LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

mobile and distributed systems group

Archetypal Routes

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Werk1, Munich
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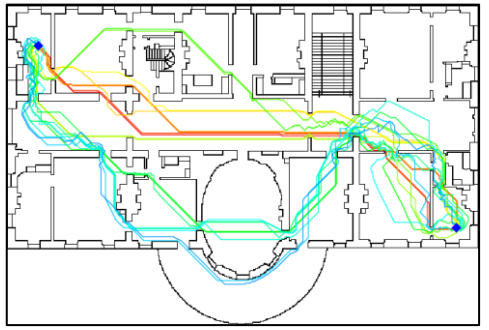
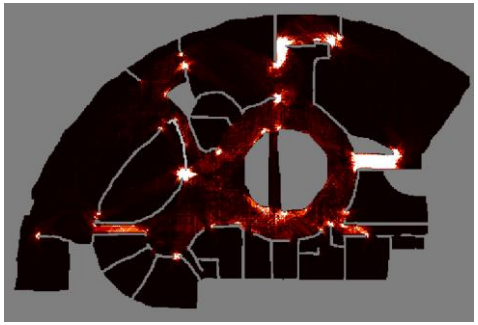
Motivation

"Map-based calculation and processing of geospatial trajectories"

- Indoor Navigation
  - Assistance in hospitals, airports, fair, ...
  - Mobile robots (smart city, ambient assisted living)
  - Non-player character in computer games



- Alternative Routes
  - What is an alternative route? How to find them?
  - Is there a quality of alternative routes?
  - How to get preferably diverse routes?

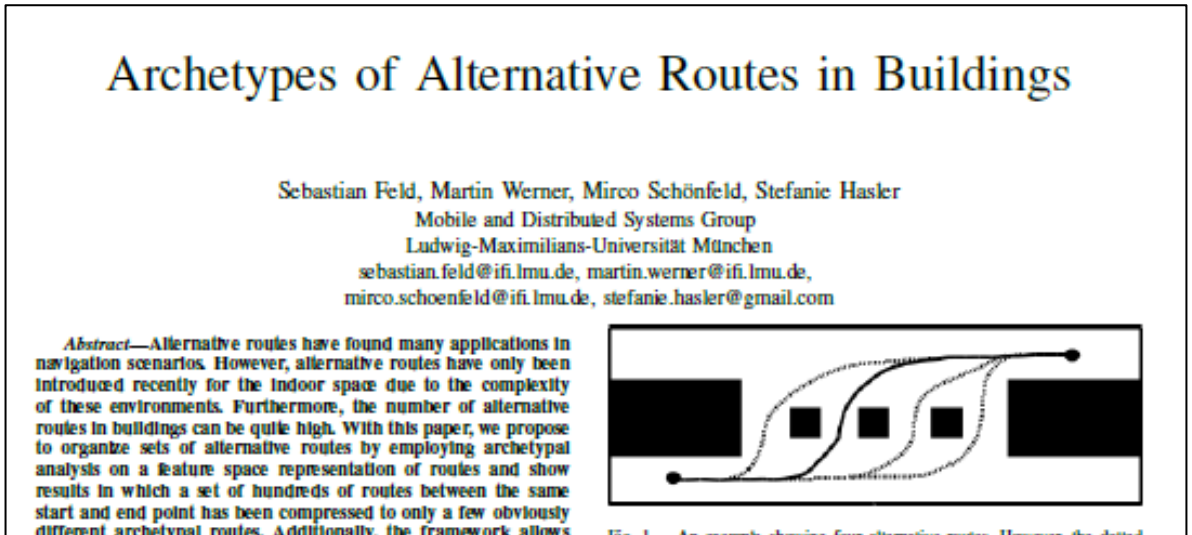


- Leaving the application level
  - Similarity or distance metrics of geospatial trajectories
  - In particular regarding indoor scenarios, i.e. floor plans

Today's topic

"Map-based calculation and processing of geospatial trajectories"

- Main idea
  - "Marry" archetypal analysis with alternative routes in buildings
  - Observations are routes, exemplary features are overlength or number of turns



Archetypes of Alternative Routes in Buildings

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Abstract—Alternative routes have found many applications in navigation scenarios. However, alternative routes have only been introduced recently for the indoor space due to the complexity of these environments. Furthermore, the number of alternative routes in buildings can be quite high. With this paper, we propose to organize sets of alternative routes by employing archetypal analysis on a feature space representation of routes and show results in which a set of hundreds of routes between the same start and end point has been compressed to only a few obviously

Three main contributions

1. Definition of
   - Abstract archetypal routes
   - Realized archetypal routes
   - (Faithful archetypal routes)

2. Novel measure for route similarity
   - Archetypal distance

3. Framework
   - Postprocessing of routes
   - Analysis, interpretation, understanding

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***Abstract*—Alternative routes have found many applications in navigation scenarios. However, alternative routes have only been introduced recently for the indoor space due to the complexity of these environments. Furthermore, the number of alternative routes in buildings can be quite high. With this paper, we propose to organize sets of alternative routes by employing archetypal analysis on a feature space representation of routes and show results in which a set of hundreds of routes between the same start and end point has been compressed to only a few obviously different archetypal routes. Additionally, the framework allows for comparing routes with archetypes and with each other. This comparison does not reveal spatial similarity alone, but rather a measure of routes' similarity representing their inherent semantic character.**

I. Introduction

Navigation is surely one of the most frequently used applications with mobile devices. Even for indoor scenarios there is a constantly growing quantity of use cases. Think of construction workers that have to inspect several machines in complex industrial buildings, visitors of unknown premises like hospitals, museums or airports, and mobile robots in store houses collecting goods [25].

An extension to the classical wayfinding problem is the identification of alternative routes. This topic is handled well for outdoor scenarios like street networks, see for example the formidable survey of Bast et al. [3]. But there is also an increasing need for alternative routes in indoor scenarios. Think, for example, of firefighters needing an alternative to a given yet blocked route, or a navigation system at an airport proposing different routes in order to proactively prevent congestions or as a basis for multi-criteria optimization along different paths (e.g., types of shops).

Like just stated, there is much literature on the identification of alternative routes in street networks [1], [10], [21]. Basically, the algorithms focus on finding routes that differ on the highways mainly used. Unfortunately, the preconditions in indoor scenarios are quite different. The main limitation is the higher degree of freedom of movement as compared to street networks: a person can walk almost freely inside the corridors and halls resulting in possible turns not only at crossroads. The first definition of alternative routes in indoor scenarios has been given by Werner and Feld [28]. In summary, they define two routes having the same start and end point as proper alternatives if they traverse obstacles like walls or pillars on different sides. See Figure 1 as an example showing four alternative routes.

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Fig. 1. An example showing four alternative routes. However, the dotted lines can be regarded as variations of the solid route.

The strength of this approach is the simple and clear definition together with the fact that this idea results in an equivalence relation. The main drawback is that the definitions given in [28] quickly lead to rather large sets of alternative routes in noisy floorplans, since small artefacts like furniture lead to the identification of alternative routes, even if the routes just have small variations.

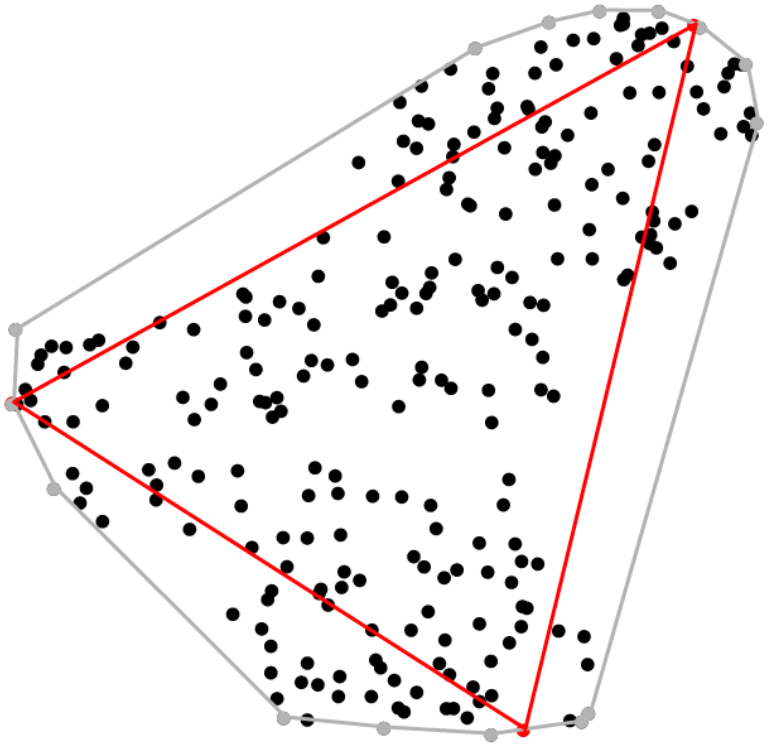
With this paper, we concentrate on the question how to extract small sets of alternative routes with pairwise sensible dissimilarity from the set of all given alternative routes between two points. Note that the following analysis has been done with alternative routes in mind, but can be applied to any set of routes, for example when tracking multiple mobile devices in a building. Therefore, we propose to utilize archetypal analysis [8] – a statistical method for analyzing multivariate data sets – in the field of indoor navigation and in particular as a postprocessing step for the further understanding of given alternative routes. Given a floorplan and a (large) set of routes having the same start and end point, the objective is to find a small subset such that these routes are "pure types" (called archetypes), i.e. they represent ideal observations the other data points are combinations of. Now, the selection of routes will no longer focus only on the geometry or shape of the route (like the homotopy-based approach of [28]), but additionally on their particular nature and properties defined by the archetypes. In summary, we cluster a given set of routes based on their similarity to extreme examples called archetypes.

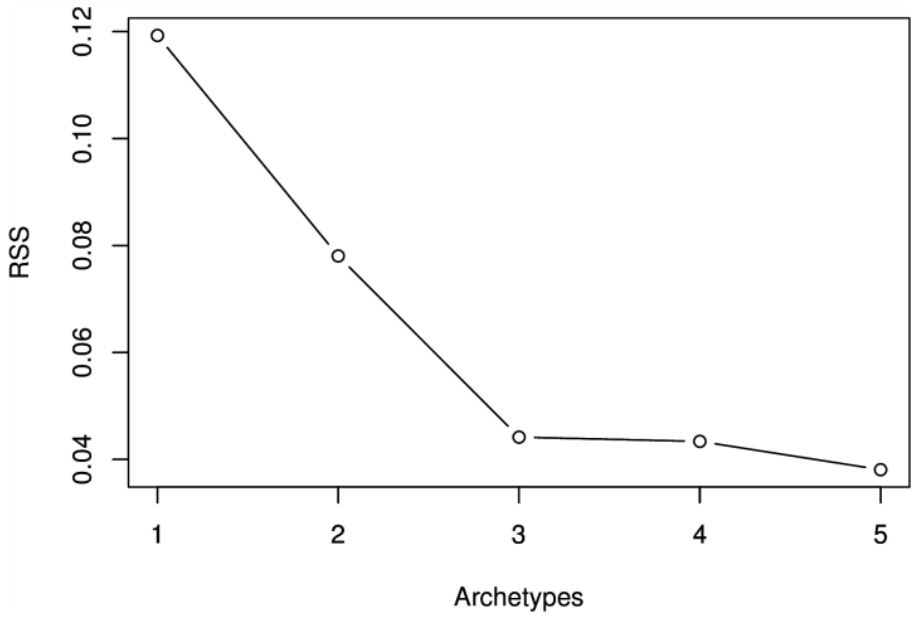
The main contributions of this paper are: (1) The definition of *abstract archetypal routes*, *realized archetypal routes*, and *faithful archetypal routes*. (2) The definition of a novel measure for route similarity, the *archetypal distance* between routes. (3) A framework to postprocess a given set of alternative routes in order to filter, analyze, and interpret them for a better understanding of the relation between routes and map.

The paper is structured as follows: Section II reviews

Archetypal analysis

- Archetypal analysis (AA)
  - focusses on extremum, prototypes, originals, pure types → “preferably diverse…”
  - approximates dataset’s convex hull in feature space using k points (=archetypes)





Archetypal analysis

Observations

Wayne Gretzky
Mark Messier
Gordie Howe
Jaromir Jagr
Ron Francis
Marcel Dionne
Steve Yzerman
Mario Lemieux
Joe Sakic
Phil Esposito
…

⇨

Features

GP	Games Played
G	Goals
A	Assists
PIM	Penalty Minutes
PPG	Power Play Goals
S	Shots
TOI/GP	Time On Ice Per Game
Shifts/GP	Shifts Per Game
FOW%	Faceoff Win Percentage
…	

⇨

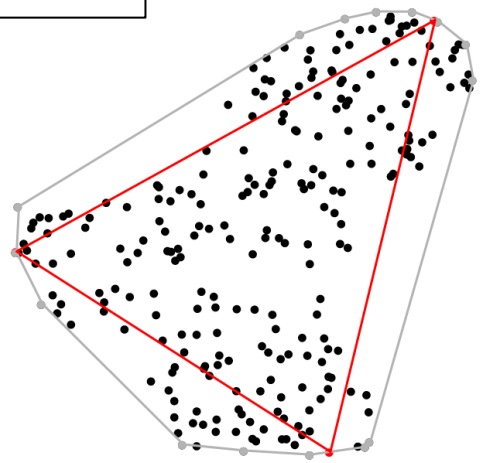
Archetypes

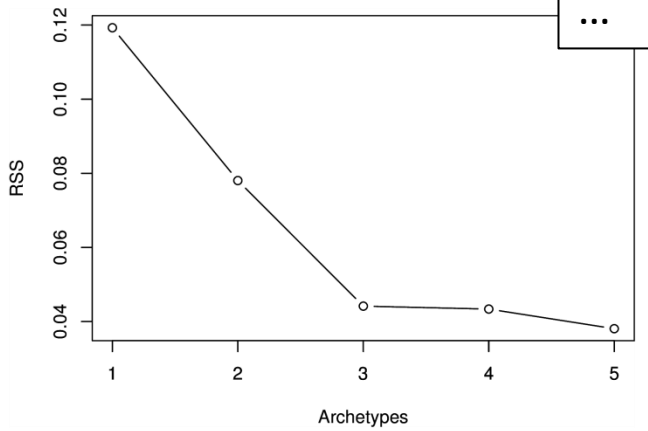
Archetype A
Archetype B
Archetype C
…

⇩

Interpretation

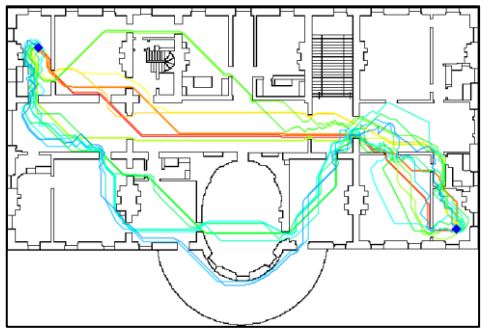
Forward
Defensemen
Goaltenders
…





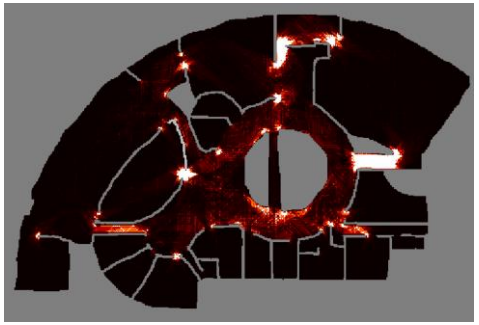
Framework's Implementation

- Observations
  - (Alternative) routes generated using "Indoor Penalty" algorithm (Werner, Feld, 2014)
  - Tupels $< x, y, id_{route}, id_{class} >$



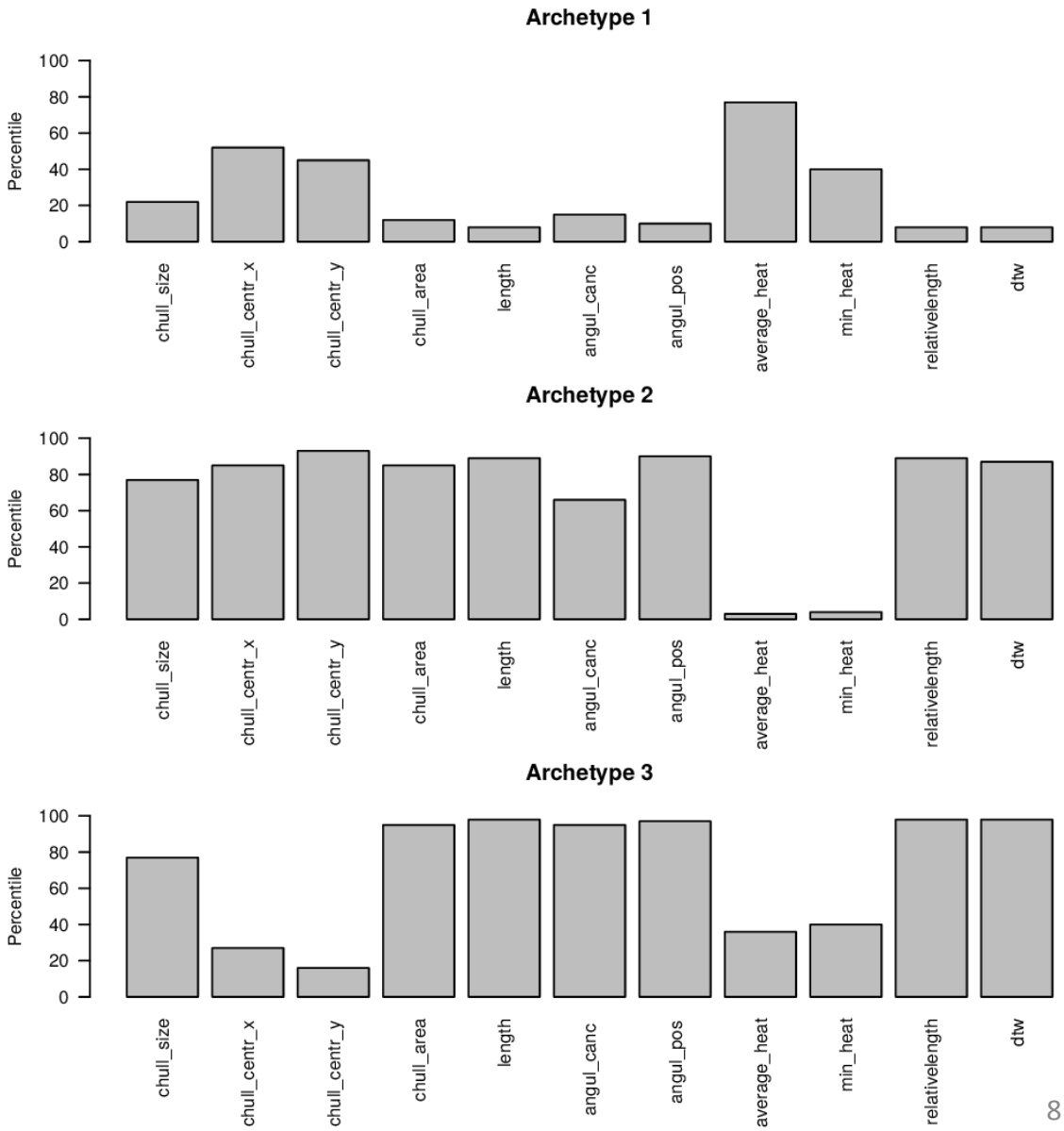
- Features
  - Convex hull's area, size, and centroid — Regarding the shape
  - Length
  - Angular sum (cancelling/positive)
  - Relative length — Regarding the shortest route
  - DTW distance
  - Pixel's average/min "heat" (Feld, 2015) — Regarding the map

- Archetypal analysis
  - R package "archetypes" in CRAN repository



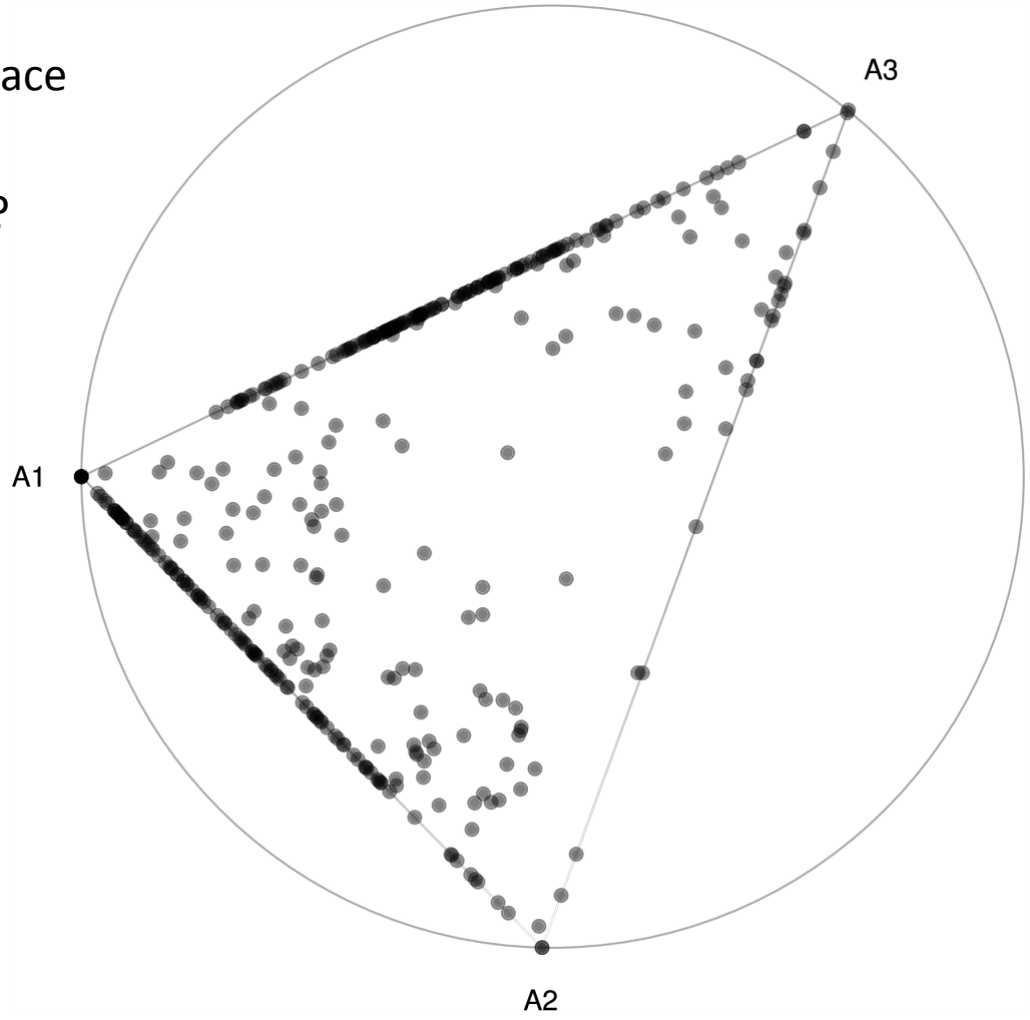
Abstract archetypal routes

- Feature set in framework
  - Few, simple features
  - “in-house means” of R
- Abstract archetypal route
  - Concrete feature configurations
  - Important: not necessarily observed!

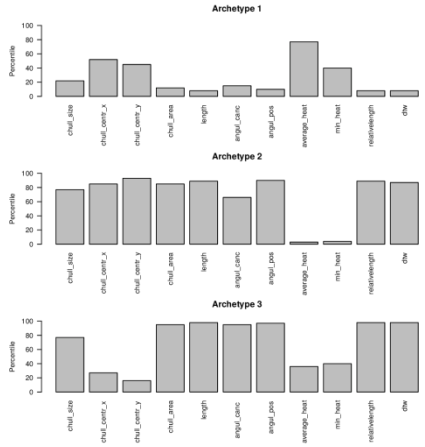


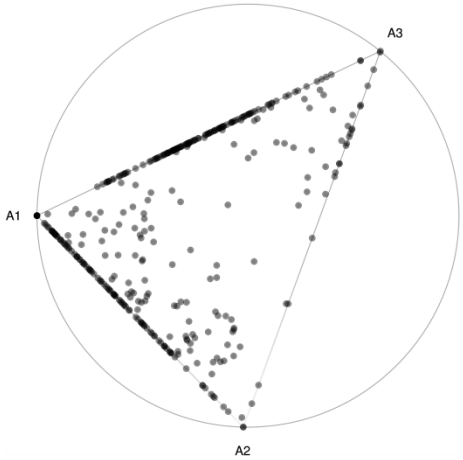
Realized archetypal routes – feature space

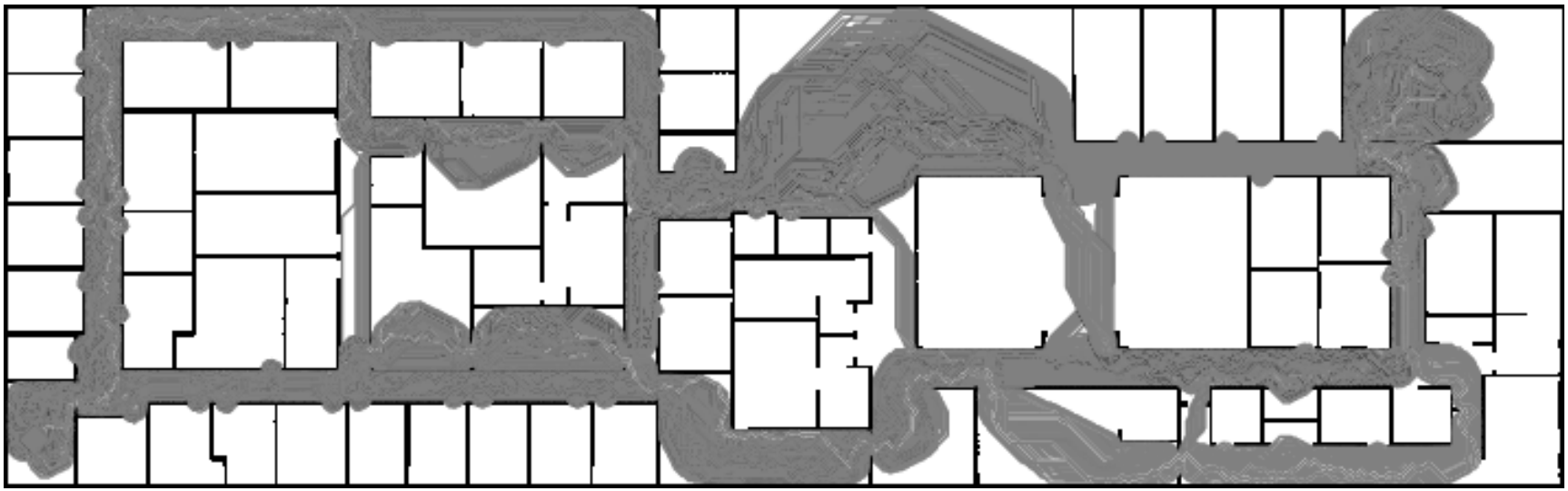
- Realized archetypal routes
  - Suggestion: “Nearest neighbor”
  - Euclidean distance in feature space
- And the corresponding observation?



Realized archetypal routes – instance space

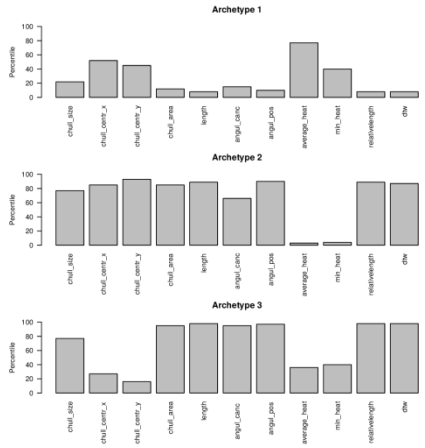


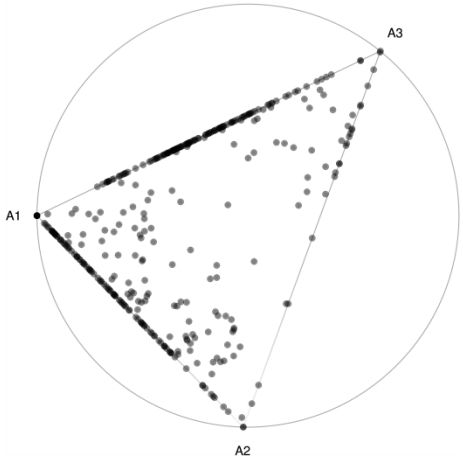


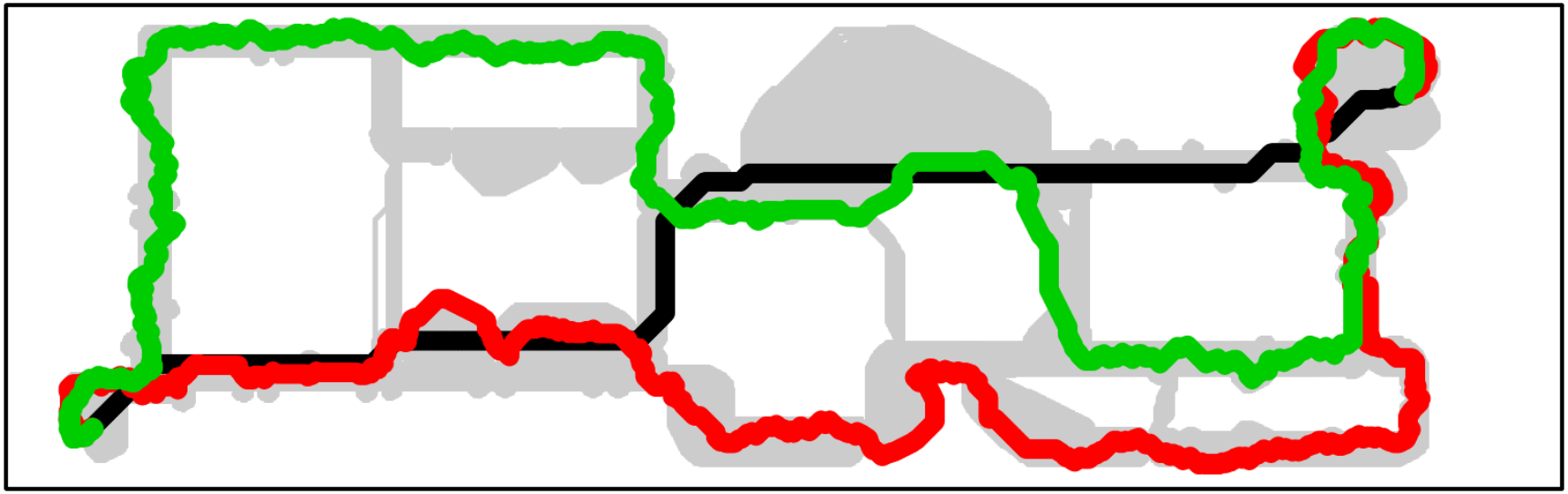


$N = 400, \qquad c = 23$

Realized archetypal routes – instance space



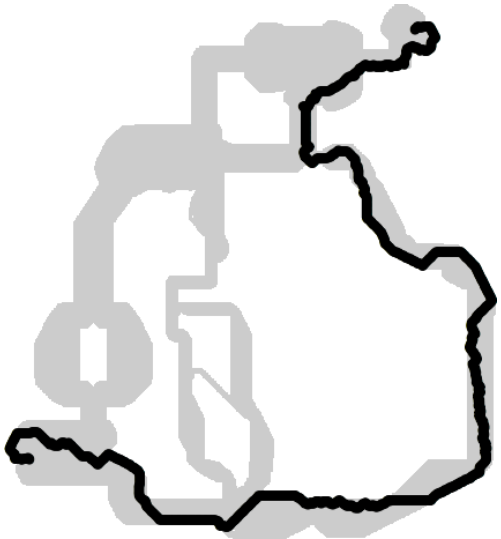


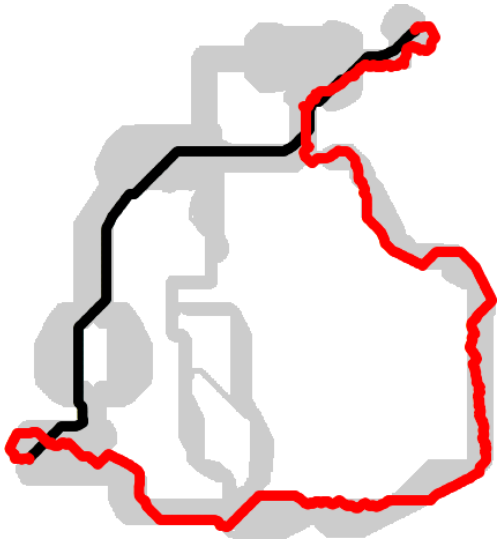


$N = 400, \quad c = 23, \quad m = 11, \quad k = 3$

Realized archetypal routes – instance space

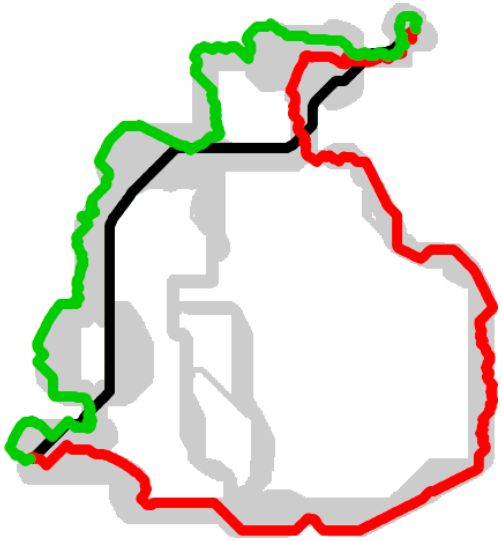
$k = 1$

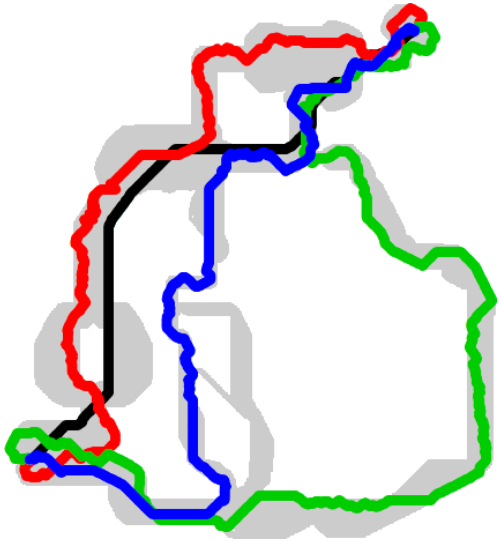




$k = 2$

$k = 3$



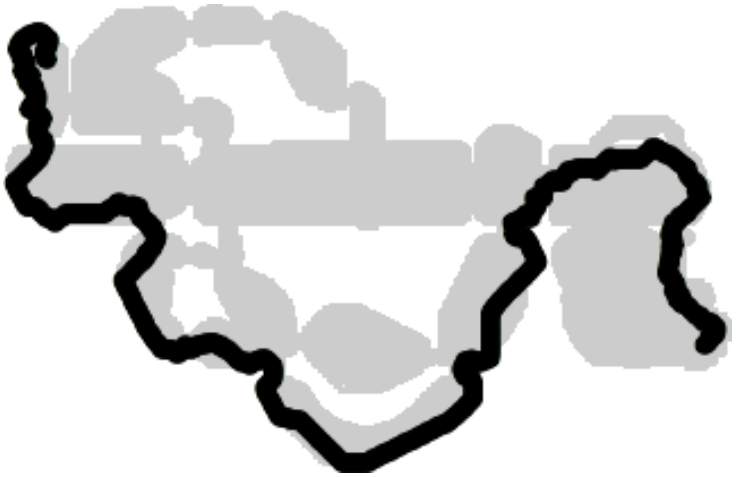


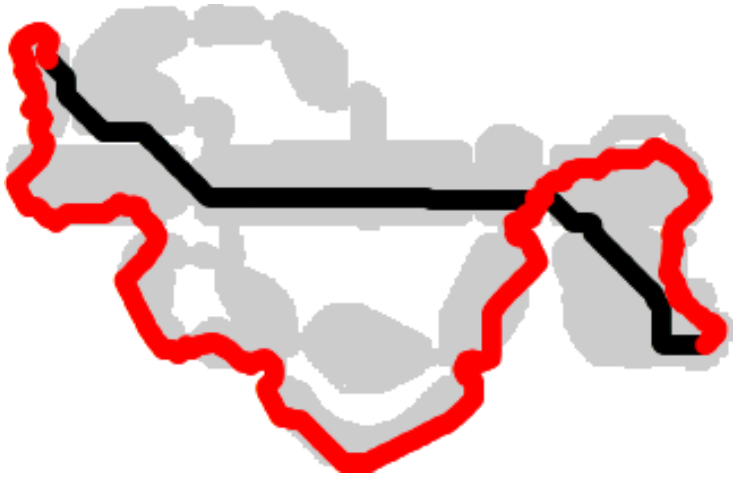
$k = 4$

$N = 400, \quad c = 10, \quad m = 11$

Realized archetypal routes – instance space

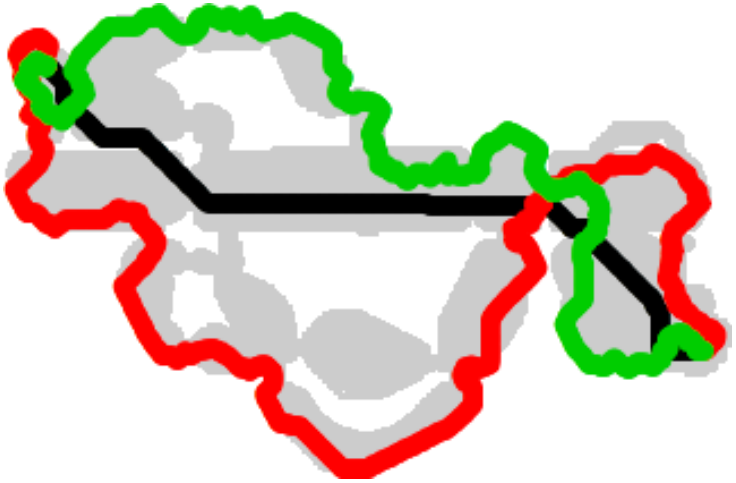
$k = 1$

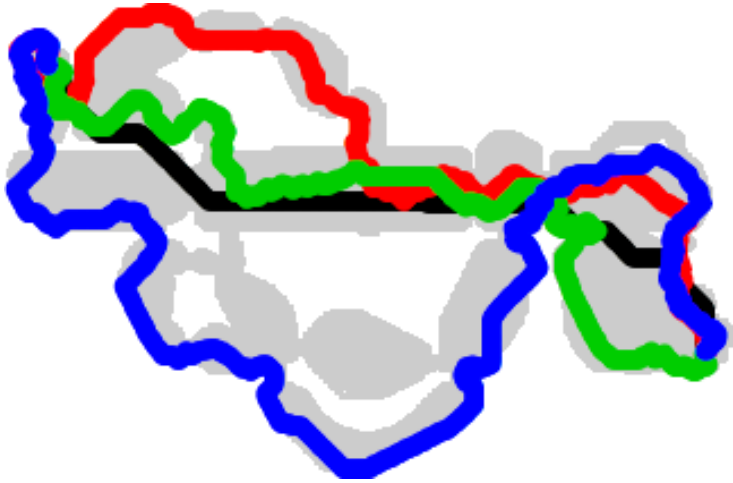




$k = 2$

$k = 3$





$k = 4$

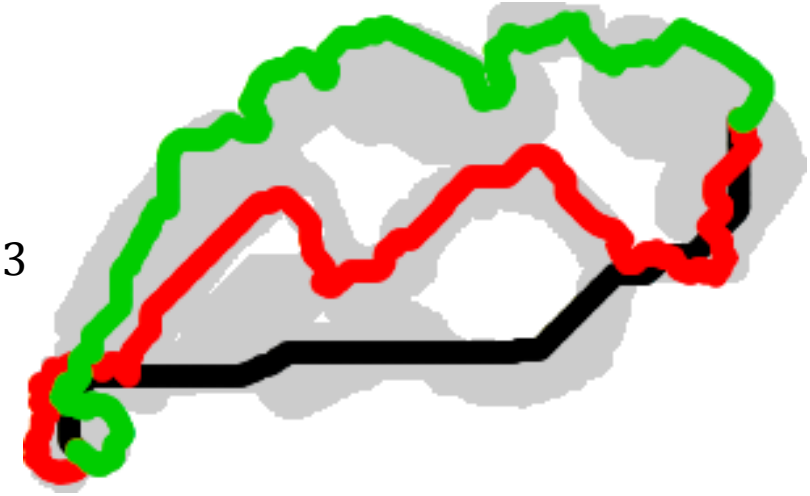
$N = 400, \quad c = 37, \quad m = 11$

Realized archetypal routes – instance space

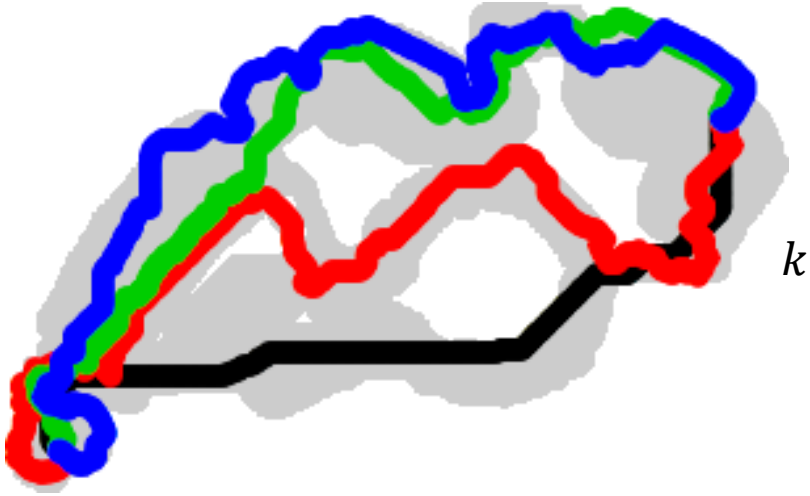
$k = 1$

$k = 2$

$k = 3$



$k = 4$

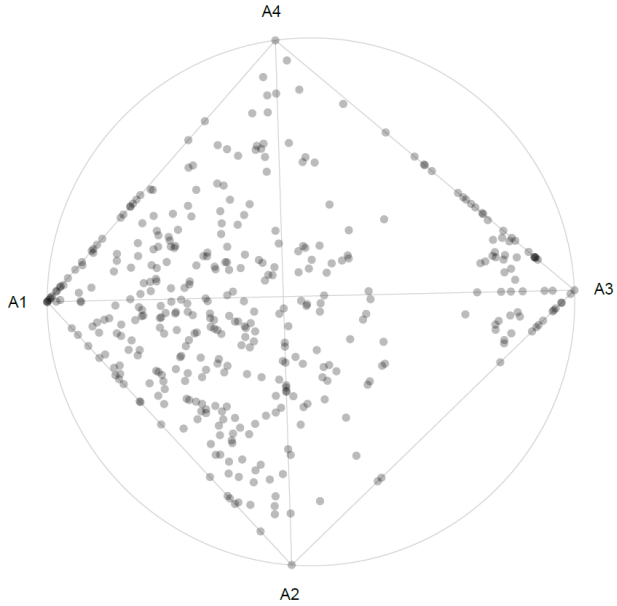


$N = 400, \quad c = 12, \quad m = 11$

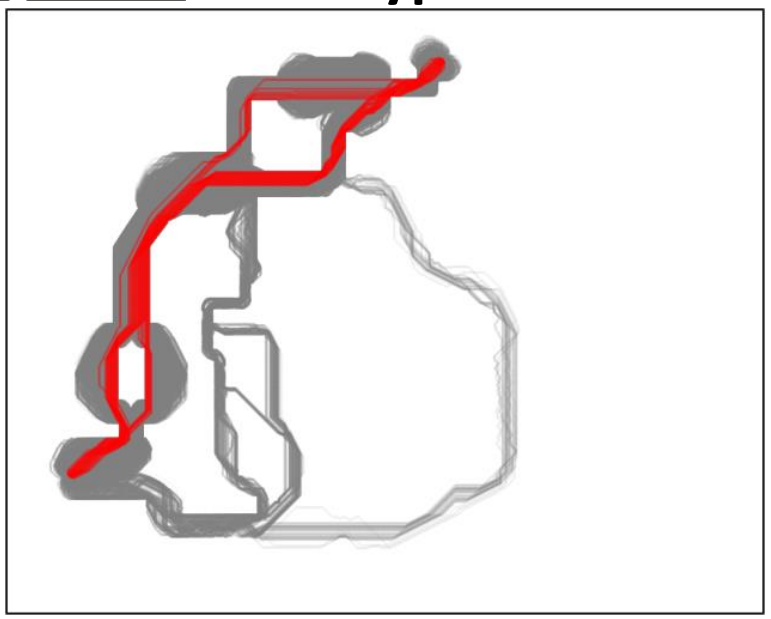
Faithful archetypal routes

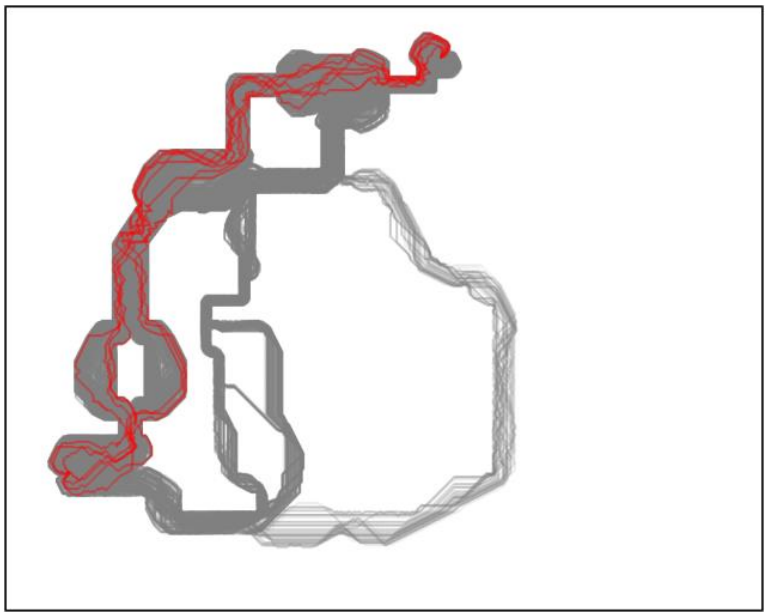
Archetypal distance

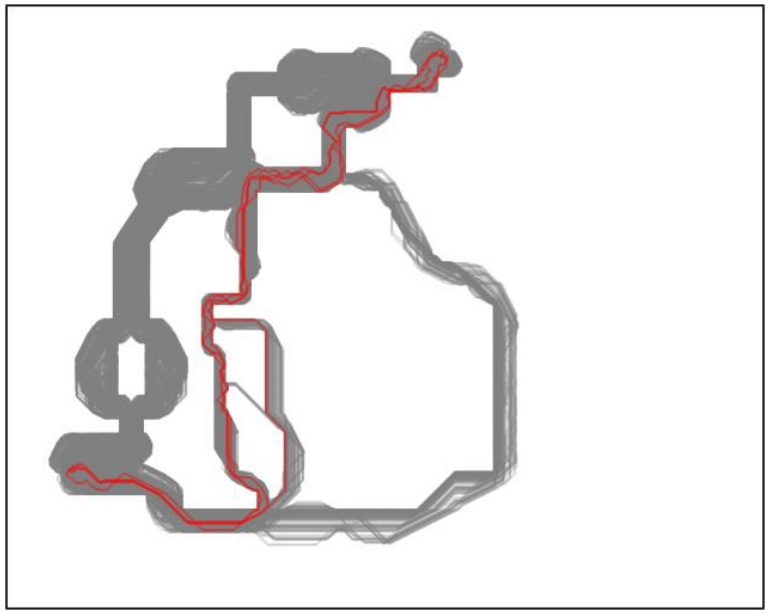
- Archetypal distance: Euclidean distance in feature space
- Expectation: observations with small pairwise archetypal distance show certain similarities (and vice versa)

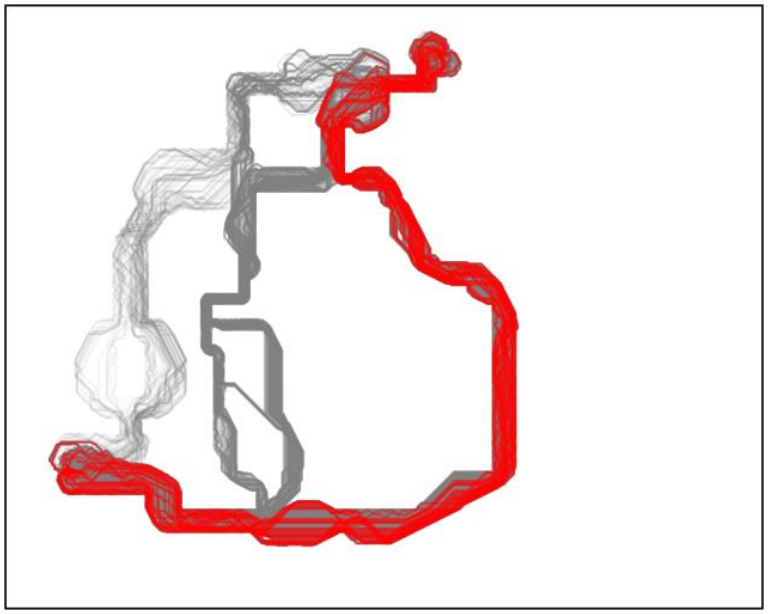


Archetypal distance



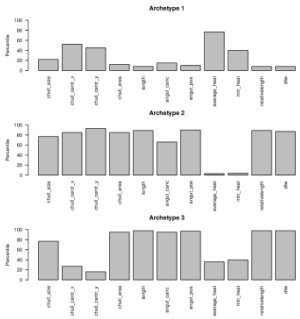




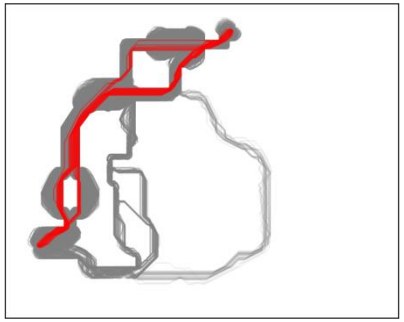


Conclusion

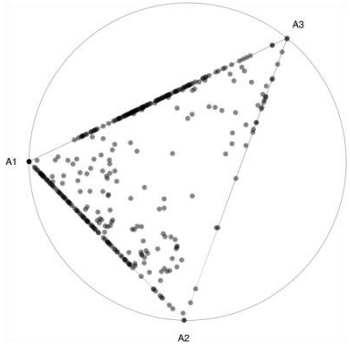
- Definition of archetypal routes
  - Focus not only on geometry or shape, but additionally on particular nature and properties



- Archetypal distance
  - Novel measure for route similarity relating to the map
  - Create sets of alternative routes (e.g. damp hunting phenomenon)



- Framework
  - Postprocess, analyze, and interpret routes
  - Subsequent comparison of observations



- Future Work
  - Analysis of feature's impact
  - Behavior of archetypal distance to existing similarity metrics

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