A Taxonomy of Attribute Scoring Functions

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Used Abbreviations

- ASF(s) = Attribute Scoring Function(s)
- VA = Visual Analytics

Introduction

Motivating Example

Imagine, you want to buy a used car. You want the car to:

- be as cheap as possible
- be as fast as possible
- be neither too old nor too new
- be black, silver or at least blue
- neither have a mileage too high or too low

Different Analysis Goals

- Multi-attribute ranking
- Multi-criteria optimization
- Similarity modeling

→ Focus on non-experts

Problem statement

- Non-experts without programming experience want to rank items based on their preferences
- Items have many different attributes
- Users have preferences for some of the attributes
- A ranking of the items should be created based on preferences for some attributes

Motivation

1. Distinction between ASFs and ASF creation tools
2. Both ASF and ASF creation tools have not yet been described systematically
3. Combine mathematical and VA research on ASFs
4. Investigate the interactive creation of ASFs
5. Support non-expert users in the interactive creation of ASFs

Our Contribution

- A hierarchical taxonomy of ASFs
- A tabular overview of ASF creation tools

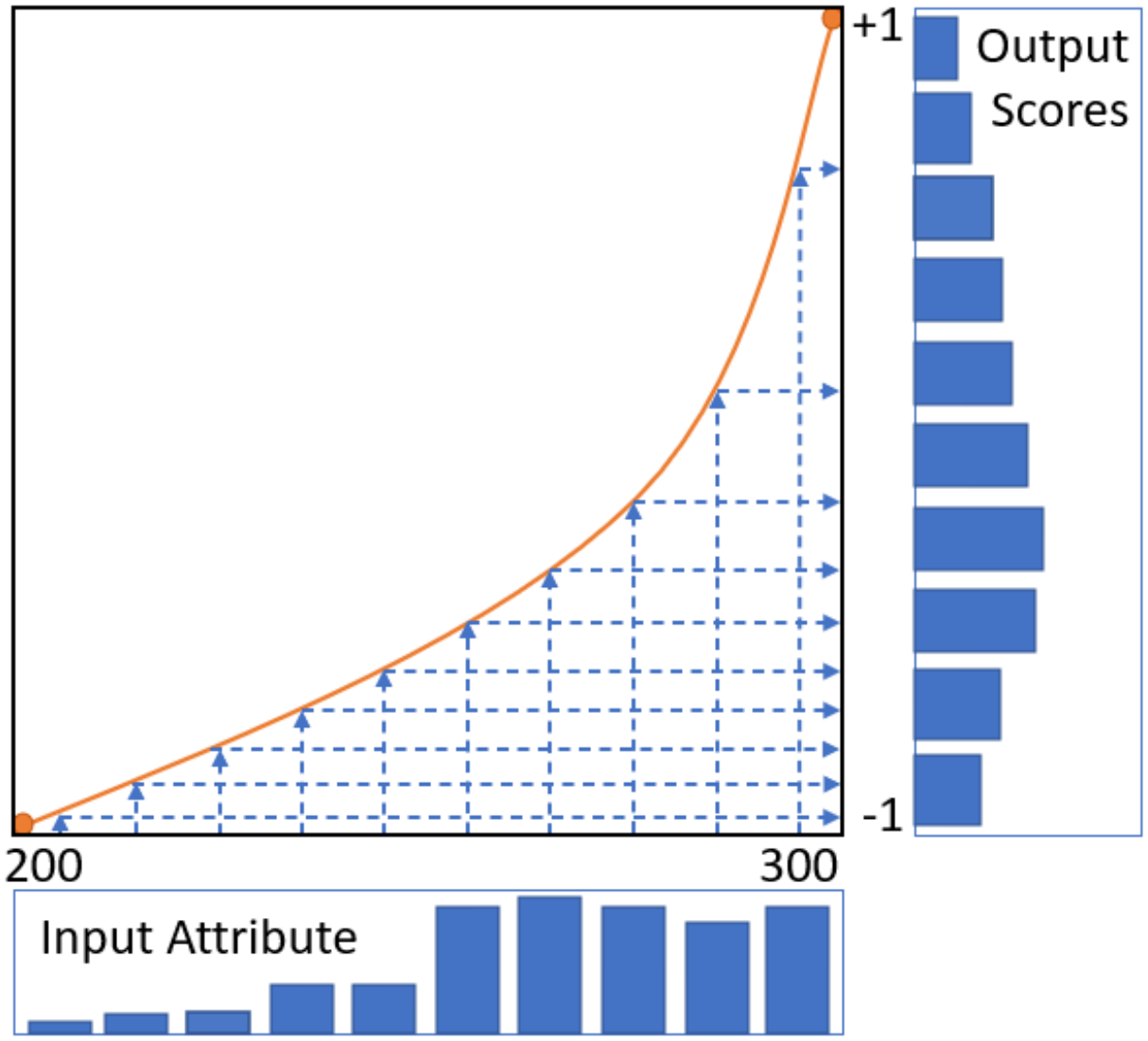
Formal Definition of Attribute Scoring Functions

What is an Attribute Scoring Function?

- An **ASF** is a transformation of attribute values (the input) into scores (the output) that carry information about user preferences
- A **score** is a numerical value in a predefined range e.g. [0 ..1]
- A score carries a **valence information** such as high values are good
- ASFs must be defined for the **entire** value domain

Visual Example

E.g. an ASF for the attribute **maximum speed**



Literature Research and Methodology

Criteria for Literature Research

- Two targets: **ASFs** and **tools for the creation** of ASF
- For **ASFs tools** we differentiate between tools with either only a mathematical or a visual analytical fit or both
- For **ASFs** we differentiate between ASFs for categorical and numerical input attributes
  - The found ASFs were used for the creation of the taxonomy

Result of Literature Research

- We found tools that:
  - support users with **programming experience** in expressing preferences **mathematically**
  - have an inspiring **VA approach** to define attribute transformations interactively but are not used for ASFs
  - contain a **VA component** and support users to **create ASFs interactively**

Result of Literature Research

	Categ.			Numerical				
	Score Assignment	Equidistant	Non-Equidistant	Linear	Non-Linear	Continuous	Discontinuous	Quantile-based
Attribute Numerification [JFJJ08]			x					
LineUp: Data Mapping Editor [GLG*13]				x		x		
PAVED [CMMK20]				x				
uRank [dSSV15]	v							
RanKit [KVD*18]		v	v					
ValueChart [CL04]			v					
Podium [WDC*18]			v					
HDR VolVis [YNCP06]						v		
VolumePro [KG01]						v		

Result of Literature Research

	Categ.			Numerical				
	Score Assignment	Equidistant	Non-Equidistant	Linear	Non-Linear	Continuous	Discontinuous	Quantile-based
TOPSIS [YH95]	m							
Weighted Sum [MA10]	m							
SMARTER [EB94]		m	m					
SMAA [TF08]		m	m					
LineUp: Scripting Interface [GLG*13]				m	m	m	m	m
Promethee [BV85]				m	m	m		
Transfer Function [CKLG98]				m	m	m		
WWW-NIMBUS [MM00]				m	m	m		
ValueTree [CL04]				m				

Taxonomy of Attribute Scoring Functions

Categorization of ASFs

- Strong **difference** between ASFs for **categorical and numerical** attributes
- Differentiation between:
  - **levels of complexity** (in a mathematical sense) for numerical ASFs
  - **degree of freedom** for creation of categorical ASFs

First Version of the Taxonomy

- Top-level differentiation between ASFs for **categorical and numerical** attributes
- For categorical ASFs:
  - Differentiation between **degrees of freedom** of parametrization (direct score assignment VS ordered categories)

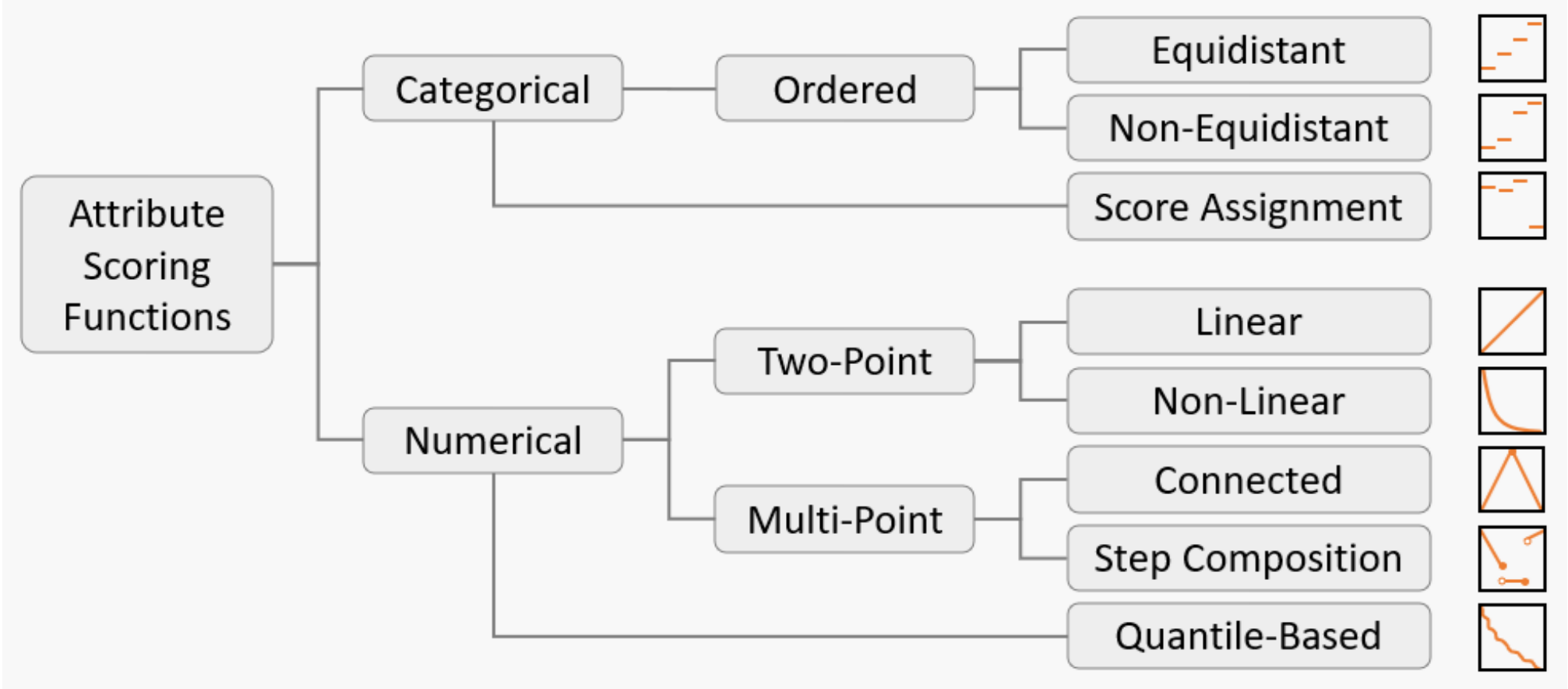
First Version of the Taxonomy

- For numerical ASFs:
  - First, grouping of ASF according to the **number of supporting points** (2 points, 3 points, 4+ points).
  - Second, grouping according to **line segment characterization** (linear VS non-linear, continuous VS discontinuous)
  - Special case for quantile-based ASFs

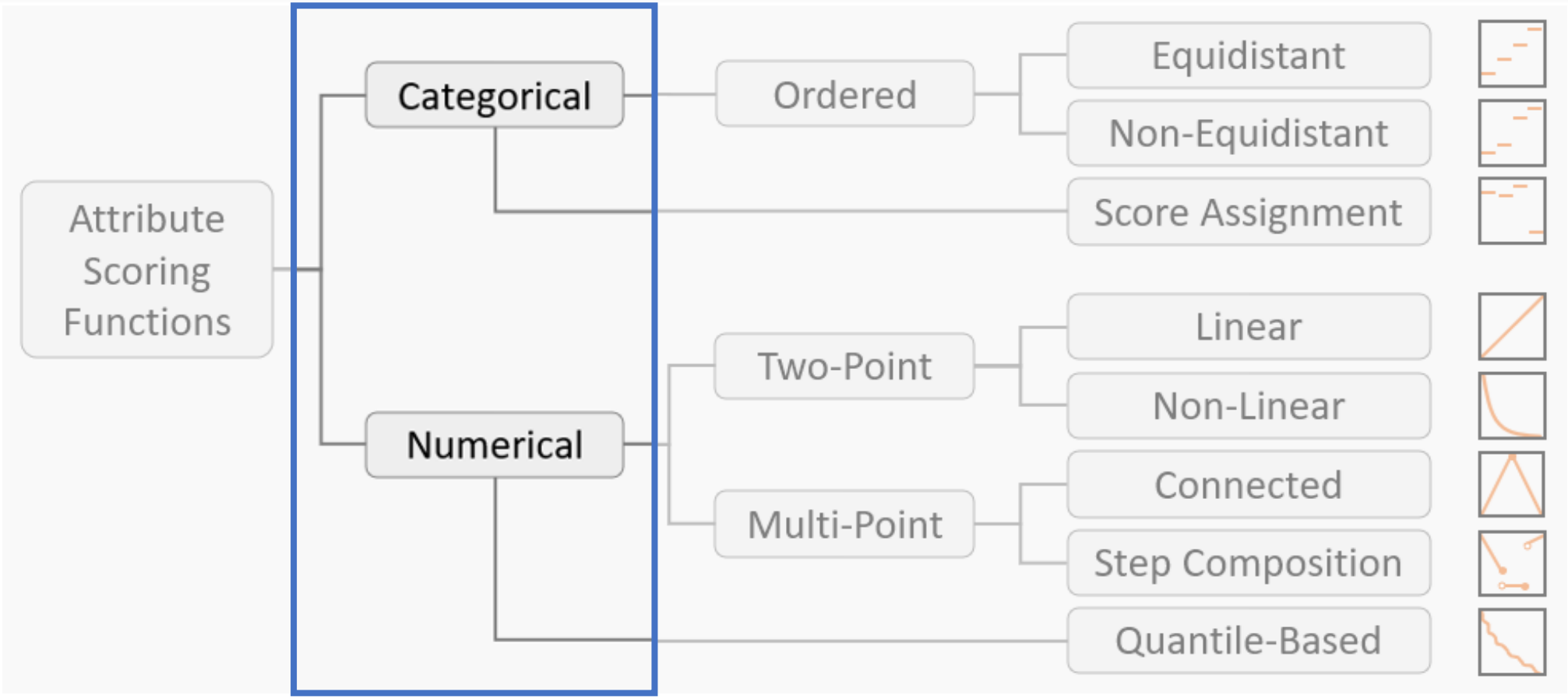
Refined Taxonomy

- Differentiation between categorical and numerical ASFs stayed
- For categorical ASF, no changes
- For numerical ASF:
  - Shift from distinction between number of points (2 point, 3 point, 4+ points) to a broader distinction between **2 points and multi-point**
  - Differentiation between **linear VS non-linea**r and **continuous VS non-continuous** stayed
  - Special case for quantile-based ASFs stayed

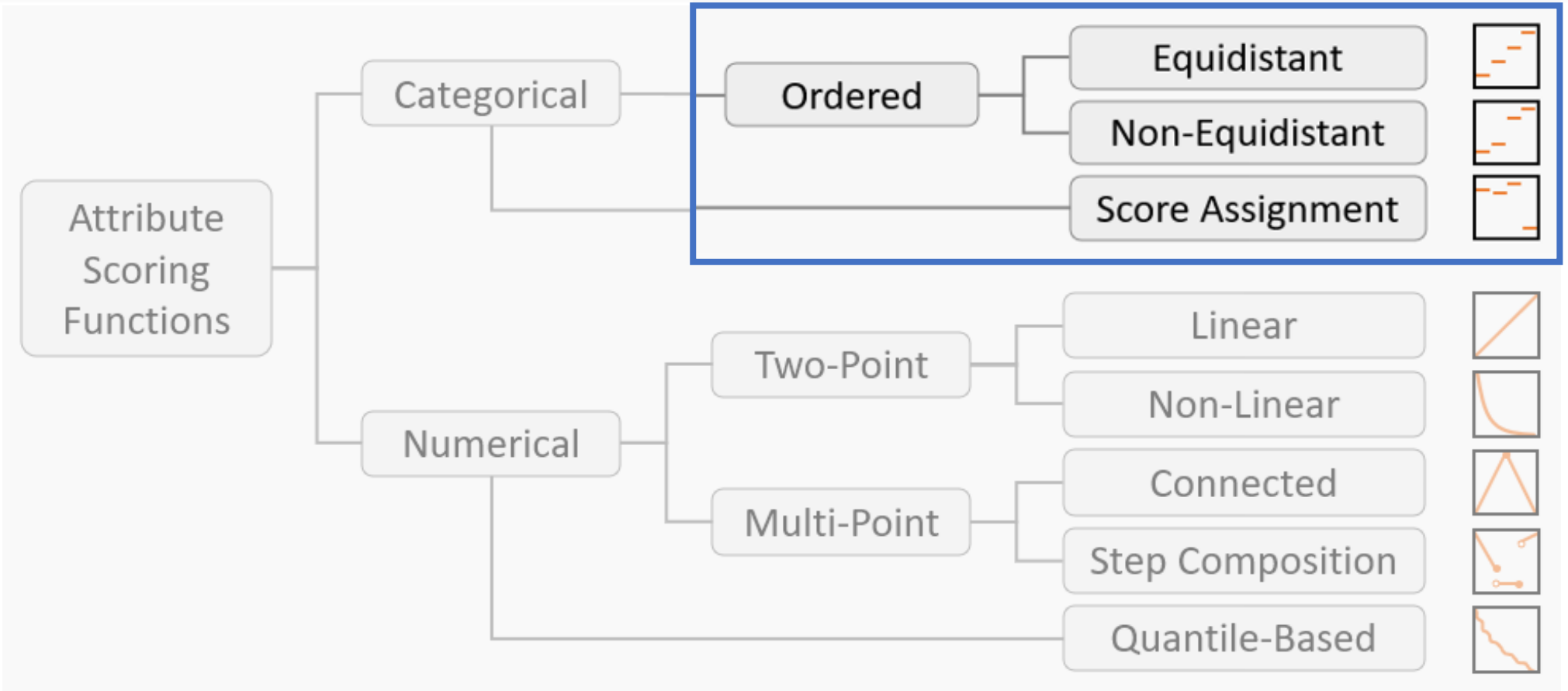
Final Taxonomy



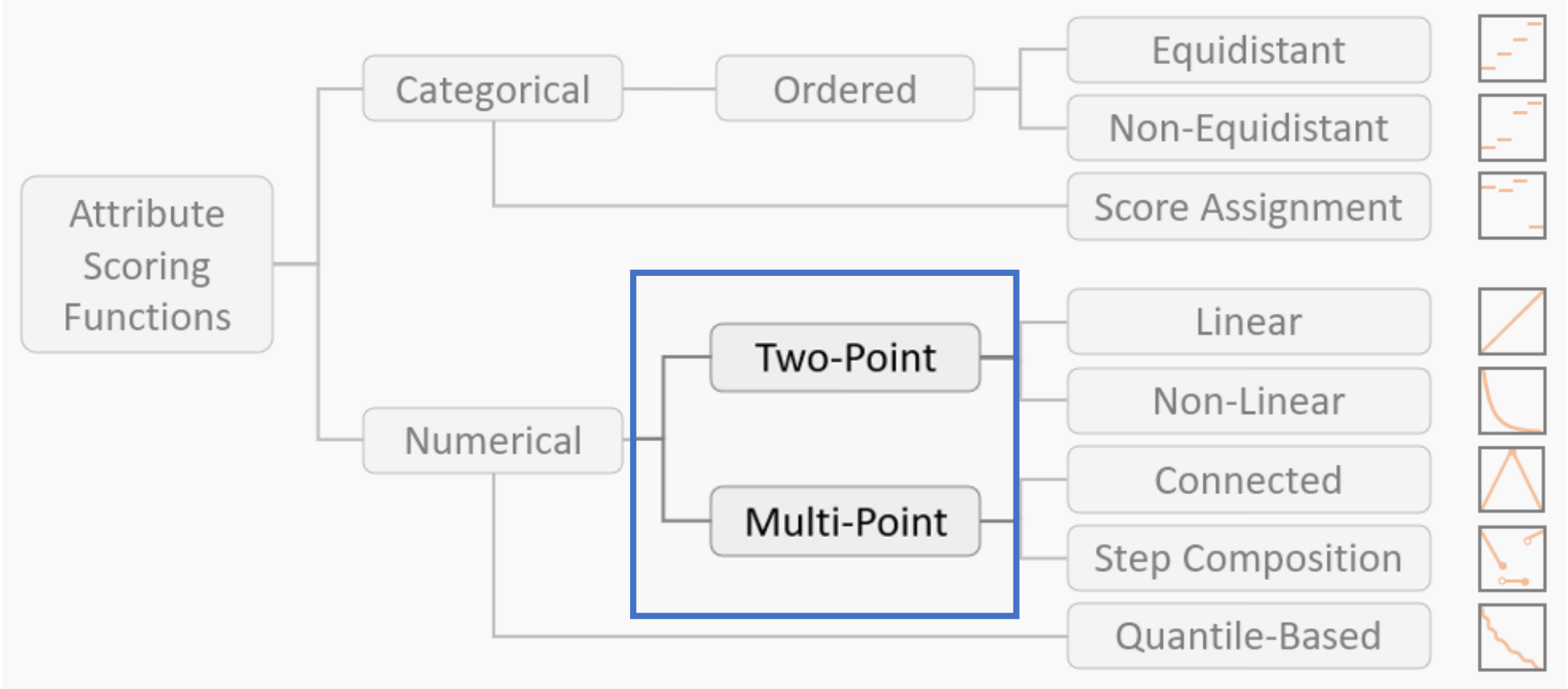
Final Taxonomy



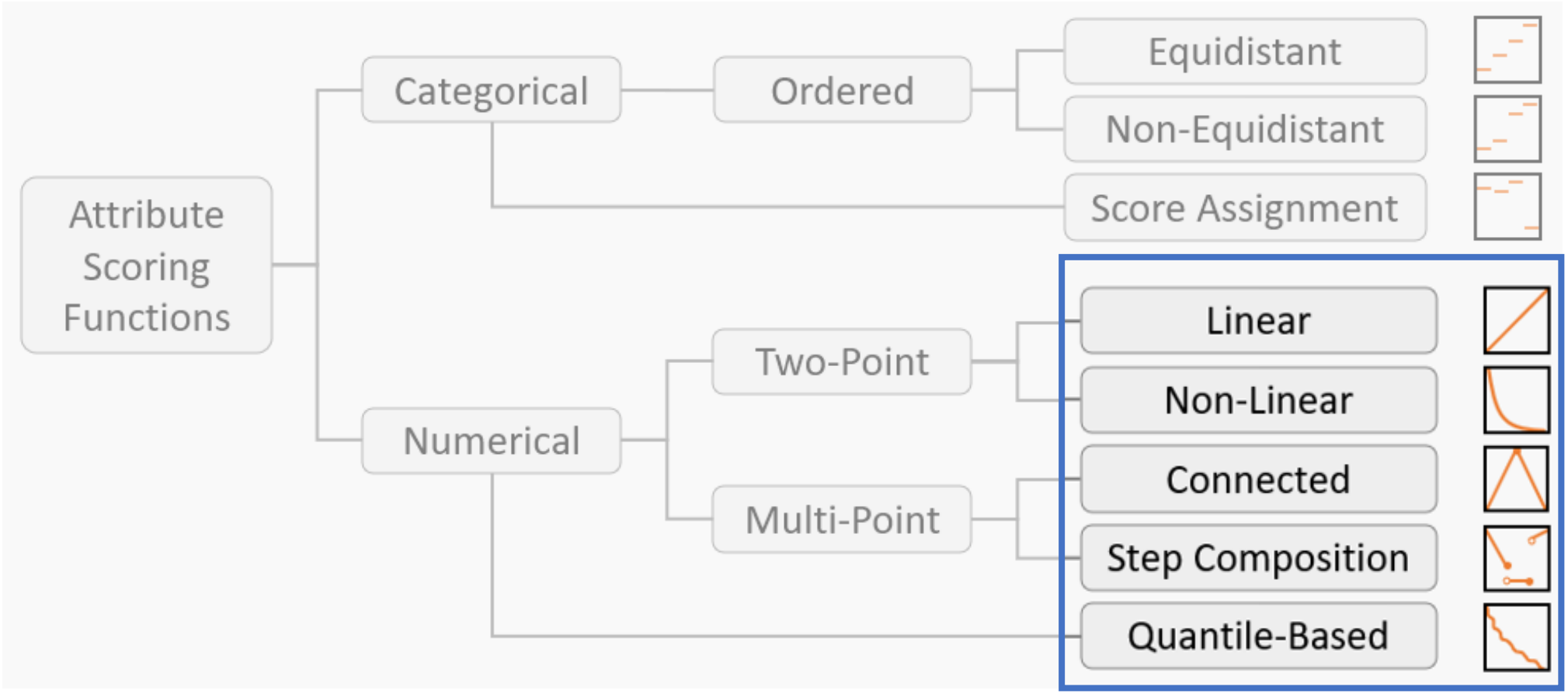
Final Taxonomy



Final Taxonomy

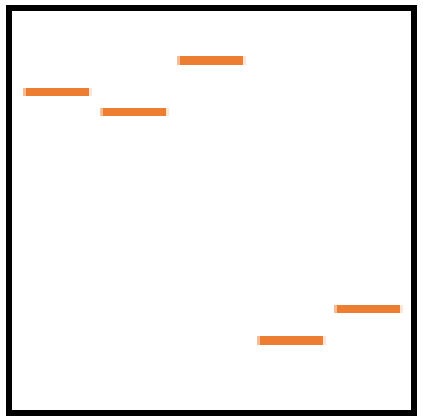


Final Taxonomy



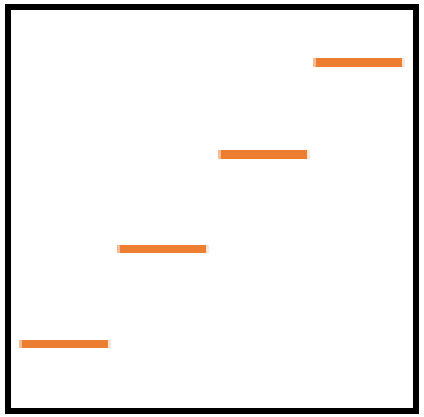
Examples of Attribute Scoring Functions

Categorical, Score Assignment



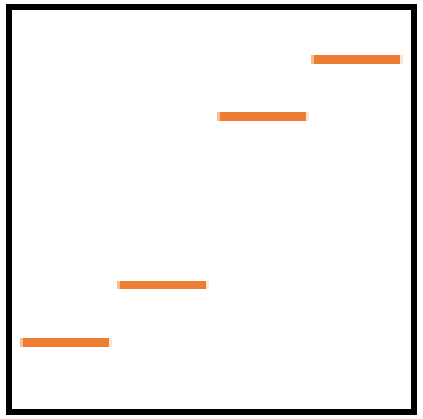
- User assigns a score to every category
- Real world example: Assign scores to different car models, car models cannot be compared to each other
- Examples of tools that support this function with a VA approach: None so far

Categorical, Equidistant



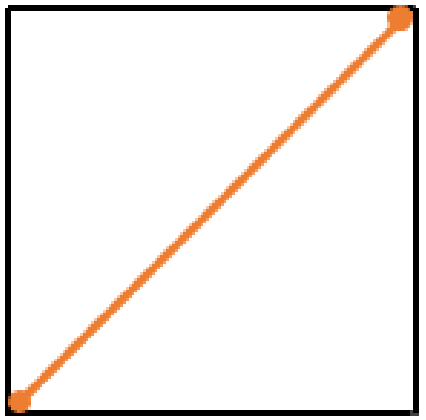
- User generates an order of categories, the distances between categories are equal
- Real world example: Order car colors according to preferences, differences between colors are not quantifiable
- Examples of tools that support this function with a VA approach: Podium

Categorical, Non-Equidistant



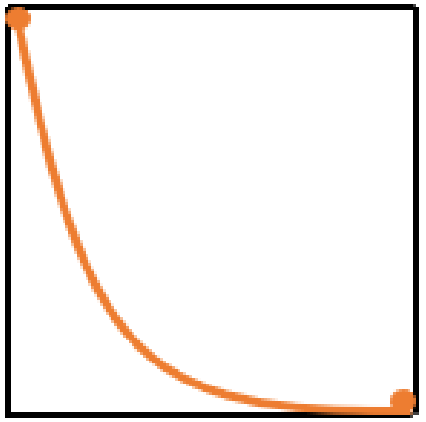
- User generates an order of categories, the distances between categories are not equal
- Real world example: Order car brands according to preferences where differences between brands are quantifiable
- Examples of tools that support this function with a VA approach: None so far

Numerical, Two-Point, Linear



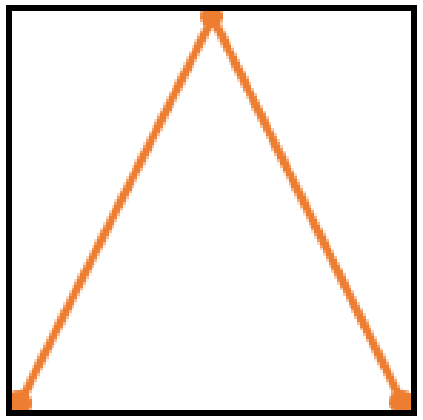
- Mathematical examples are min-max or max-min normalization
- Real world example: Find a car as fast as possible
- Examples of tools that support this function with a VA approach: LineUp and PAVED

Numerical, Two-Point, Non-Linear



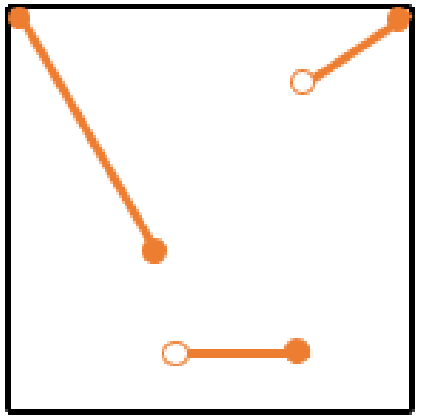
- Mathematical examples are logarithmic or exponential functions
- Real world example: ??
- Examples of tools that support this function with a VA approach: None so far

Numerical, Multi-Point, Continuous



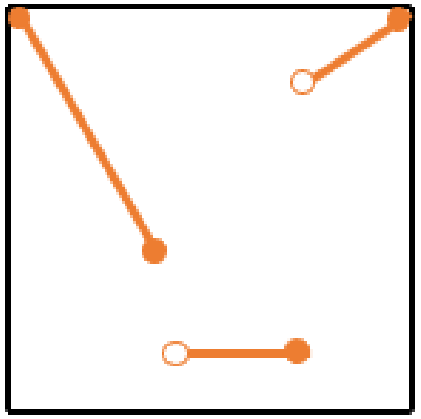
- Mathematical examples are the absolute value function
- Real world example: Find a car that is neither too old nor too new
- Examples of tools that support this function with a VA approach: LineUp (up to a certain number of points)

Numerical, Multi-Point, Discontinuous



- Mathematical examples are step functions
- Real world example: Find a car that has an engine size below certain thresholds
- Examples of tools that support this function with a VA approach: None so far

Numerical, Quantile-Based

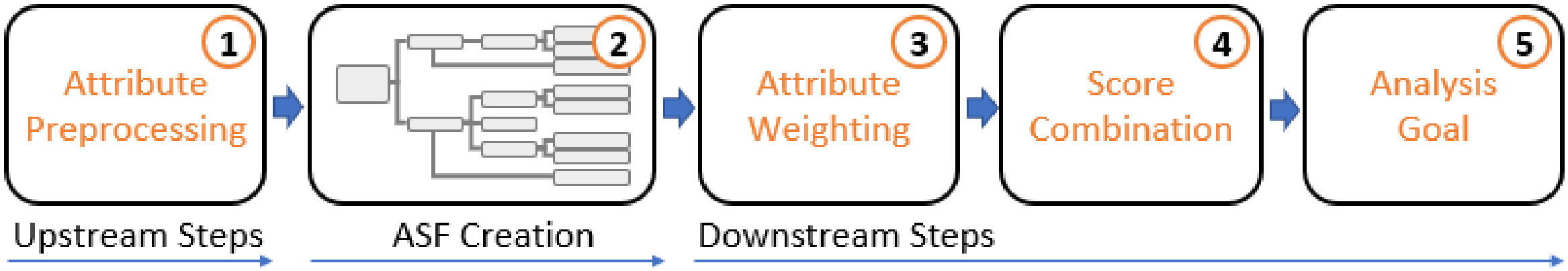


- Based on quantile normalization
- Can be used for data with outliers
- Examples of tools that support this function with a VA approach: None so far

Discussion

VA Workflow

Attribute Scoring is just one step in the whole process



Future Work

- Design visual interfaces for the creation of ASFs
- Address the weighting of attributes
- Implement a combination of multiple attribute scores to create a final ranking