Natural Electrosensory Systems: Object Sensing by Weakly Electric Fish and Technical Devices

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Weakly electric fish from

South America

Africa
Gnathonemus petersii

Electric Organ Discharge

Amplitude (mV)

0.5 ms
Eigenmannia sp.
All mormyrids are nocturnal.
Electroreceptor organs are distributed over the entire body surface of the fish.
Active Electrolocation
Conducting object
The electric field produced by *G. petersii*
Object detection during
active electrolocation:
Object-Detection: Discrimination between animated and dead objects

\[ Z = R \]

\[ Z = \sum R_i + \sum Z_i \]

\[ Z = \frac{1}{2\pi f C} \]

R = Ohmscher Widerstand
C = Kapazität
f = Frequenz
Experimental set-up for object discrimination
Capacitance Detection

Correct Choices [%]

Resistance [kOhm]

G. petersii 1
G. petersii 2
G. petersii 3

G.p.2 G.p.1 G.p.3

G. petersii 1
G. petersii 2
G. petersii 3
Capacitive Objects distort the EOD Waveform

"Ohmic Object

Capacitive Object

Amplitude [mV]

Inside positive

Inside negative

125 μs

Modified after: von der Emde (2001)
Electroreceptor organs for active electrolocation
Response of afferent fibers to waveform-distortions caused by capacitive objects.

A-fiber

B-fiber

3-dimensional Orientation:
Distance measurements
The electric image of a sphere at different distances from the fish

The fish measures the blur of the electric image by calculating its ‘slope/amplitude ratio’.
Determination of the slope/amplitude ratio for Distance measurements in *G. petersii*
3-dimensional Object recognition:
Shape-Detection
These objects were discriminated
## Recognition of object properties during active electrolocation

<table>
<thead>
<tr>
<th>Object parameter</th>
<th>Analysis parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position along the body</td>
<td>location of peak amplitude</td>
</tr>
<tr>
<td>Distance</td>
<td>Slope/amplitude ratio</td>
</tr>
<tr>
<td>Size</td>
<td>Distance + image diameter</td>
</tr>
<tr>
<td></td>
<td>Peak amplitude + Object distance + Object size</td>
</tr>
<tr>
<td>Electrical resistance</td>
<td>Waveform distortion + Object distance + Object size</td>
</tr>
<tr>
<td>Capacitance</td>
<td>Object distance + Object size + additional parameters</td>
</tr>
<tr>
<td>Shape</td>
<td>Object distance + Object size + additional parameters</td>
</tr>
</tbody>
</table>
Applying the principles of active electrolocation in electric fish to technical systems
Principle of a simple sensor for object detection

1) Amplitude measurement
2) Comparison with template
3) Detection of object
Principle of a multielectrode sensor

Electrical fieldlines

medium

Sensor

Sensorarray

amplifiers

A/D-converters

Analysis-unit
Principle of a multielectrode sensor for **distance measurement**

1. Array imaging
2. computation of max. amplitude
3. computation of max. slope
4. From 2 and 3: slope-amplitude ratio for distance determination
Distance Sensor

Slope/amplitude = \frac{0.47}{1.38} = 0.34

max. Slope = 0.47

max. Amplitude = 1.38

Field of electrodes

Analysis Unit

Computer for data processing

Amplitude modulation

image width

1.5

1.4

1.3

1.2

1.1

1.0

0.9

0.8

0.7

0.6

0.5

0.4

0.3

0.2

0.1

0.0

13 12 11 10 9 8 7 6 5 4 3 2 1 0
Principle of a simple sensor for detection of capacitive properties

1) Waveform detection
2) Comparison with template
3) Detection of material properties
Sensor system for the detection of material faults

Computer – Analysis unit

Emitter-electrodes

Measuring electrodes

Work piece
Object detection and analysis during production

Miniaturization
Principle of a multielectrode sensor for Skin Imaging

Skin irritation

Skin

Sensor

Sensorarray

amplifiers

A/D-converters

Analysis-unit

Logical unit for 2-dimensional imaging

Electrical fieldlines
3-dimensional sensor array for electrical imaging
Gnathonemus petersii