Statistical evaluation of artificial intelligence systems
Project I
January 2022

Human movement patterns in obstacle avoidance

Scientists at *Institut für Neuroinformatik* at *Bochum University* have conducted experiments studying how humans move objects with the hand. Here the focus is on obstacle avoidance, a trivial task to do, but not to analyse.

Introduction Ten right-handed people were asked to move a cylinder over another cylinder in 16 different experimental setups. The movement were recorded by motion capture equipment. Each person repeated this movement 10 times.

This is foundational research without a clear application. But an understanding of the possibility of using AI in this quite restricted setup could help us assessing the potential of using AI on motion capture data, with applications in e.g. robotics, sports sciences, or as a diagnostic tool.

There are some clear patterns in data, but also systematic differences to be investigated. Note that the main focus of the project is on statistical evaluation and not on getting the best/most advanced prediction models.

Experiments The size and position of the obstacle cylinder were changed. There were three different obstacle sizes (20 cm (S), 27.5 cm (M), 35 cm (T)) and five different obstacle positions (15 cm, 22.5 cm, 30 cm, 37.5 cm, 45 cm), measured from the start. Furthermore, one experiment was conducted without an obstacle giving sixteen different experimental setups in total:

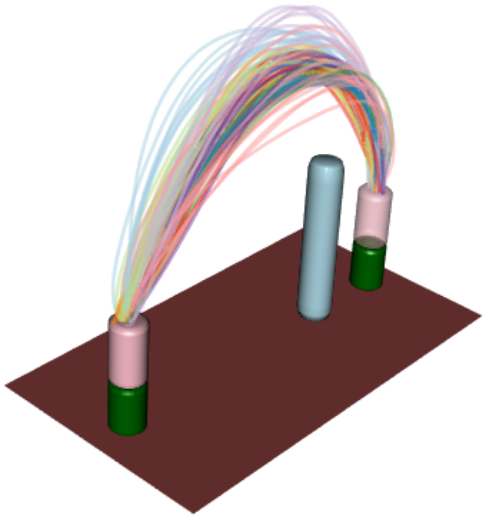
Experiment no.	d	obstacle
1		S
2	15.0 cm	M
3		T
4		S
5	22.5 cm	M
6		T
7		S
8	30.0 cm	M
9		T
10		S
11	37.5 cm	M
12		T
13		S
14	45.0 cm	M
15		T
16	NA	-

Data Data is a nested list of matrices with three layers. Each matrix has dimensions 100×3, where x (longitudinal), y (transversal) and z (vertical) coordinates are column 1, 2 and 3, respectively.

- First layer: *Experiments*.
- Second layer: *Persons*.
- Third layer: *Repetitions*.

Data have been slightly pre-processed so that all curves have the same length. Some curves have missing data.

An illustration (here of experiment 15) is seen below. Colours are according to the individual doing the experiment:



Project goals

1. Assess if there is a significant effect of person on the observed trajectories.
2. Use one or more appropriate machine learning models to predict the size and position of the cylinder from observation and evaluate this prediction.
3. Assess if we can do this prediction equally well with only two of the spatial coordinates [ie. x/y, x/z, y/z vs. x/y/z].
4. There is a potential bias and fairness issue since the participants are all right-handed, however a minority of the population are left-handed. Discuss this issue from a statistical evaluation perspective. You may assume a left hand/right hand mirror symmetry across the x/z plane.
5. Summarize your most important findings in a conclusion. Do you think there is basis for conducting further research/experiments in relation to using AI with motion capture systems and obstacle avoidance?

Remarks The attached pdf `armmovement.pdf` contains a good introduction to data.

Visualisation 3d plots in R can be made using the `rgl` package. Try for instance:

```
library(rgl)

start_cyl <- cylinder3d(cbind(0, 0, seq(0, 10, length = 10)), radius = c(3,3,3), sides = 20, closed = -2)
target_cyl <- cylinder3d(cbind(60, 0, seq(0, 10, length = 10)), radius = c(3,3,3), sides = 20, closed = -2)
cyl1 <- cylinder3d(cbind(0, 0, 10 + seq(0, 12.5, length = 10)), radius = c(3,3,3), sides = 20, closed = -2)
cyl2 <- cylinder3d(cbind(60, 0, 10 + seq(0, 12.5, length = 10)), radius = c(3,3,3), sides = 20, closed = -2)
cyl3 <- cylinder3d(cbind(30, 0, seq(0, 20, length = 10)), radius = c(3,3,3), sides = 10, closed = -2)

shade3d(addNormals(subdivision3d(start_cyl)), col = 'darkgreen')
shade3d(addNormals(subdivision3d(target_cyl)), col = 'darkgreen')
shade3d(addNormals(subdivision3d(cyl1)), col = 'pink')
shade3d(addNormals(subdivision3d(cyl2)), col = 'pink', alpha = 0.5)
shade3d(addNormals(subdivision3d(cyl3)), col = 'lightblue')

surface3d(c(-7, 67), c(-20, 20), matrix(0, 2, 2), col = "brown", alpha = 0.9, specular = "black")

lines3d(armdata[[7]][[1]][[1]])
```

References

B. Grimme, *Nachweis und Analyse elementarer Invarianten als Bausteine menschlicher Armbewegungen*, PhD thesis, Internationalen Graduiertenschule Biowissenschaften, Ruhr-Universität Bochum, 2014.

L.L. Raket, B. Grimme, G. Schöner, C. Igel, B. Markussen, *Separating timing, movement conditions and individual differences in the analysis of human movement*, PLOS Computational Biology, 2016.

N.L. Olsen, B. Markussen, L.L. Raket, *Simultanous inference for misaligned multivariate functional data*, Journal of the Royal Statistical Society, Series C, 2018.