An Artificial Life perspective on traditional Pacific wave navigation

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Abstract

Constructing an autonomous robot or artificial agent using an Artifical Life perspective requires analysis of its perceptual interface with its world. Appropriate sensorimotor dynamics are needed for its embodied interactions with the physical environment in which it is embedded. Similar issues occur for small craft navigation across the seas. These parallels are explored in the context of a newly proposed explanation for the *dilep*, a wave-mediated pathway between islands in the Pacific as used by traditional wave-navigators in the Marshall Islands.

Introduction

Polynesians and Micronesians traditionally navigated small sailing outrigger canoes over vast distances without navigational instruments or maps. Wave navigation uses patterns of wave reflections and refractions around islands to infer what course to set. A particular mystery, till now with no agreed scientific explanation, is the *dilep* wave pattern used by Marshall Islanders to navigate directly between isolated islands perhaps 100km apart (Genz et al., 2009; Huth, 2016). How does a sensing organism, here embodied in a small sailing outrigger canoe, have appropriate sensorimotor interactions with its environment of winds and waves? We argue that this mystery has affinity with ALife problems such as constructing a robot or agent that perceives its world.

An explanation for *dileps* has recently been proposed (Harvey, 2018). A constant primary swell is reflected from the two islands, forming two weaker secondary swells radiating out from each island acting as a secondary source. Such secondary swells, of similar wavelength and period, interfere with each other both constructively and destructively in the inter-island region, with (near-)invariant patterns of maximal additive interference. Analysis of these invariants suggests that they provide multiple (near-)parallel pathways leading fairly directly between the islands, potentially exploitable by the Micronesian navigator.

This explanation proposes, along with many further testable predictions, multiple *dileps* rather than the single *dilep* that was assumed until now. Its validity will depend on satellite photo evidence, hydrodynamic simulations, experiments by small boat navigators in the right conditions, and ethnographic reports. Regardless of this validity, we focus here on the inspiration from, and affinity with, Artificial Life.

Sensorimotor Dynamics

A lesson learnt early by those constructing autonomous robots is that the world does not present itself with labels such as 'obstacle', 'door' or 'destination'. In many cases where language is not needed, labels are entirely unnecessary; the programmer may want them but the robot can do without symbols. Evolutionary Robotics (Harvey et al., 2005) is predicated on aligning the sensorimotor dynamics of robot-environment interactions so that the desired behaviour forms an attractor. Perturbations from the desired behaviour, through noise or other external influences, should ideally be naturally corrected within the attractor basin. The embodiment of the robot, the way it is embedded in its world, is core to the analysis rather than merely an afterthought.

Likewise for a small boat navigating across the Pacific. At the most naive and simplistic level, building a craft with density less than water but more than air provides a natural attractor at the sky/ocean interface, bobbing along the surface. An ideal navigation strategy builds responses to environmental cues into another class of attractor that maintains appropriate direction, such as towards a destination island. To find such attractors we need to analyse sensorimotor dynamics in terms of possible invariants.

One such invariant class that Micronesian navigators use at night is that of star paths. Regularly each night, from a specific latitude, the same sequence of constellations rises at one point of the horizon and arcs across the sky to set at another point. Rigorous training allows the navigator, from just a brief glimpse of the night sky, to identify such star paths and hence infer the equivalent of compass bearings around the horizon (Hutchins and Hinton, 1984). Whereas Western navigational traditions would use such compass bearings to relate to a desired course plotted on a map, the Micronesian tradition does not conform to maps. They conceptualise the boat as stationary with respect to the sky full of star paths, while the islands all around pass by the boat in a direction dictated by the course set. The job of the navigator is to use star paths to set this course, so that the destination island comes over the horizon and meets the boat. Though

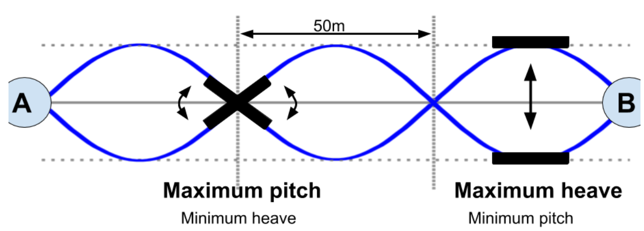

Figure 1. Heave and pitch from the standing wave derived from reflected secondary swells, as experienced by a boat travelling along a *dilep*.

strange to Western ears, this 'island moves' concept 'meets the stern test of landfall' and can be analysed as minimising the cognitive load on the navigator (Hutchins and Hinton, 1984).

Wave navigation raises different issues. Any regular swell, whipped up from a constant direction by trade winds or a distant storm, provides both a reliable sense of direction and also environmental clues as it is reflected and refracted around islands. Alife inspiration suggests that navigational principles may arise from analysing the invariants and attractors in such waves and their interactions with a boat and its pilot.

Dileps and invariant wave patterns

A Marshall Islands navigator can apparently detect, through the distinctive motion of an outrigger sailing canoe, when it is on a *dilep* or wave pathway leading directly from origin island to a destination island perhaps 100km distant. What possible invariants are there, in waves and responses thereto?

We focus on the disturbances the two islands A and B create, from a primary swell, assumed wavelength 100m. As a simplification, reflections create weaker secondary swells, of the same wavelength, radiating outwards from A, B approximated as point sources. If AB was an integer number of wavelengths (say 100kms = 1000 wavelengths) then on the direct line AB the matching swells would form a (weak) standing wave like a plucked guitar string. Every 50m (Figure 1) there would be maximum pitch of the combined waves; in between there would be maximum heave. The heave of these weaker secondary swells is likely swamped by that of the primary; but regions of maximum pitch are strong candidates for causing detectable cues through the boat's motion.

As well as such a potential direct *dilep* AB, we may also consider the path traced by a point E such that AE+EB = 1001.0 wavelengths (or 1002.0, 1003.0 …). On such pathways there will be similar standing waves created. These form elongated ellipses, with A, B as foci, visible in Figure 2.

Less than ideal, interruptions and noise

The idealisation assumes perfect point sources and completely regular waves. Under these conditions we can calculate the typical maximal inter-*dilep* distance (assuming distance AB is N=1000 wavelengths w=100m) as around $w\sqrt{N} \cong 3.2$km. The real world is messier, islands are not point sources, waves come in intermittent slightly variable wavetrains. Analysis and some guesswork (Harvey, 2018) suggests that despite all this what remains are numerous *dilep* segments of standing waves, having in common their direction towards the destination island. Many testable predictions can be made, and this theory awaits evidence to validate or eliminate the core proposal.

Embodiment

The regions of maximum pitch, every 50m along such a *dilep*, also give maximal directional cues. Opposing secondary swells from ahead and behind, meeting an off-course boat, generate a distinctive pitch-and-roll-and-back, possibly mixed with yaw-and-back, that lasts a second or two; the handedness of this sway depends on whether it is left or right of course.

The details of this depend intimately on the dimensions of the boat with outrigger. The sail and keel provide the motor, the pitch and roll provide the sensors, this is an embodied sensorimotor whole. Add the steersman and steering oar, and the appropriate responses to the sensory cues can provide a higher level behavioural attractor or invariant, that brings the destination island over the horizon to meet the boat.

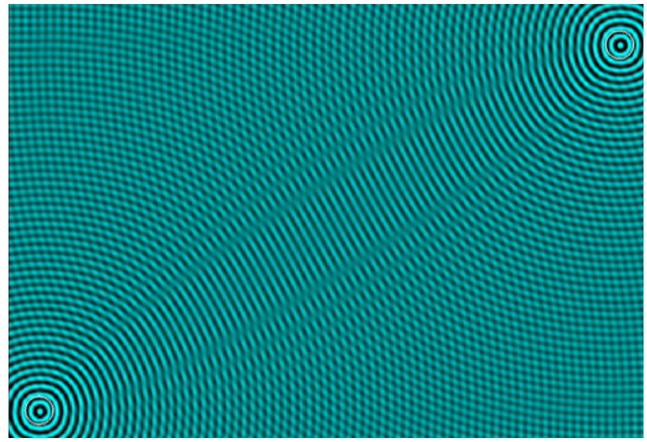

Figure 2. Simulation from rippletank app, www.falstad.com. Point sources bottom left, top right, around 80 wavelengths apart. Elliptical standing waves are visible.

Ontology and Epistemology

Our analysis suggests multiple near-parallel *dileps*, whereas the literature and ethnographic reports have till now suggested there is but a single *dilep* between A and B. But the Marshallese navigator will experience sometimes being on a *dilep* (with associated pitch and directional cues), sometimes being off. When the cues are rediscovered, they will feel much the same, point in the same direction, serve the same purpose — so for a pragmatic navigator it will count as the same *dilep*. For them it is one; for us, many — no contradiction.

Artificial Life, Navigation and Representations

Some navigation uses representations, such as Western maps and memorised star paths. Much navigation and cognition has no need for representations, e.g. this *dilep* proposal (Harvey, 2018). Embodied cognition involves getting the sensorimotor dynamics to have the appropriate invariants and attractors, whether through Evolutionary Robotics or via schools of navigation in the Marshall Islands.

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