6	Nickel cadmium battery	General Electric**	2.4 V dc, 2 A. H.	41BOO2BD03-61
	1	Battery charger	Chart-Charge Co.†	Nicad charger	250-L
F1	1	Circuit breaker	Wood Electric Corp.††	7A	375-207-101
SW1	2	SPST switch	UND Laboratories	120 V, 5 A	C & K U31
	1	Transmitter	Heath Co.		GDA-19-1
	1	Receiver	Heath Co.		GDA-19-2
	1	Servo	Heath Co.		GDA-19-4
	5	Male connector	Heath Co.	4 Pin	432-104
	2	Female connector	Heath co.	4 Pin	432-103

*05624 Rockford, Illinois

**Gainesville, Florida

†Chicago, Illinois

††Danvers, Massachusetts

motors. Figure 2 shows the logical operation of the total electromechanical system. The two channels used for track control originate from the left and right control levers mounted on the front of the transmitter. The channels are so arranged that an "up" movement of a lever generates a "forward command" to a drive track and a "down" movement generates a "reverse command" to its associated track. The left and right levers control the left and right tracks, respectively.

At the receiver in the transitory platform, the lever movements become pulses of a width proportional to the amount of "up" or "down" movement. These proportional length pulses are conditioned for use in the TTL logic circuitry (Texas Instruments, Inc., 1973) by being applied to the input of a TTL Schmitt trigger (SN7413). This part of the circuitry removes any spurious noise and makes the output of the receiver compatible with TTL logic.

To recognize a forward or reverse command, the logic was arranged in the following manner. First, the leading edge of the input signal from the Schmitt trigger fires a monostable multivibrator (SN74121), which, in turn, generates a reference pulse of constant width. This reference pulse is then compared to the width of the input signal in two pulse-width detectors, each made up of one inverter (1/6 SN7404) and one NAND gate (1/4 SN7426). The detector sums both signals but the output of the NAND gate of each responds differently. When the input signal is longer than the reference pulse (a lever down condition), the reverse command detector generates an output. If the input signal is shorter than the reference signal (a lever up condition), the second, or forward command, detector generates an output signal. The output is inverted or negative going and its width is equal to the difference between the input signal and reference signal. The amount of this difference

depends on the extent of travel of the control levers. When the control levers are in a neutral, or center, position both the input and reference signals are of equal length and no output signal generates from either of the detectors.

Since the output pulses of these detectors are far below the dc current required to drive the motors, the pulses must be stretched and shaped to provide a similarity of dc voltage. The pulse-stretcher circuit that receive the pulses from the detector comprise a HEP 254 (T1, Figure 1), a resistor, and a capacitor. The output of the detector is applied to this circuit through a current-limiting resistor (R7). For very narrow pulses (lever just off center), the capacitor at the base of T1 has but a short time to charge. During the OFF time of the detector, this capacitor begins to discharge through the base-emitter junction, turning ON T1 for a short time. The greater the pulse width, the higher the charge on the capacitor and the longer the discharge time to create a greater current through T1. Discharge time is determined by the base-emitter resistance, size of the capacitor (C3), the base-emitter resistor (R6), and the width of the pulse. Those factors are carefully balanced until the optimum discharge times are derived for the widest possible range of speed conditions of the locomotory model. This circuit is, by far, the most critical in the design of the electronic sub-assembly.

The discharge base current of T1 controls its collector current, which is the base current supply for the HEP 714 (T2, Figure 1) driver. If complimentary symmetry transistors are used for motor control, then one driver transistor is sufficient. In the bridge circuit (Figure 3) forward and reverse circuits are combined using complementary symmetry transistors (T3 and T4). The bridge circuit allows forward and reverse control of the same motor without the use of bulky and power-depleting relays. Zener diodes (Z2) in the motor circuitry limit the high-frequency spiking problems inherent in dc motors.

Logic driver components are placed on a G-10 glass epoxy printed circuit board (Figure 5) along with a regulated 5-V dc power source compatible for use in the TTL logic circuits. The use of a removable circuit board aids field serviceability when required. Integrated circuits are wired to Molex 14-pin connectors, which facilitates removal when faults occur. A complete list of components required to build a two-channel logic driver board and 5-V dc regulated supply is provided in Table 1.

The complementary symmetry power transistors are mounted on external flanges at the sides of the platform cover to aid heat dissipation. A cable goes from the logic driver board to each transistor on the heat sink flange. This cable can be unplugged from the logic driver board to aid in field repair. All wiring in the platform is with Beldon 20-AWG 10 x 30 flexible hook-up wire.

A NICAD battery pack with six 2.4-V dc cells supplies a 14.4-V dc potential. The battery pack is tapped at 4.8 V dc to operate the Heath receiver circuitry directly and the Heath servo (GDA-19-4) in the taxidermic mount on the locomotory platform. Under normal full-speed operation, current drain averaged about 3 A, giving an operating time of approximately

Figure 2. A flow diagram illustrating the logical operation of the locomotory platform.

Figure 3. Schematic of the power circuitry for use in driving the servo motors. T3 and T4 are complementary-symmetry transistor pairs. Zener diodes (Z2) are used for limiting high-frequency spiking caused by the motor.

45 min per battery pack. The battery pack is situated at the rear of the model to increase traction (Figure 5).

Mechanical Design

Success of the mechanical design depends on selection and/or design of: (1) the dc drive motors which need to be rugged,

small, dependable, and have high torque capacity; (2) the gear boxes, which must withstand large torque loads, be oil tight, and have approximately a 60 to 1 gear ratio (this ratio was estimated from the approximate maximum speed needed, i.e., 5 km/h, the motor RPM, and the radius of drive sprocket); (3) the drive tracks, which must withstand tremendous abrasion from rocks and rough terrain, cannot slip under heavy load, and must have good traction capabilities on an inclined surface.

The servo drives are made by Barber-Colman Company and are used mainly for aerospace applications (Table 1). The servo motor is coupled to a custom-built gear box (Figure 4), constructed of hardened steel and heavy-duty brass gears, and hardened steel shafts that turn on roller bearings. The gear box housing is machined out of aluminum. The motors and gear boxes have given no problems in over 1,200 h of operation. Several previously tested commercial gear boxes broke down when subjected to rigorous field conditions. Table 2 lists all mechanical parts for the gear boxes and platform.

To overcome tread slippage, a chain-sprocket drive arrangement gives no play when the platform is pivoted. Stainless steel cleats are attached to the chain, which allows movement of the model over rough terrain without damaging the chain

Figure 4. Front and side view of the custom-built gear box used to drive the locomotory platform. Gear ratio is 60 to 1. Table 2 lists the mechanical parts used in the construction. Circled numbers denote specific parts and are referenced also in Table 2.

Table 2
Mechanical Parts for Transitory Platform

Quantity	Part Name	Manufacturer	Value	Model Number	N*
4	Bearing	Barden Corporation		34BX4	2
2	Worm gear	Perfection American	Hardened steel	WHG48R	3
2	Bearing	Delco--New Departure		77R4	4
2	Bearing	Delco--New Departure		77R2	5
2	Gear	Perfection American	Brass, 12 tooth/24 pitch	B2412	7
2	Gear	Perfection American	Brass, 18 tooth/24 pitch	B2418	8
2	Bearing	Delco--New Departure		77R3	9
2	Worm gear	Perfection American**	Brass, 50 tooth	WB4850	10
2	Bearing	Delco--New Departure		77034	12
1	Chassis	Alcoa	.090 x 8 in. x 11 in.		
6	Idlers	Martan	8 tooth/35 pitch 3/8 bore with bronze bushing, 1/4 ID x 3/4 in. L x 3/8 pressed into idler, 1/4-in. shoulder bolt used for axles	35B8	
2	Drive sprocket	Martan	16 tooth/35 pitch	35A16	
60	Master link chain (male)	Moline Malleable Iron Co.†		35 K-1CC	
60	Master link chain (female)			35 K-1KL	

*N = Number on Figure 4

**Division of Rex Chain Belt, Inc., Darlington, South Carolina

†St. Charles, Illinois

Figure 5. Placement of electrical and mechanical components on chassis of locomotory platform. Note: battery weight is shifted to rear for added traction. Receiver is located under the logic driver board.

tread. The chain is flat No. 35 pitch K-1 attachment chain made by Moline Malleable Iron Company, St. Charles, Illinois. Each cleat is embedded in silastic "J" RTV rubber. A machined mold, used as a form allows 10 cleats to be made simultaneously. On certain surfaces, that is, bare rock and carpet, the rubber cleats give too much traction, making a pivoting movement difficult to execute. The user should determine before constructing cleats whether or not rubber molds are necessary to enhance traction.

A scale outline of all parts mounted on the platform is depicted in Figure 5. A Heath receiver mounted below the logic driver board is encased in foam rubber to isolate it from mechanical shock. Overall dimensions of the platform are 11 x 12 in. (27.9 x 30.5 cm). An aluminum cover is hinged in front and attached at the back of the platform by two machine screws. This allows quick removal of the top when battery replacement or electrical repairs are necessary.

PERFORMANCE

After mounting a taxidermically prepared gull on the platform, the complete model was placed near a nesting bird's territory. When the resident returned, the model

(controlled from a nearby hide) was moved so as to duplicate nearly all of the normal Glaucous-winged gull behavioral repertoire. Movements toward the resident bird, along with nonmovements and movements away, were executed and resident responses were recorded. Figure 6 is a representation of the model inter-

Figure 6. Drawing of the locomotory platform and taxidermic mount of a gull interacting with territory defender.

Table 3
Comparison Among Rank of Commonly Seen Defender Behaviors
Occurring During Natural Intruder-Defender Interactions and
the Locomotory Model Experimental Series

Locomotory Model Defender Responses		Natural Defender Responses	
Trumpet	(.03)	Trumpet	(.004)
Mew	(.05)	Mew	(.07)
Choke	(.05)	Choke	(.07)
Flare wings	(.07)	Upright toward	(.09)
Attack	(.09)	Flare wings	(.11)
Turn toward	(.15)	Upright still	(.14)
Fly toward	(.15)	Turn toward	(.15)
Upright toward	(.19)	Attack	(.16)
Upright still	(.21)	Fly toward	(.20)

$\uparrow$ $p < .05$ $\uparrow$
 $R_s = .66$

Note—A Spearman rank correlation between the ranks is below the chart. Proportions of each behavior within a column are represented in parentheses.

acting with a live territory resident. In order to compare natural interactions with territory defender-model interactions, a total of 623 previously coded strings of natural intruder-defender interactions were utilized (see Tinbergen, 1960, and Stout, 1975, for descriptions of behaviors). A Spearman rank correlation (Siegel, 1959) was significant at the .05 level (Table 3).

Attack is a commonly used defender strategy when intruding gulls move away (Hayward et al., in press; Amlaner & Stout, in press). Defender attack also occurs when a static model is placed on a territory but at a much lower frequency. Table 4 shows the results of a chi-square test between 272 static and 152 locomotory model experiments. In the locomotory model experiments, with the model moving about a territory, attack by a territory resident directed to the moving model occurred in 74.3% of the territories tried, compared with 46% in other static model experiments. The moving model was attacked significantly more frequently than were static models unaccompanied by locomotory movement.

A more detailed account of performance along with two-act sequence analysis and territory defender-model

orientation results will be published elsewhere (Amlaner & Stout, in press). In general, the locomotory platform with the stuffed mount performed beyond our expectations and design specifications. We were able to pilot the platform over a wide range of terrain types, including grassy areas about 15 cm tall, rocky areas with 2- to 5-cm cobbles, and slopes with up to 45-deg inclination.

FURTHER APPLICATIONS

One possible future application is in the study of predator-prey responses. Since the platform can handle a 7-kg load, one could conceive of mounting a taxidermically prepared stoat (Kruuk, Note 2), otter, or any small predator on the platform and then moving it, via remote control, through the area to be tested. Experimental techniques could then be developed to evaluate prey responses to predator movements.

Another application might be in the dispersal of birds on aerodromes. Recent studies (see Stout, Gillett, Hayward, & Amlaner, Note 3) have shown that static plastic models of dead gulls are effective in dispersing other sea gulls from aerodromes. A locomotory platform can be utilized to move a plastic model around the periphery of a landing zone under direct radio control from a preprogrammed microprocessor, thus making the platform move through certain tested procedural behaviors proved to be effective in dispersal. Movement of this type, we anticipate, will lessen the amount of habituation usually seen in response to static models.

We have tested and used a miniature radio receiver within the body of the taxidermic model mounted on top of the platform. Certain vocal behaviors are transmitted by a small FM transmitter from a nearby hide and are received and amplified within the model. By so doing, we are now able to duplicate not only postural and movement behavior but also vocal behavior. With this experimental apparatus, we hope to independently evaluate the factors leading to an individual behavior or a series of behaviors following a standard model movement, posture vocalization, or a combination of these variables.

Table 4
Acceptance of Locomotory Model Compared with Acceptance of Static Models
as Measured by Number of Attacks by Territory Defender

	Defender						
	Attack			No Attack			Attack Ratio
	Observed	Expected	Chi-Square	Observed	Expected	Chi-Square	
Static Model Experiments	125	152.7	5.02	147	119.3	6.43	.460
Locomotory Model Experiments	113	85.3	9.00	39	66.7	11.50	.743

Note— $\chi^2 = 31.95$, $df = 1$, $p < .001$, $n = 424$.

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