Changes in the Flight Paths of Pigeons Based on Extended Spatial Landmarks

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SPATIAL PERCEPTION IN MIDDLE-DISTANCE MOVEMENTS

Level 1. External spatial data

1.1. Environmental Information
Boundaries between different terrains.
Regions of interest and landmarks. — Remote sensing data

1.2. Weather Conditions
Wind, atmospheric precipitation, poor visibility. — Weather data

Level II. Animal Tracks

2.1. Collective Motion Analysis
Group polarity. .
Nearest neighbour distance. — GPS logger + GIS *Processing*

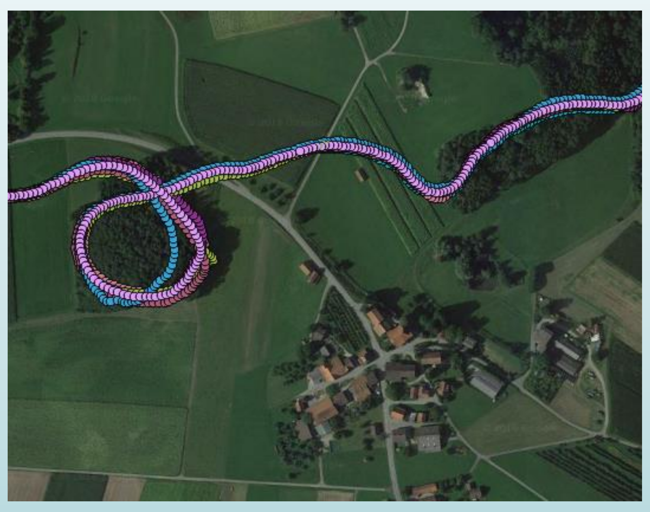
2.2. Individual Motion Analysis
Variety of trajectories and directions. .
Survey flight over unknown terrain — GPS logger + GIS *Processing*

Level III Perception and brain reaction

3.1. Total Brain Activity
EEG activity — Neurologger

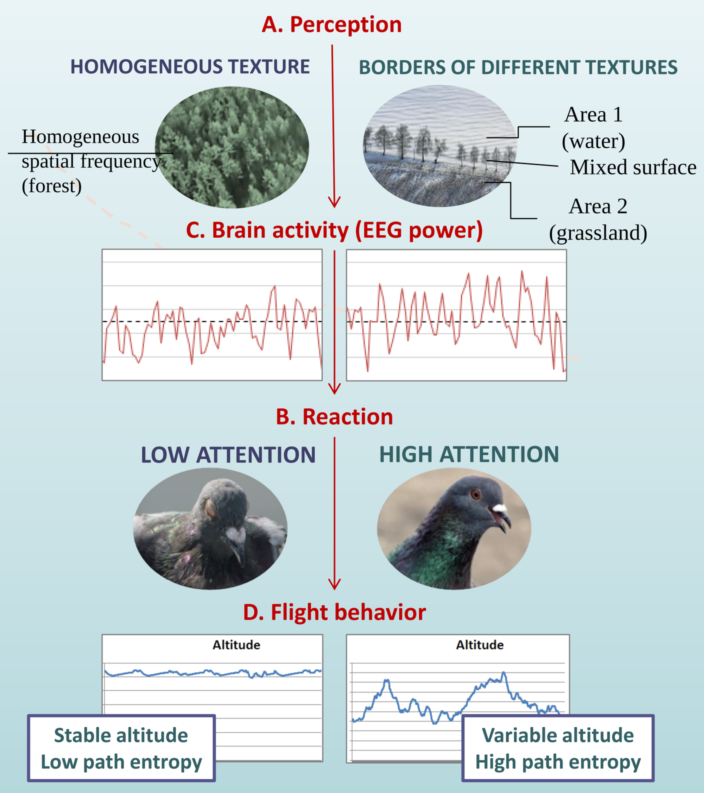
3.2. Activity of individual brain cells
Border cells, grid cells, place cells — Mathematical Processing

NAVIGATIONAL BEHAVIOR



The study of voluntary navigational behavior helps to predict main routes and possible changes in these routes. To identify dynamically changing movement trends and to understand the navigation strategies of subjects, it is important to analyze the characteristics of the spatial perception of subjects and take into account the features of the landscape along which they move.
Montello [1] defined "navigation" as goal-directed movement through the environment by organisms or intelligent machines, where "wayfinding" is planning and decision making coordinated with distal as well as local surrounds. Navigational behavior is typically based on a preliminary internal plan of the route that is compared with multiple external data. Sets of natural landmarks or artificial signposts which make it possible to determine the current location and estimate distances to the next waypoints.
In work [2] authors suggest that primacy of geometric or landmark information in orientation tasks depends on the size of the experimental areas, likely reflecting a preferential use of the most reliable data source, available during visual exploration of the environment. Spatial cognition, as well as spatial representations in memory tasks can involve discrete (landmark arrays) or continuous elements (enclosed environments) [3].

PERCEPTION AND BEHAVIOR



During flight pigeon can change its speed, direction, and altitude based on the varying visual information.

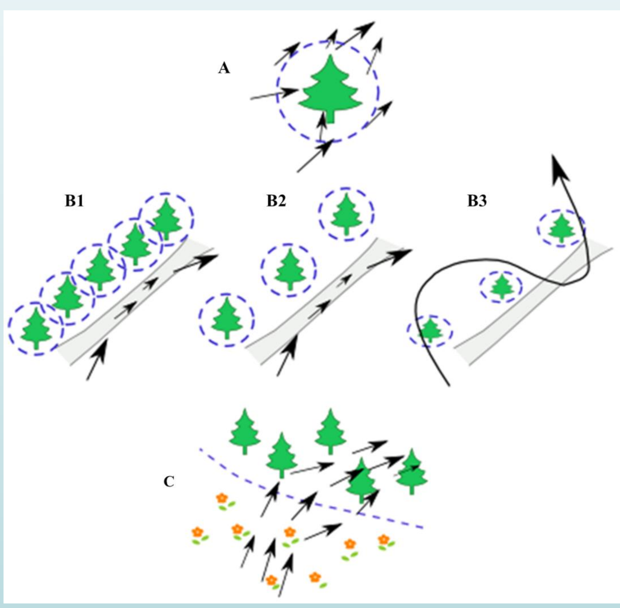
GPS records allow to understand how the pigeons' flock chooses the path when flying over the real terrain over important "stimuli".

Neurologgers are used to measure the brain activity of a pigeon, where multichannel EEG records from the flying and resting pigeons combine with GPS recording.

Observations made with the help of neurologgers, allow to notice that in flight over a homogeneous texture pigeons are less attentive than over a diverse surface with numerous landmarks and stimuli.

A similar effect is observed for car drivers in monotonous journey: they get tired of the monotony and begin to fall asleep.

DISCRETE AND CONTINUOUS LANDMARKS IN SPATIAL PERCEPTION



Here we suppose, that depending on the level of detail in the perception, the same objects can either be perceived separately or merge with the surrounding background. A free-standing tree can serve as a landmark, like a "beacon". But a similar tree in a forest or in a long alley will only be an element within the texture.

Figure shows typical pigeon flight paths in relation to external discrete or continuous landmarks:
A. Detached reference point. The flight is performed around the «point of interest", without a certain direction of movement.
B1. Continuous linear object. The flight is performed along an extended object.
B2. Discrete landmarks. The flight is performed along extended landmarks.
B3. Discrete landmarks as control points in a survey flight. The flight is performed along an extended set of objects, with deviations in different directions.
C. Boundary between distinct homogeneous areas. The flight can also be per-formed both along the boundary between different surfaces, and perpendicular to them.

STIMULI AND TEXTURES

Datasets
In this work, calculations were carried out based on data packages published in open repositories (Dryad Digital Repository and Movebank Data Repository). The calculations were made for 150 flights: 50 flights over terrain near the sea-shore: sea coast, urban terrain and agricultural fields (data packages [4]), 50 flights over natural forests and rural areas (data packages [5]), 50 flights over mixed suburban areas (data packages [6]).
In these datasets, typical pigeon's flights occur at an altitude 100-500 meters with an average speed of 60-120 km/h, at distances about 10-15 km. During flight pigeon can change its speed, direction, and altitude based on the varying visual information. Measurements of coordinates between separate points of GPS tracks were taken from two to five times per second. Distances between the distinct coordinates in GPS tracks were within the range of three to five meters.

Comparison of Flight Features and Visual Features of Terrain
The flight features were distinguished by calculation methods, using GIS applications in QGIS (https://qgis.org). Borders between dissimilar textures, as well as linear objects, were selected using tools for constructing isolines. Flight characteristics at the intersections of isolines and pigeon trajectories were considered in more detail: mean standard deviations were calculated for all characteristics for 10 seconds before and 10 seconds after crossing the isolines. Figure shows an example of identifying intersections of flight tracks and of extended objects.

INTRODUCTION

The topic of spatial perception plays an important role in understanding the relationship between the earth's surface and living species, between the environment and the movements and migrations of animals. The study of landscape's and landmarks' features allows to better explore how space is represented in the mind. To improve their investigations, researchers need more detailed information about spatial perception and cognition, and about brain organization, which controls these processes.

This presentation is devoted to the application in the field of spatial perception systems during the movement. Such topic are fundamentally interdisciplinary and it includes many specific questions for studying: from the complexity of neurological systems, to the ambiguity of the landscape features and the uncertainty in localization while perceptions.

The presentation shows possible influence of natural landscape on spatial perception and, as result, on changing in trajectories.

The navigational behavior of birds is based on the spatial perception of the terrain over which they fly. Not only single reference points, but also continuous linear and areal objects can be visually perceived in flight and affect the flight path. In this work, we studied the features of the trajectories of pigeons during flights in order to identify the effect of discrete or continuous extended landmarks on spatial orientation. For this purpose we compared the GPS tracks of pigeons flying over weakly familiar terrain, and the visual features of this terrain, calculated on the basis of remote sensing data. Various cases of linear landmarks (alleys, rivers, roads) and boundaries between different surfaces (vegetation covers, water surfaces, rural or urban areas) were considered. Values of changes in flight parameters of pigeons were calculated for 150 flights over various mixed landscapes: natural forests, agricultural fields, urban and suburban areas, and the sea coast. Linear and area landmarks were recognized by satellite images of the territories, using spatial analysis methods to highlight the boundaries of particular homogeneous and heterogeneous patterns. As a result, typical reactions to extended objects during movement were revealed: either a long flight along the border with small fluctuations in the trajectory, or a sharp perpendicular crossing of the object's border. In this study, all spatial data were processed using the geographical information system QGIS.

RESULTS

In this study, 150 flights of pigeons were analyzed. The number of points in GPS records for individual pigeons ranged from 1,600 to 7,400. Pigeons flew over a mixed territory composed of forests, agricultural fields and urban territory with low-rise buildings.

Based on the calculations made in this work, various cases were identified, for which the flight characteristics of pigeons are stable or sensitive to a change in external environment. Such methods can be applied to study the navigational mechanisms in pigeon flight over mixed terrains.

Using the method of multi-factor analysis, it was found that in order to compare the flight characteristics of pigeons with the type of territory over which they fly, it is necessary to take into account four factors in GPS track sections: i) a stable direction for five or more seconds, ii) a high variability in direction or sharp change in direction, iii) stable height for five or more seconds, iv) a high variability in height.

This study shows the roles of sustainability (return to the previous value after deviation), sensitivity (variations in flight features near lengthy linear objects or near boundaries of distinct areas), and scale perception (represent itself in change of flight height).

GIS APPLICATIONS

Geographic information system (GIS) allow the handling of the flight path with reference to the locations and terrain features, including:

Process GPS data with precise spatial reference to terrain.

Calculate variation in directions of motion and in neighbour distances by vector data.

Build summary diagrams of the dependence of different flight parameters with reference to time and to coordinates along the flight trajectories.

Calculate the terrain features obtained from remote sensing data-such as the boundaries between different types of terrain, or the density of special points on the surface in the form of a heat map.

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