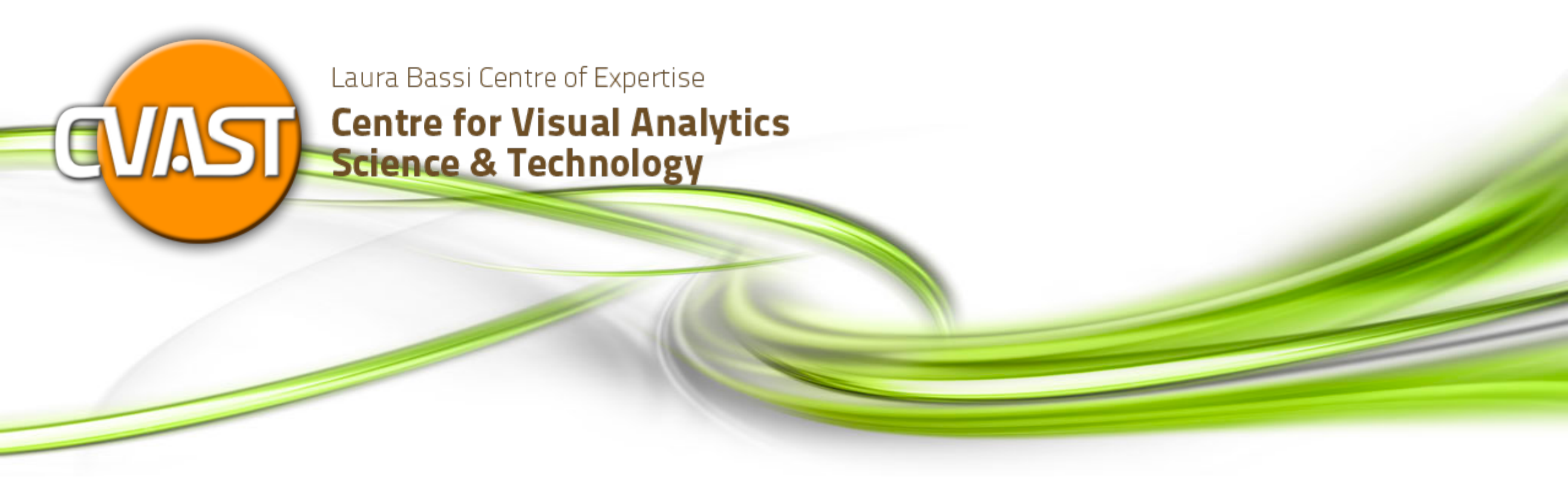


Guidance-Enriched Visual Analytics

Davide Ceneda

Advisors: Univ.Prof. Silvia Miksch and Priv.Doz. Christian Tominski

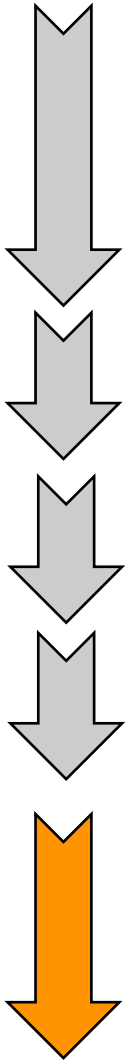
Table of Contents

Table of Contents

Table of Contents

Table of Contents

Table of Contents



Introduction – What is guidance?

Guidance is «*the act of helping somebody reach a goal*»

We experience guidance since birth

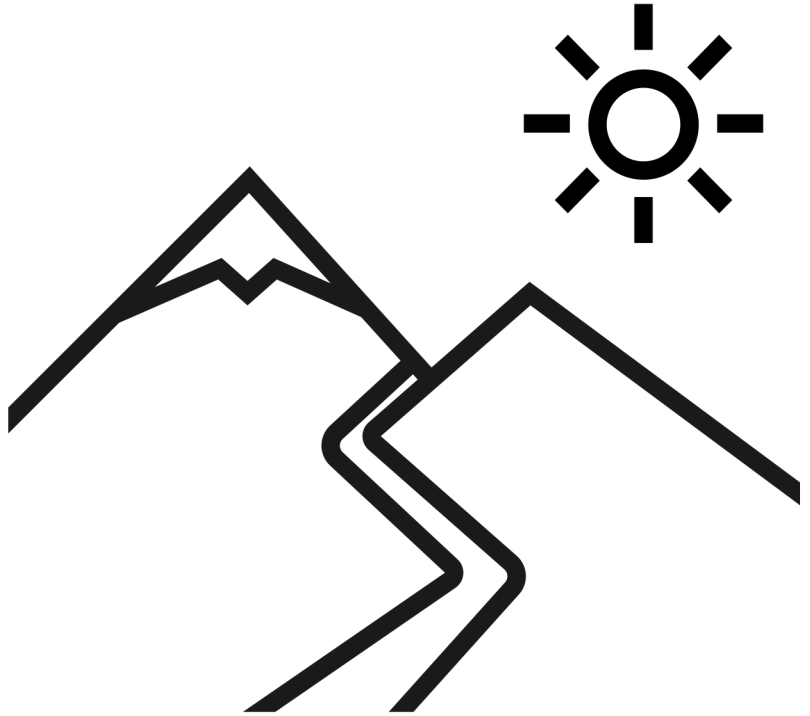
Examples:

- *Parents*
- *Teachers*
- *…*

©Murdo Macleod

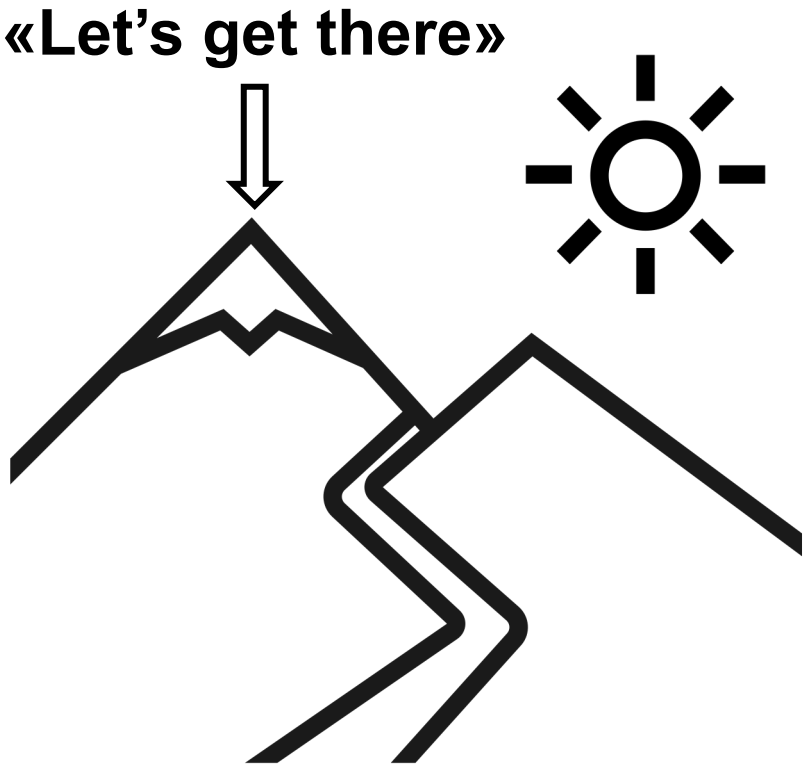
Introduction – Why do we need it?

A goal in mind



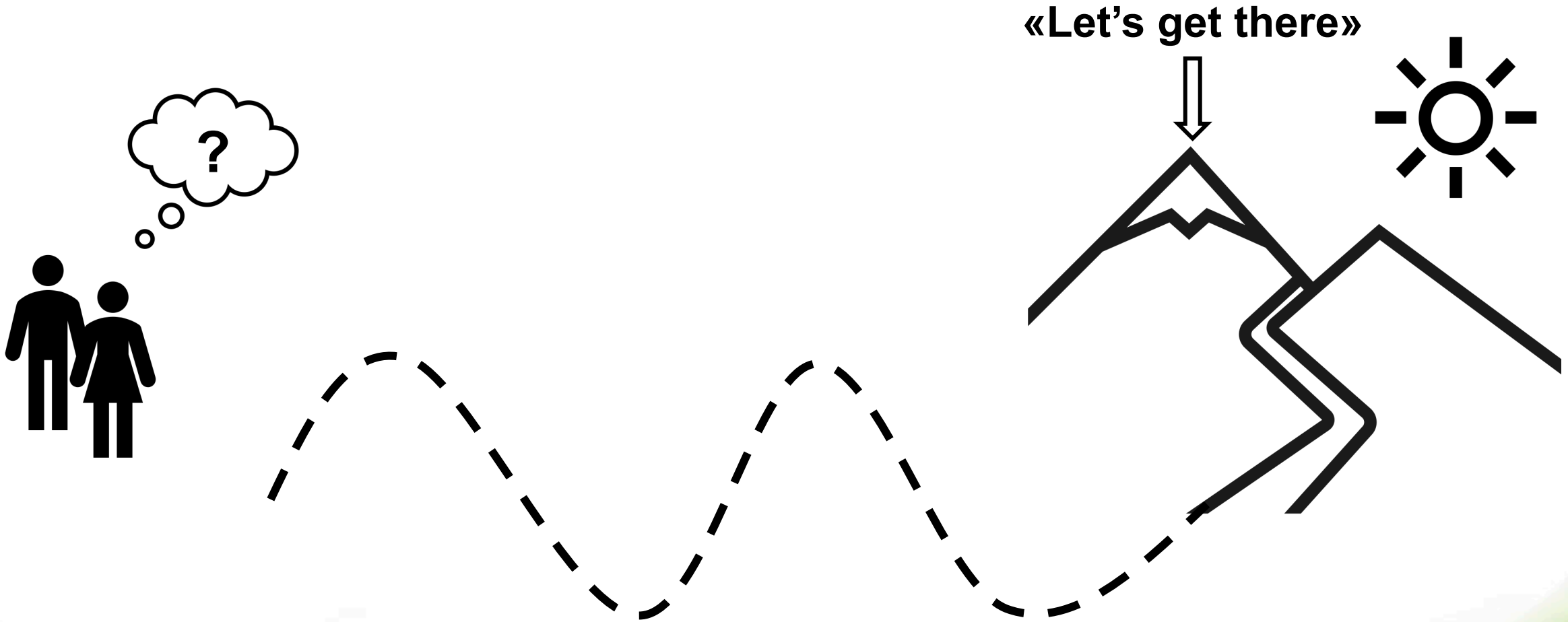
Introduction – Why do we need it?

A goal in mind



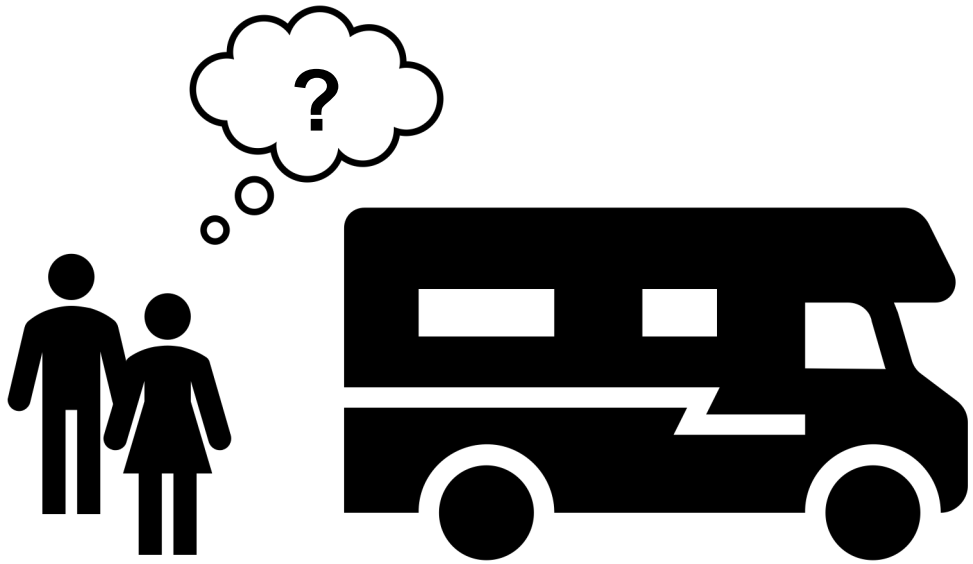
Introduction – Why do we need it?

Do we walk?

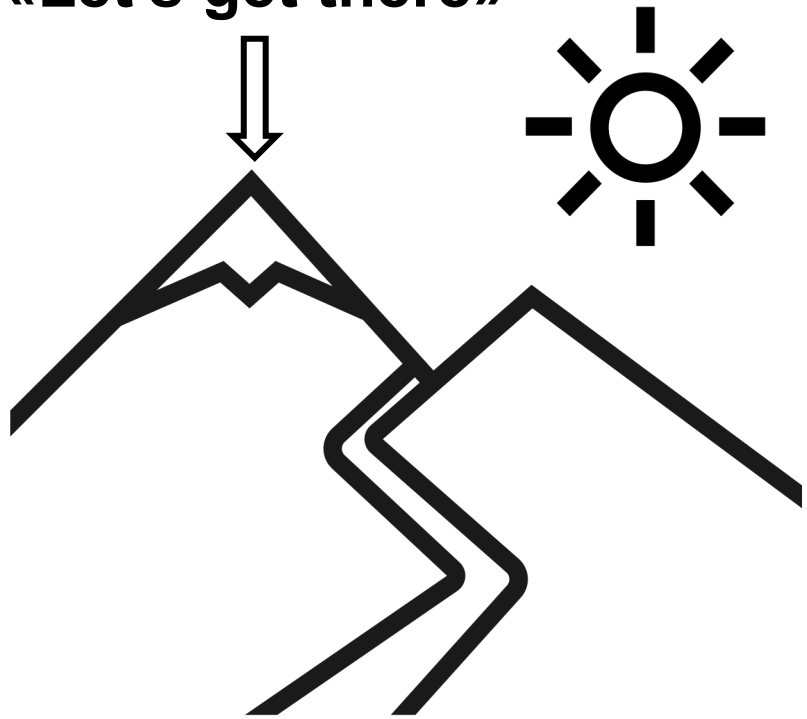


Introduction – Why do we need it?

Do we walk?
Do we drive?

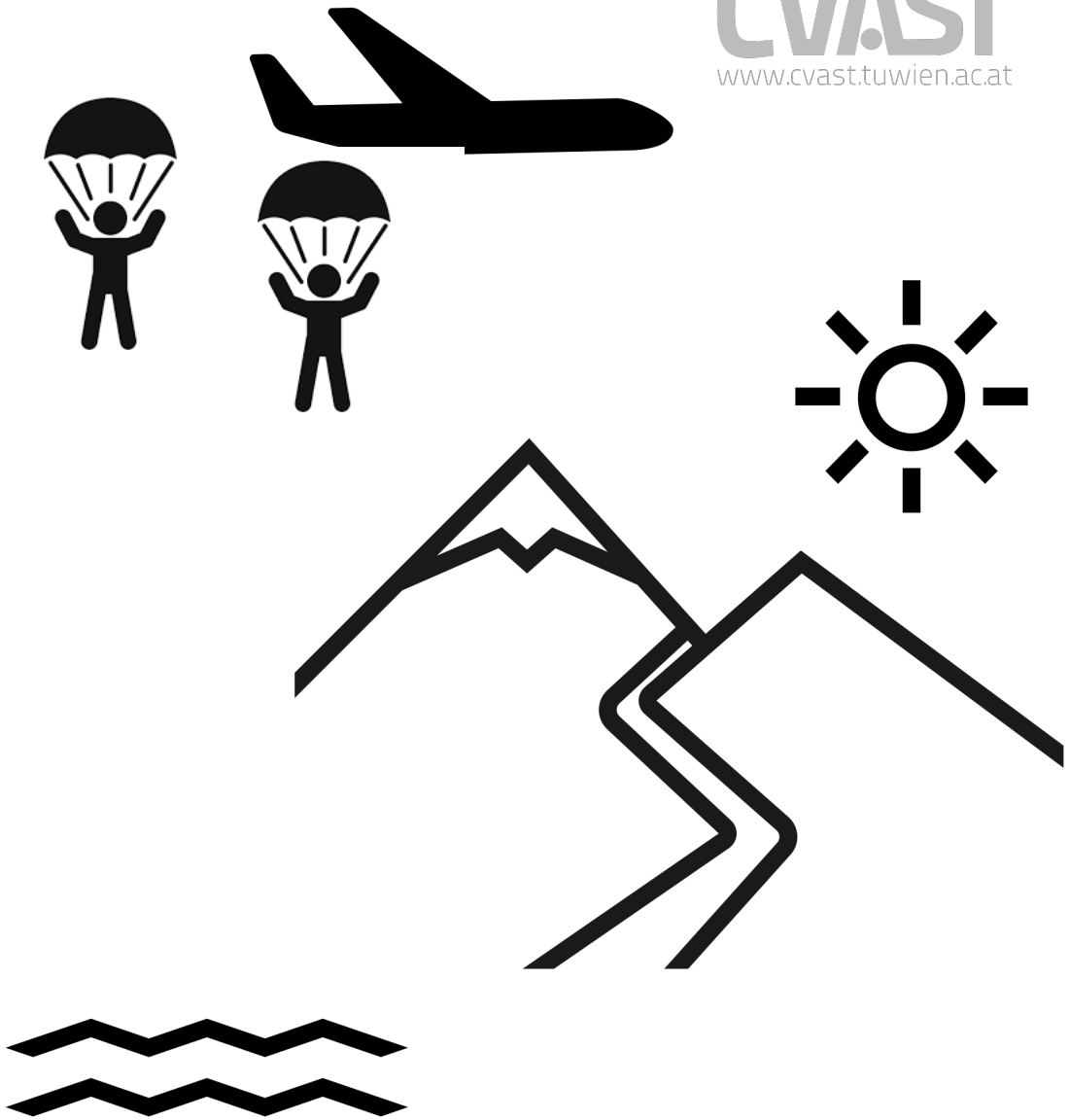


«Let's get there»

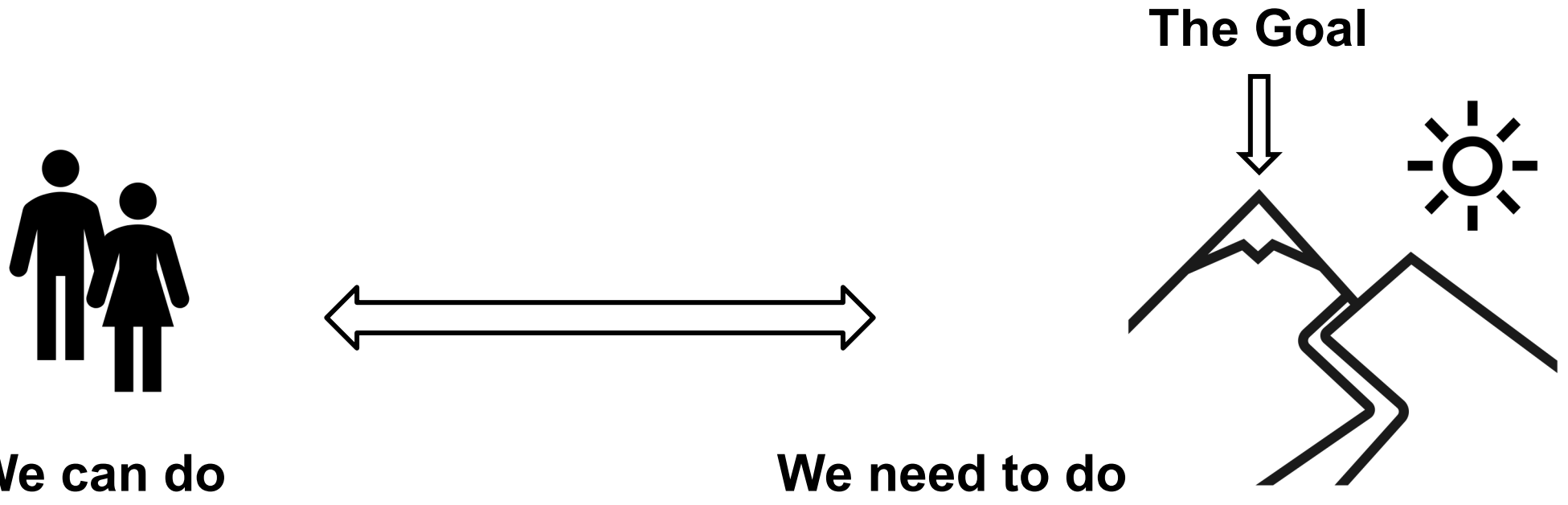


Introduction – Why do we need it?

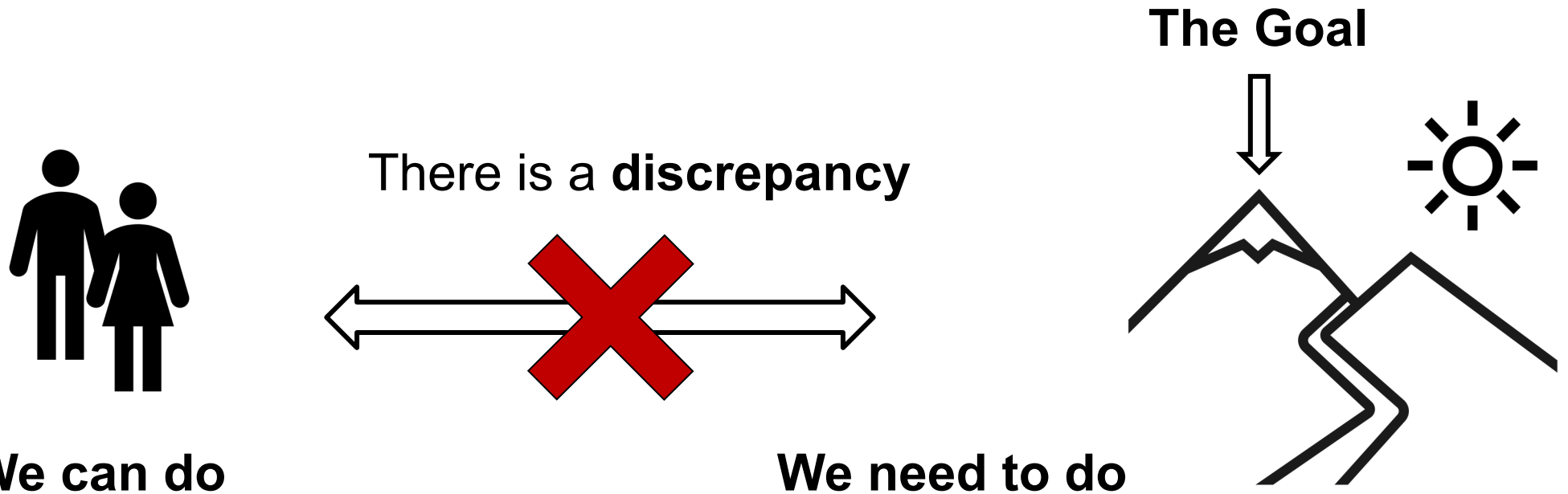
Do we walk?
Do we drive?
Do we parachute?



Introduction – Why do we need it?



Introduction – Why do we need it?



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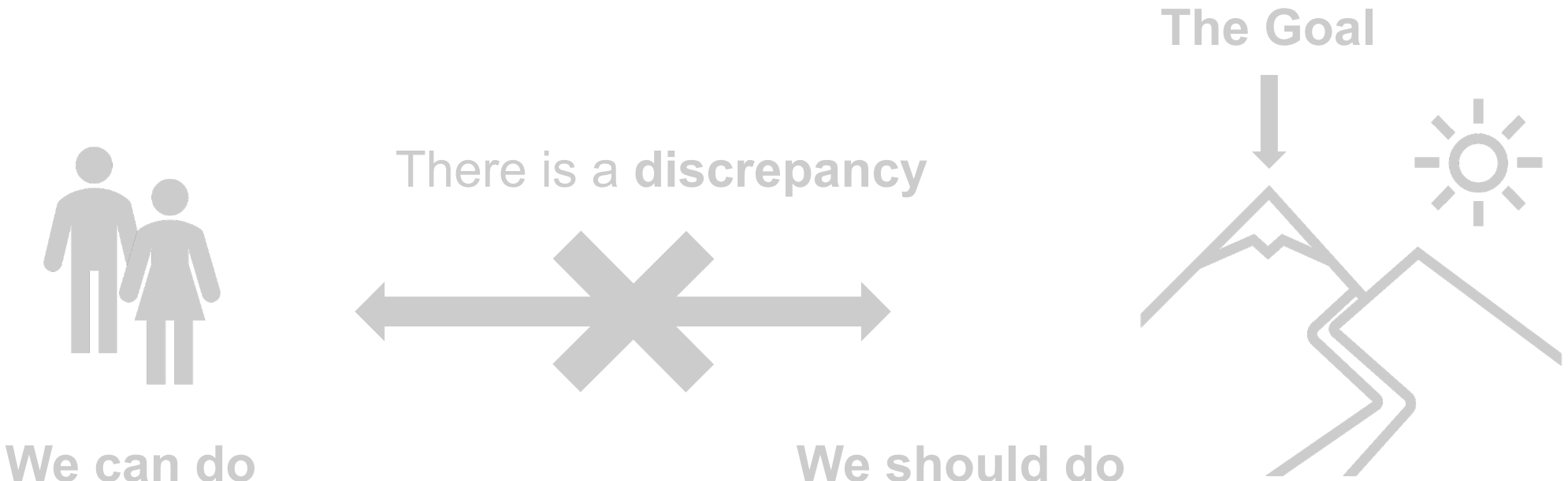


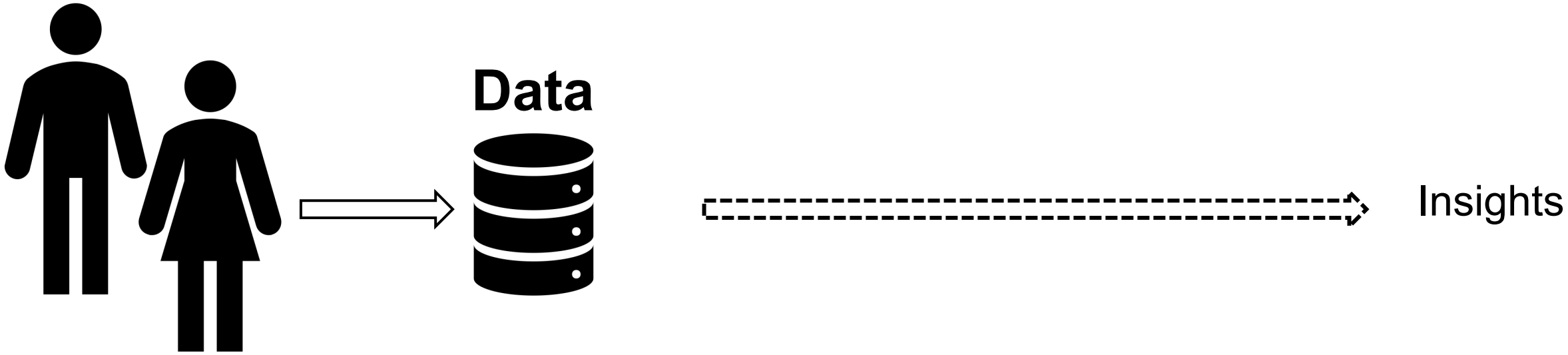
There is a **Knowledge gap**

We need **Guidance**

Table of Contents

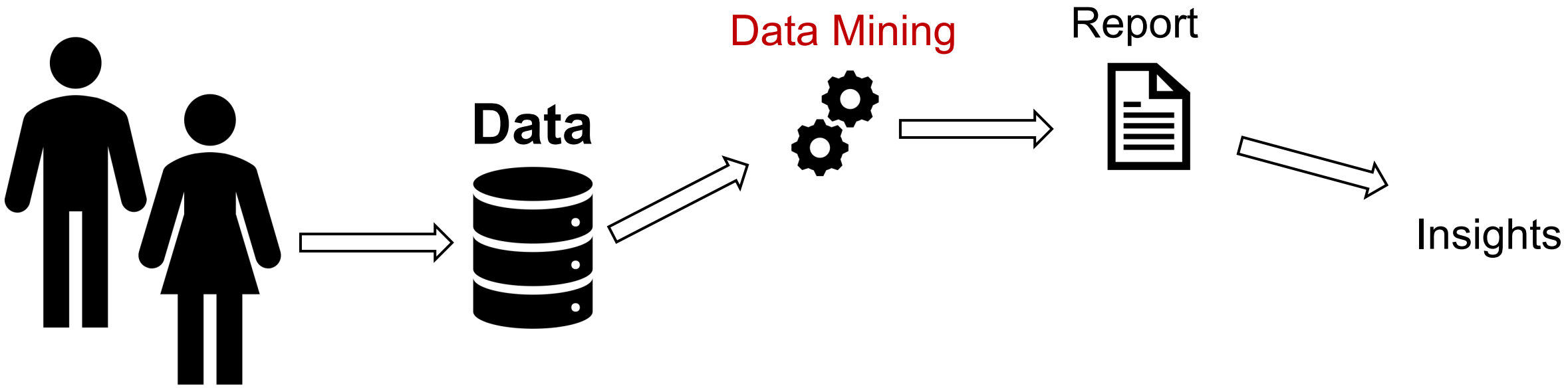
Motivation: A need for Visual Data Analysis

Two strategies



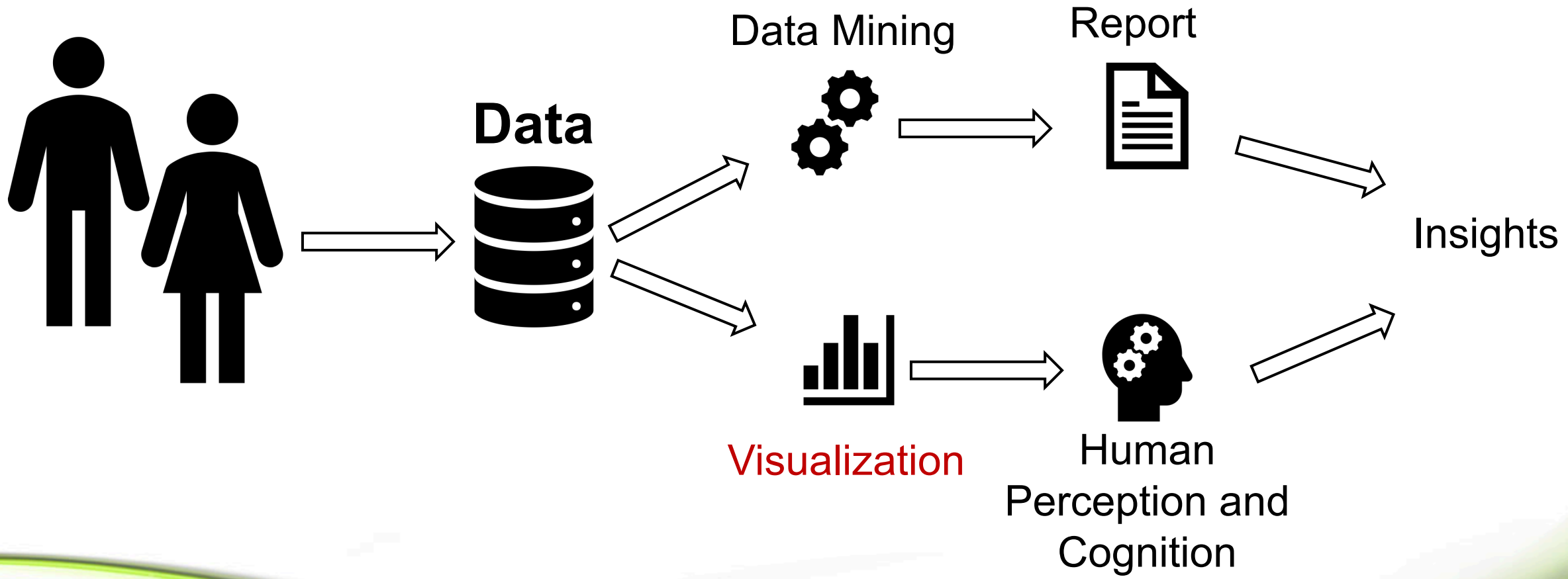
Motivation: A need for Visual Data Analysis

Two strategies



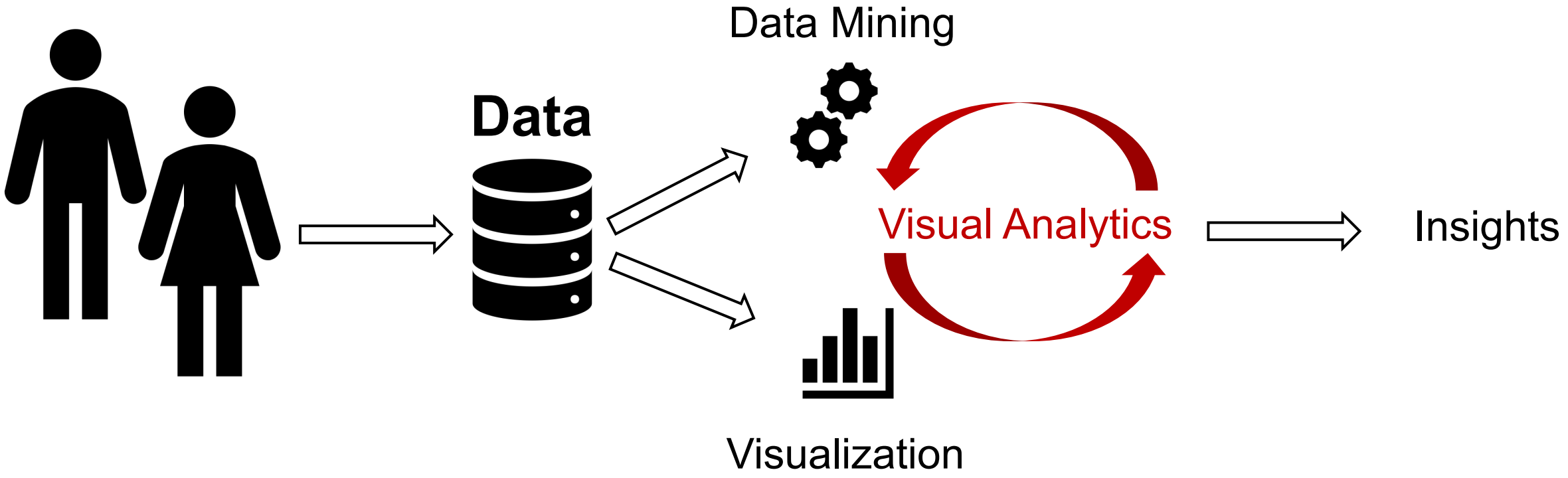
Motivation: A need for Visual Data Analysis

Two strategies



Motivation: A need for Visual Analytics

Two strategies, plus one



[Keim et al.2005]

Motivation: A need for Visual Analytics

Visual Analytics combines the strenghts of the human and the computer

Perception and Cognition

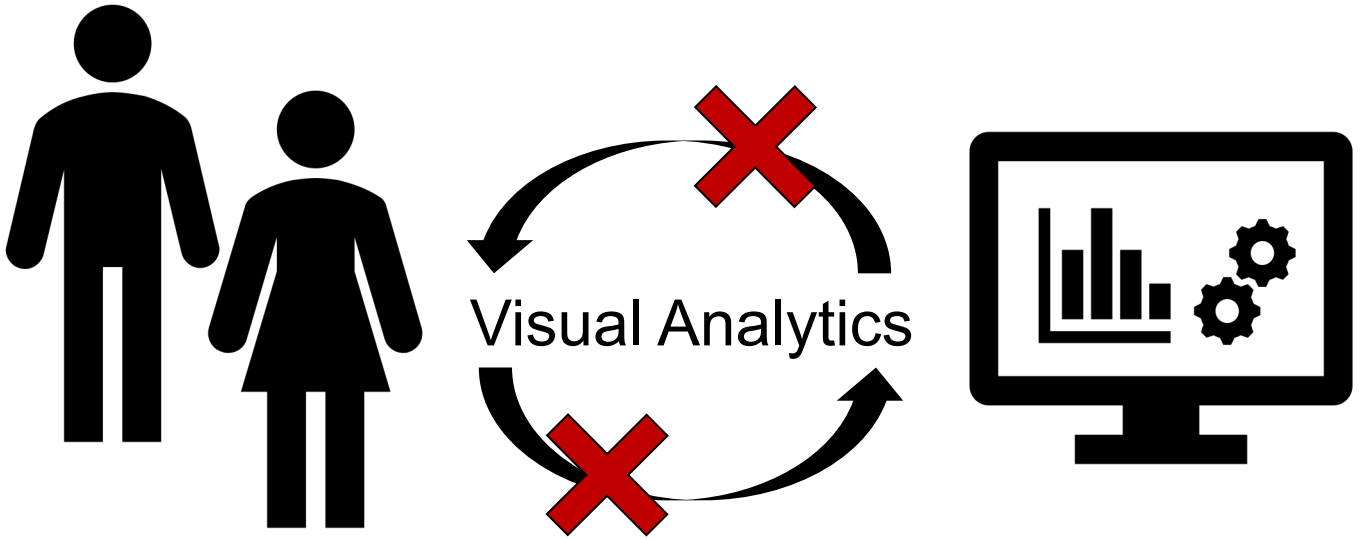
Visualization and Data Modeling

VA aims to enable an effective Human-Computer Collaboration

[Keim et al., 2005]
[Bertini and Lalanne, 2009]

Motivation: VA is challenging

Visual Analytics combines the strenghts of the human and the computer



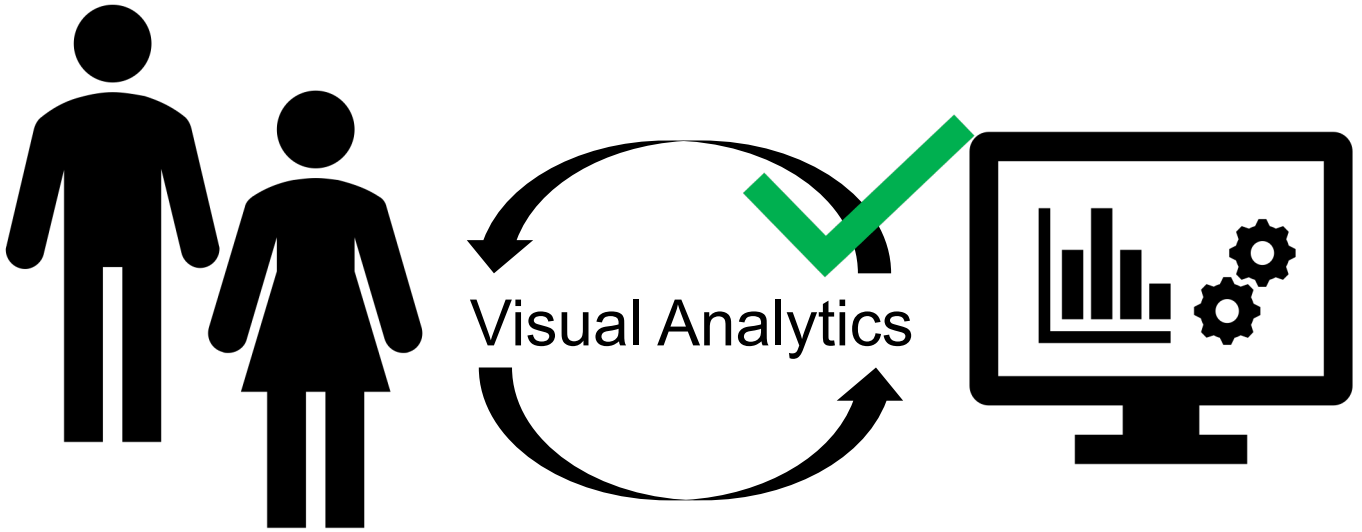
Effective collaboration is hard to achieve

Affordances of Human and System are often unbalanced

[Bertini and Lalanne, 2009]

Motivation: VA is challenging. We need guidance.

In this thesis, we propose guidance …



… as a way to enable a better human-computer collaboration

[Ceneda et al. 2019]

Table of Contents

Research Questions

«How can we devise guidance methods for supporting users performing visual analytics tasks?»

…and subquestions

«How can we devise guidance methods for supporting users performing visual analytics tasks?»

[S1] Is it possible to devise a general **framework** and a common **guidance definition** embodying the current state-of-the-art approaches and literature?

…and subquestions

«How can we devise guidance methods for supporting users performing visual analytics tasks?»

[S1] Is it possible to devise a general **framework** and a common **guidance definition** embodying the current state-of-the-art approaches and literature?

[S2] What are the **benefits** (if any), and in general what are the **effects of using guidance** during visual analytics?

…and subquestions

«How can we devise guidance methods for supporting users performing visual analytics tasks?»

[S1] Is it possible to devise a general **framework** and a common **guidance definition** embodying the current state-of-the-art approaches and literature?

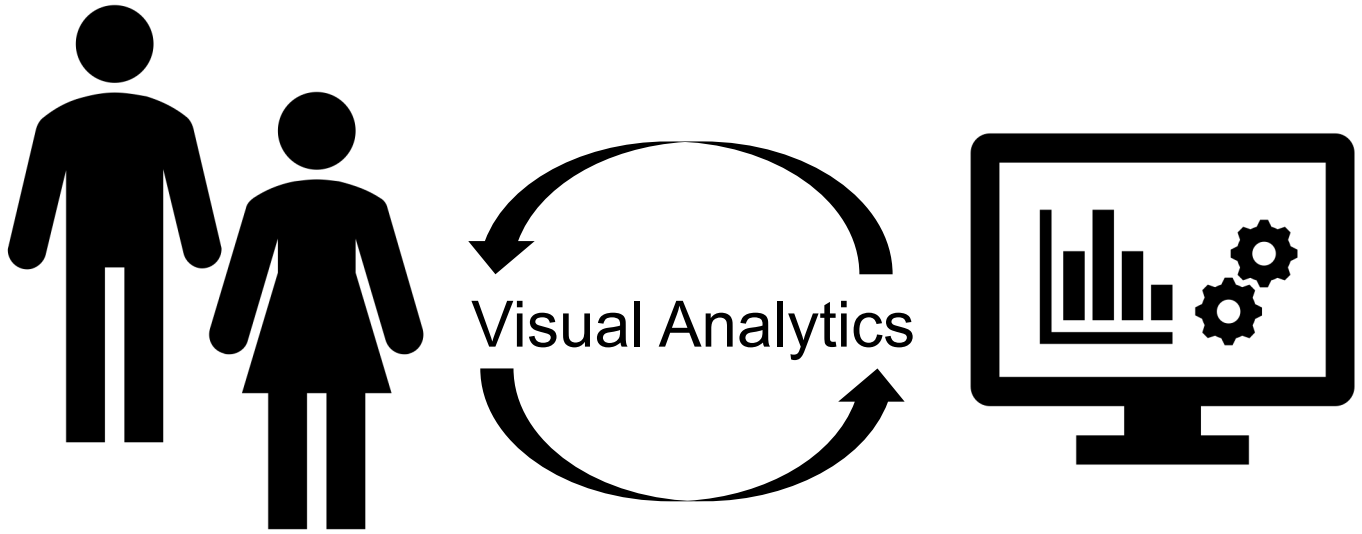
[S2] What are the **benefits** (if any), and in general what are the **effects of using guidance** during visual analytics?

[S3] How is it possible to **design effective guidance** to support users throughout the visual analytics process?

Excursus: Methodology

The user in the loop!

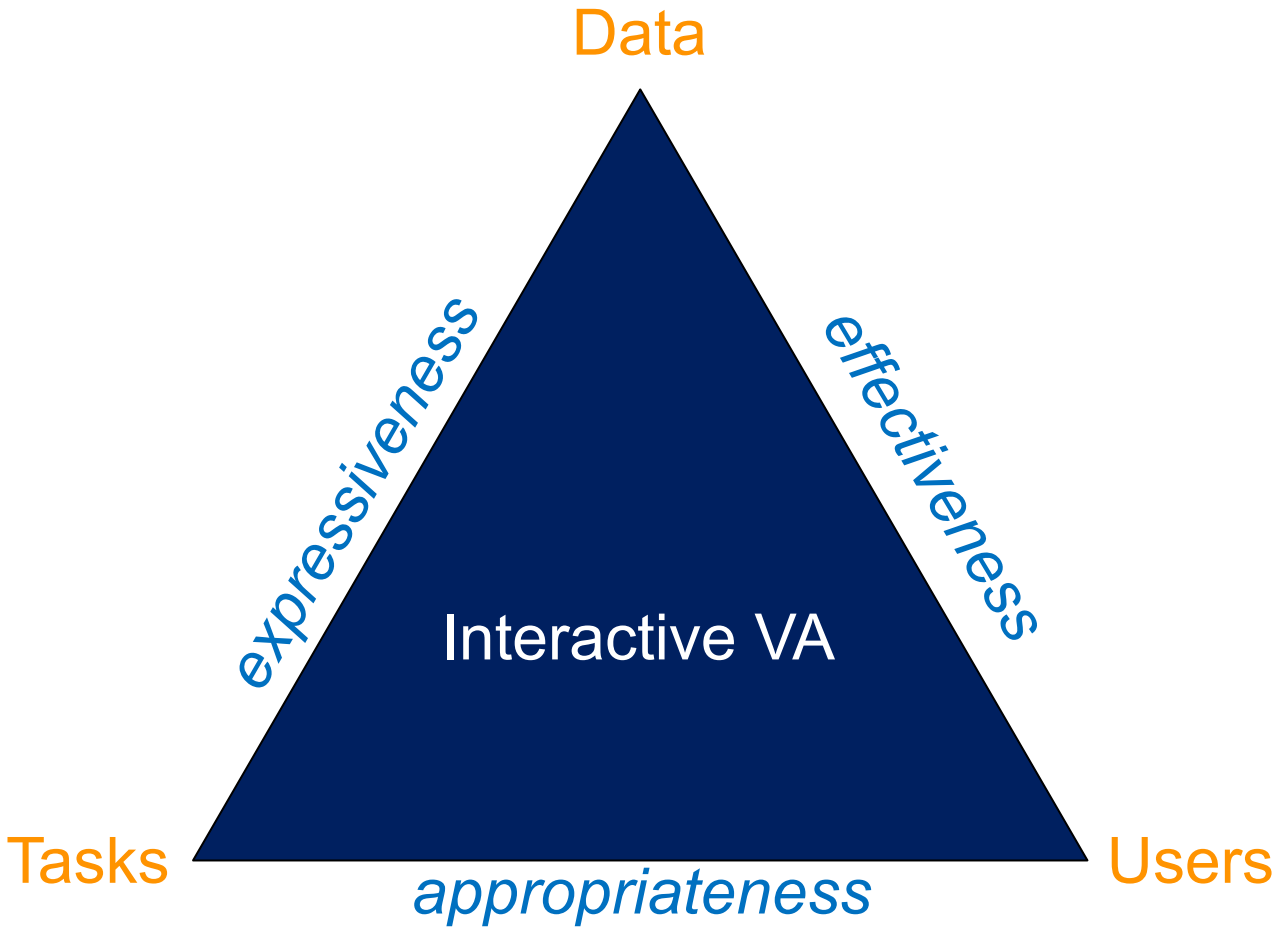
Interactive analysis
Exploit user's feedback
Steer the analysis



Excursus: Methodology

The Data-Users-Tasks Triangle

[Miksch,Aigner, 2014]



Excursus: Methodology

[Lam et al., 2011]

Evaluation Methodologies:

We can Evaluate:

1. *Environments and Work Practices*
2. *Visual Data Analysis and Reasoning*
3. *Communication through Visualization*
4. *Collaborative Data Analysis*
5. *User Performance*
6. *User Experience*
7. *Visualization Algorithms*

Excursus: Methodology

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Excursus: Methodology

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We can Evaluate:

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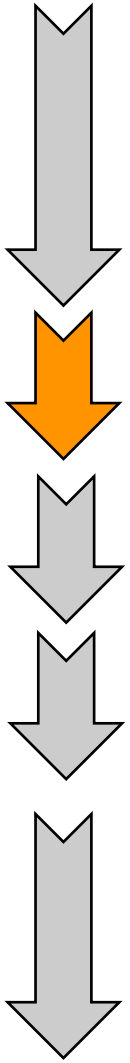
3. *Communication through Visualization*
4. *Collaborative Data Analysis*
5. ***User Performance***
6. ***User Experience***
7. *Visualization Algorithms*

2 User Studies:

- Does guidance improve insights discovery?
- How does the user react to guidance?

Table of Contents



Defining Guidance - Overview

Answering **S1**:

*«Is it possible to devise a general **framework** and a common **guidance definition** embodying the current state-of-the-art approaches and literature?»*

Reviewed the state of the art – Visual Analytics and related fields

Findings condensed in **a framework, a definition** and a description of **guidance characteristics**

D. Ceneda, T. Gschwandtner, T. May, S. Miksch, H.-j. Schulz, M. Streit,and C. Tominski. ***Characterizing Guidance in Visual Analytics***. In: IEEE Transactions on Visualization and Computer Graphics 23.1 (Jan. 2017), pp. 111–120. Presented @IEEE VIS2016

Defining Guidance

What is Guidance?

Dictionaries: «supervised care or assistance»

Smith and Mosier, 1986

«pervasive part of design…contributes to effective system operation»

Engels, 1996

Guidance composed by a «what» and a «how»

Schultz et al. 2013

Too many synonims used → Unified the terminology → Guidance

Initial characterization: Context, Domain, Target and Degree

Defining Guidance

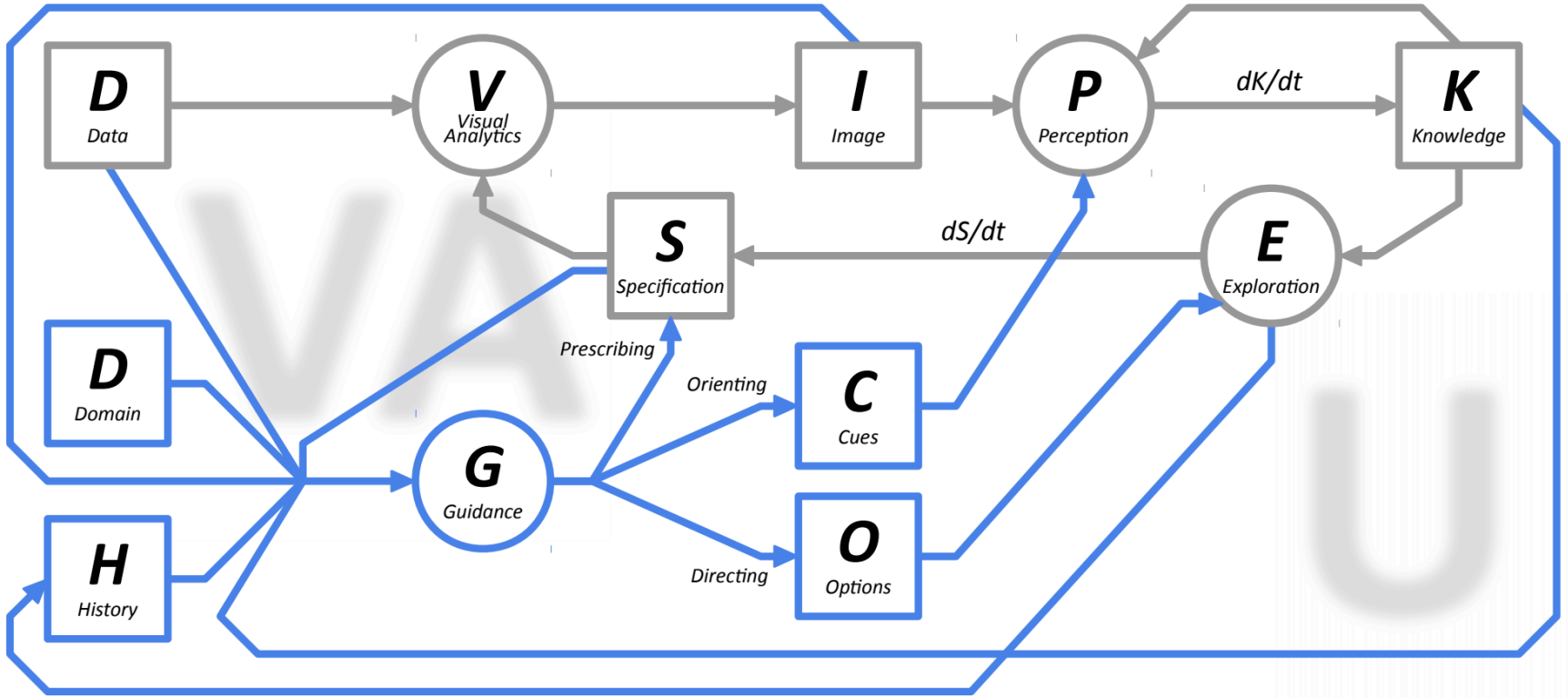
The Definition

«Guidance is a computer-assisted process that aims to actively resolve a knowledge gap encountered by users during an interactive visual analytics session»

[Ceneda et al.2017, p2]

Defining Guidance

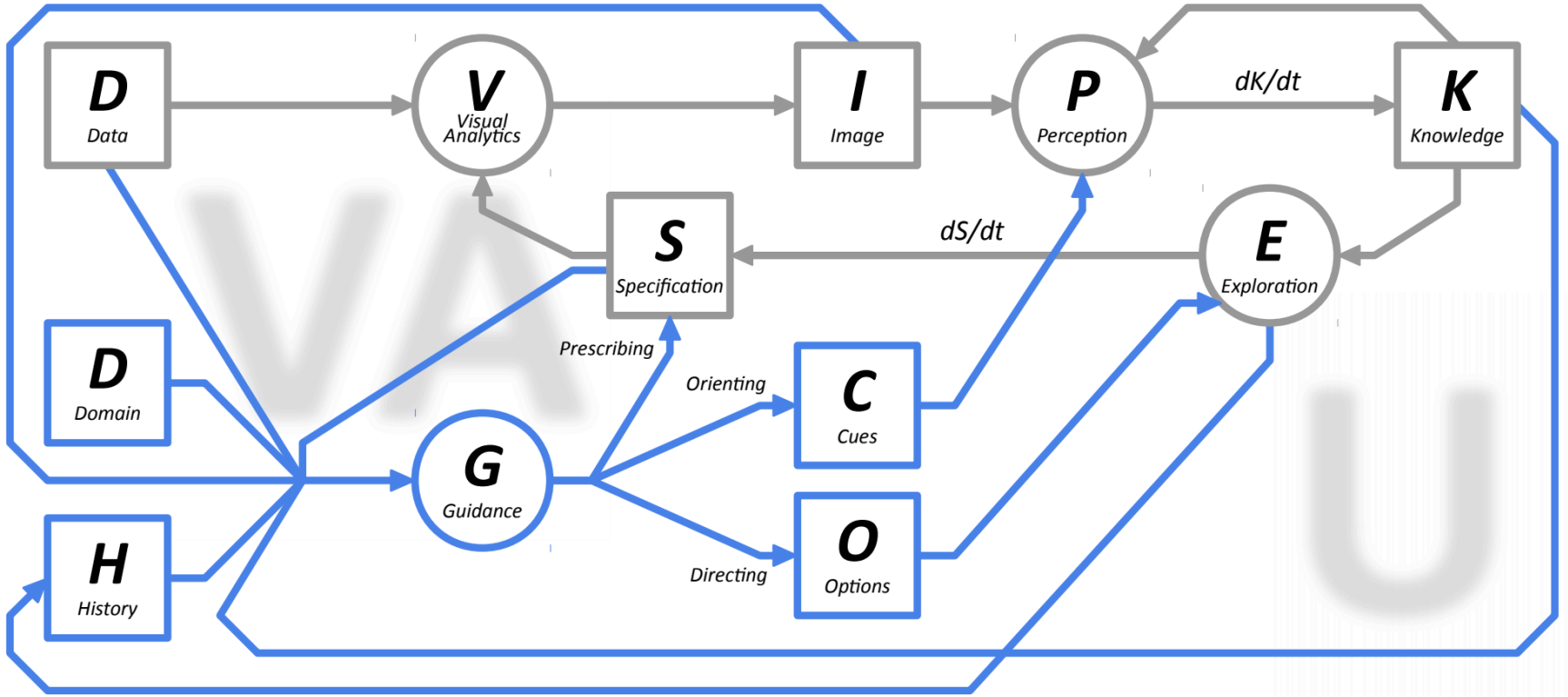
A Visual Framework



[Ceneda et al.2017a]
[van Wijk, 2005]

Defining Guidance

A Visual Framework

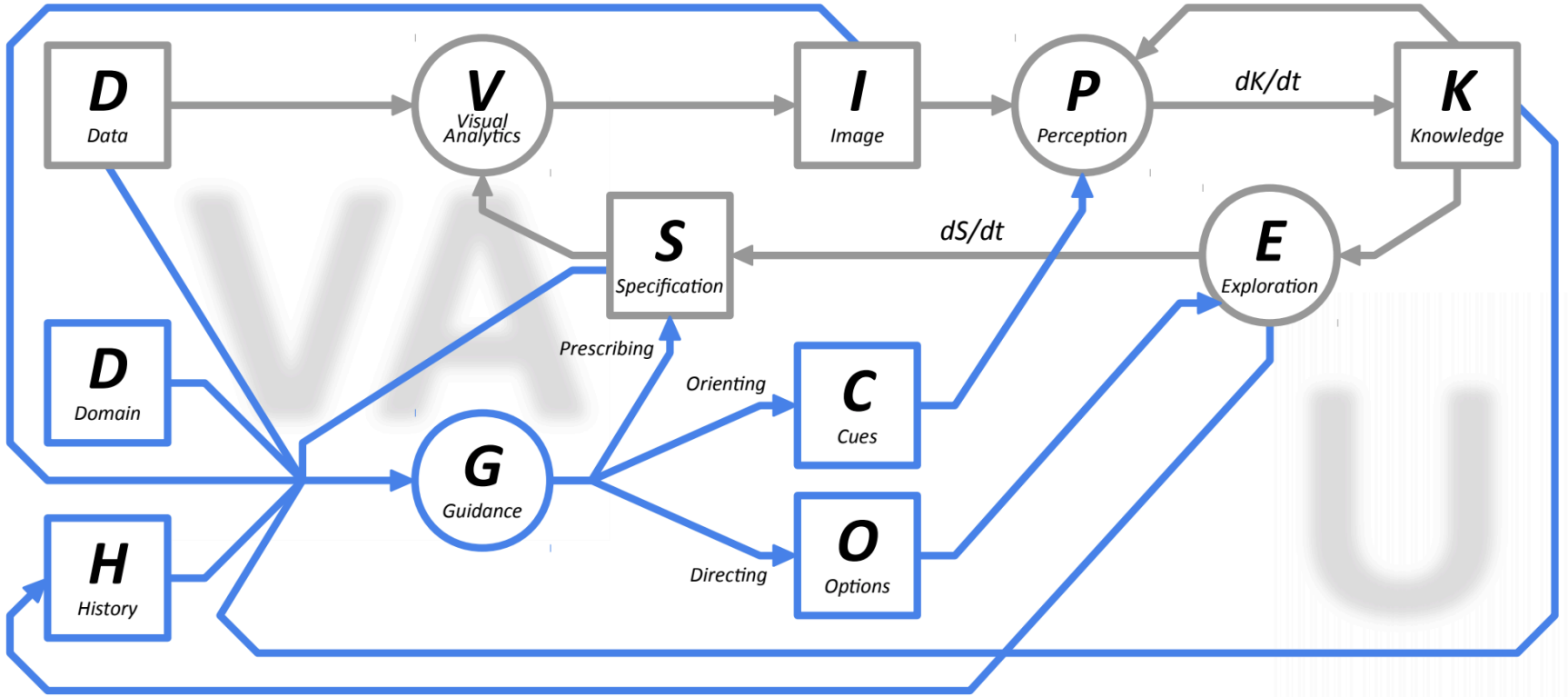


- Model of vis/VA

[Ceneda et al.2017a]
[van Wijk, 2005]

Defining Guidance

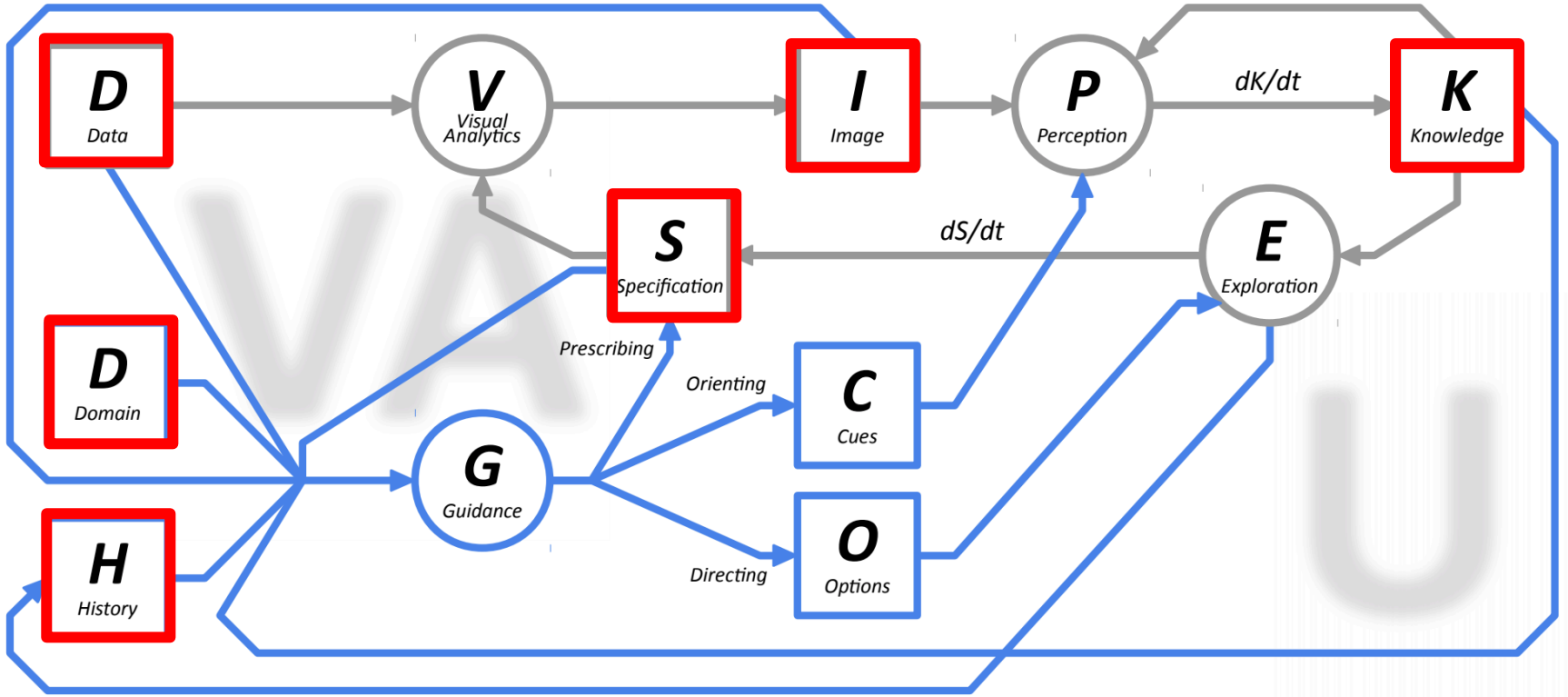
A Visual Framework



- Model of vis/VA
- Guidance

Defining Guidance

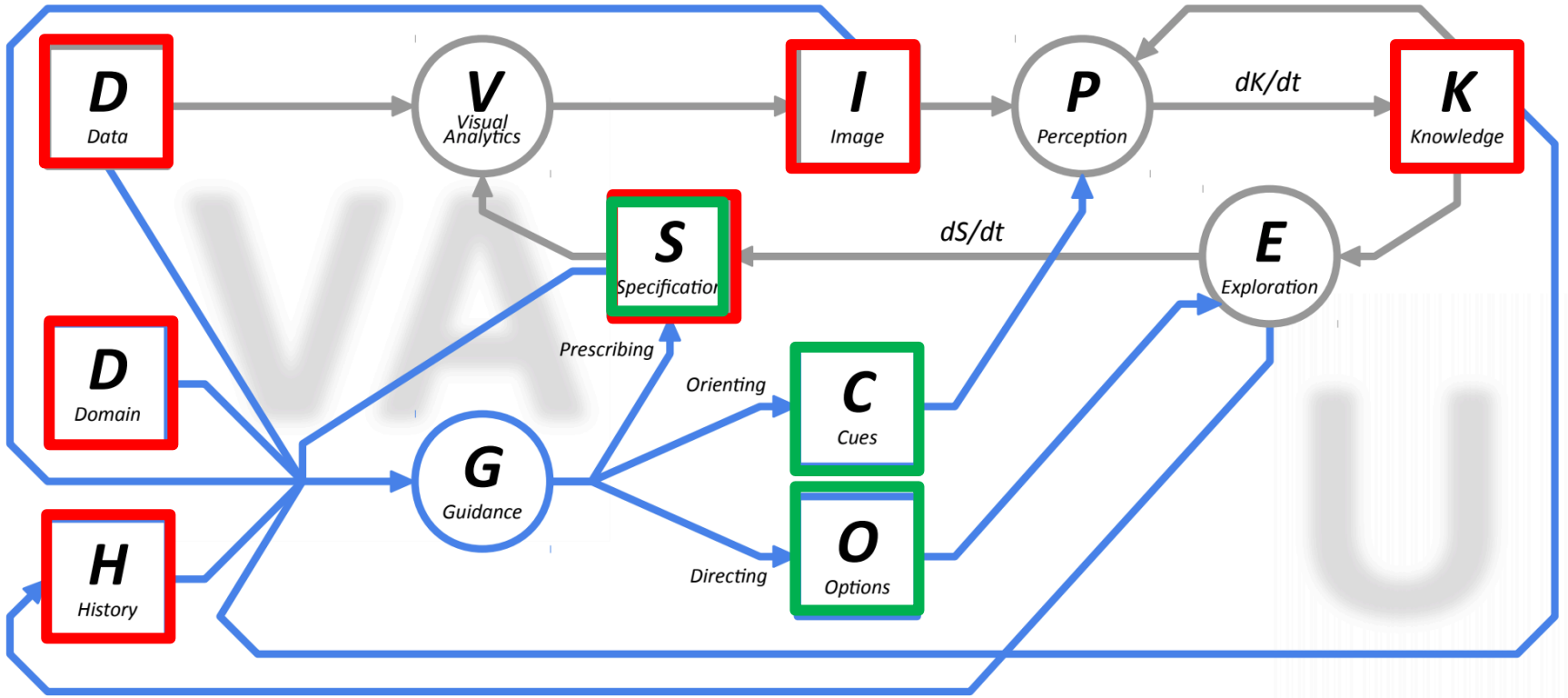
A Visual Framework



- Model of vis/VA
- Guidance
- Input

Defining Guidance

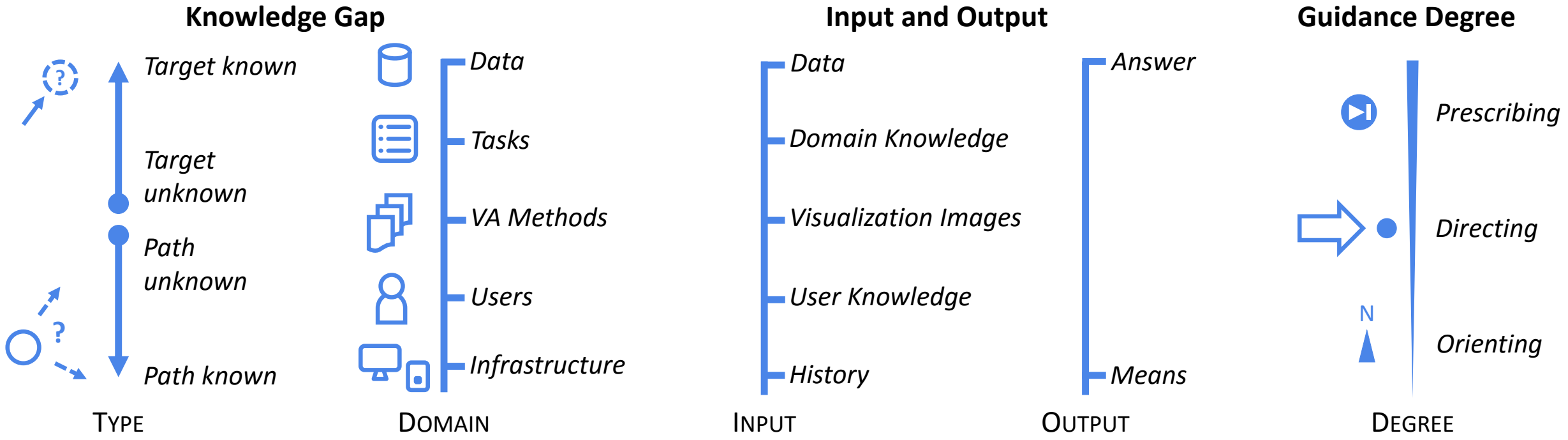
A Visual Framework



- Model of vis/VA
- Guidance
- Input
- Output

Defining Guidance

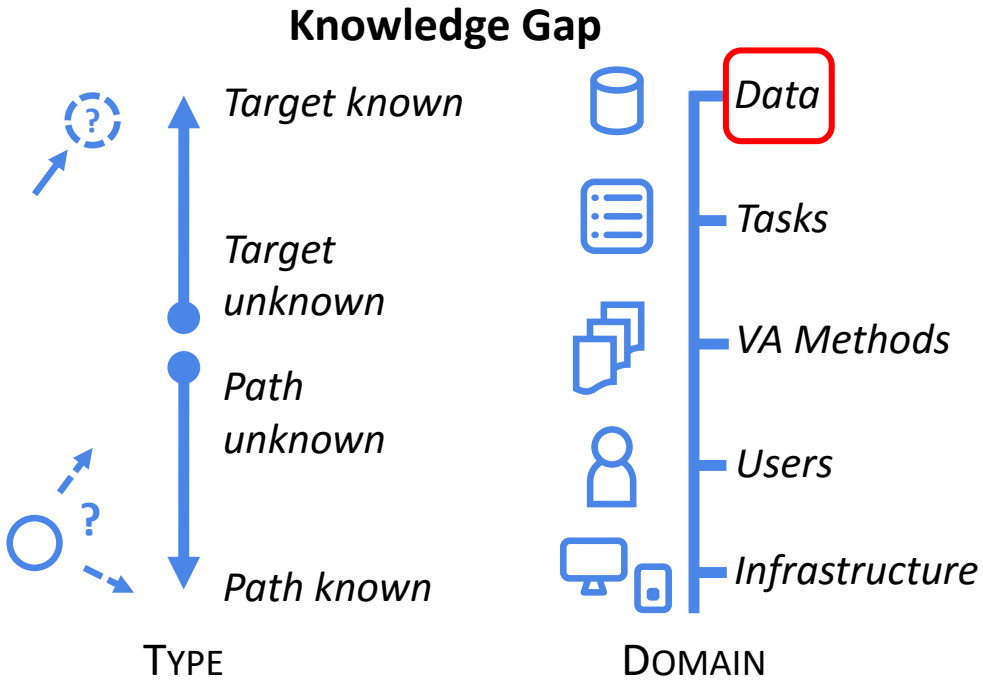
The Characteristics



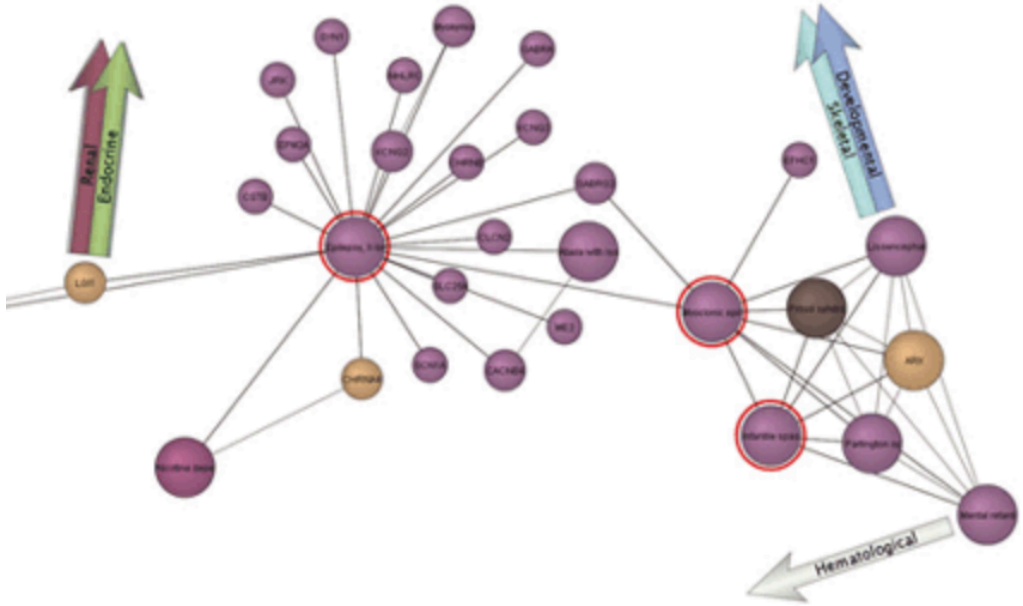
[Ceneda et al.2017a]

Defining Guidance

Some Examples



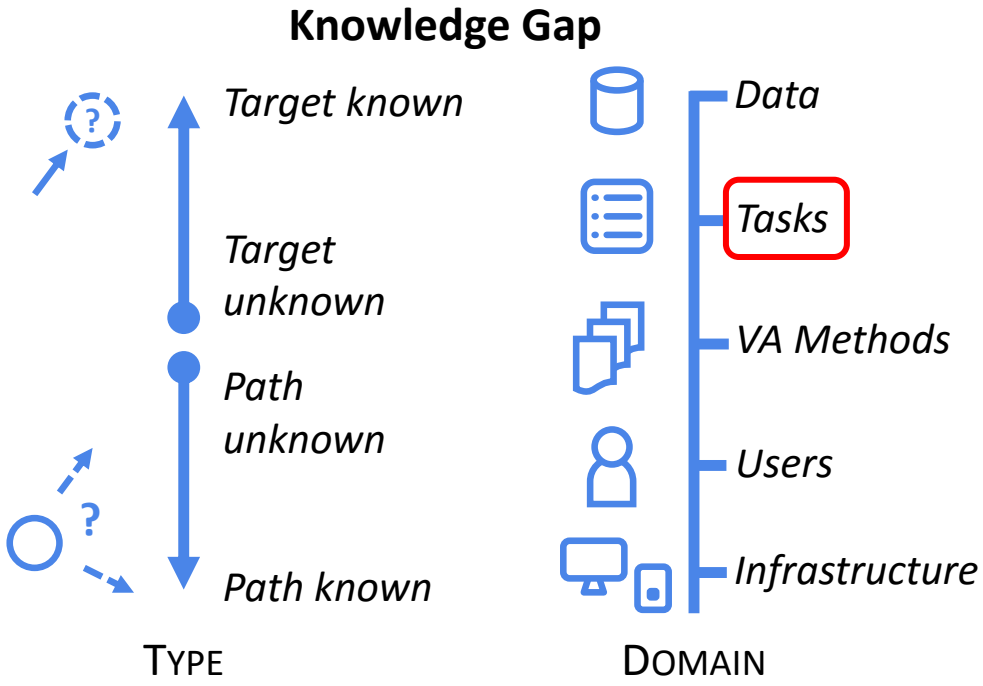
[May et al., 2012]



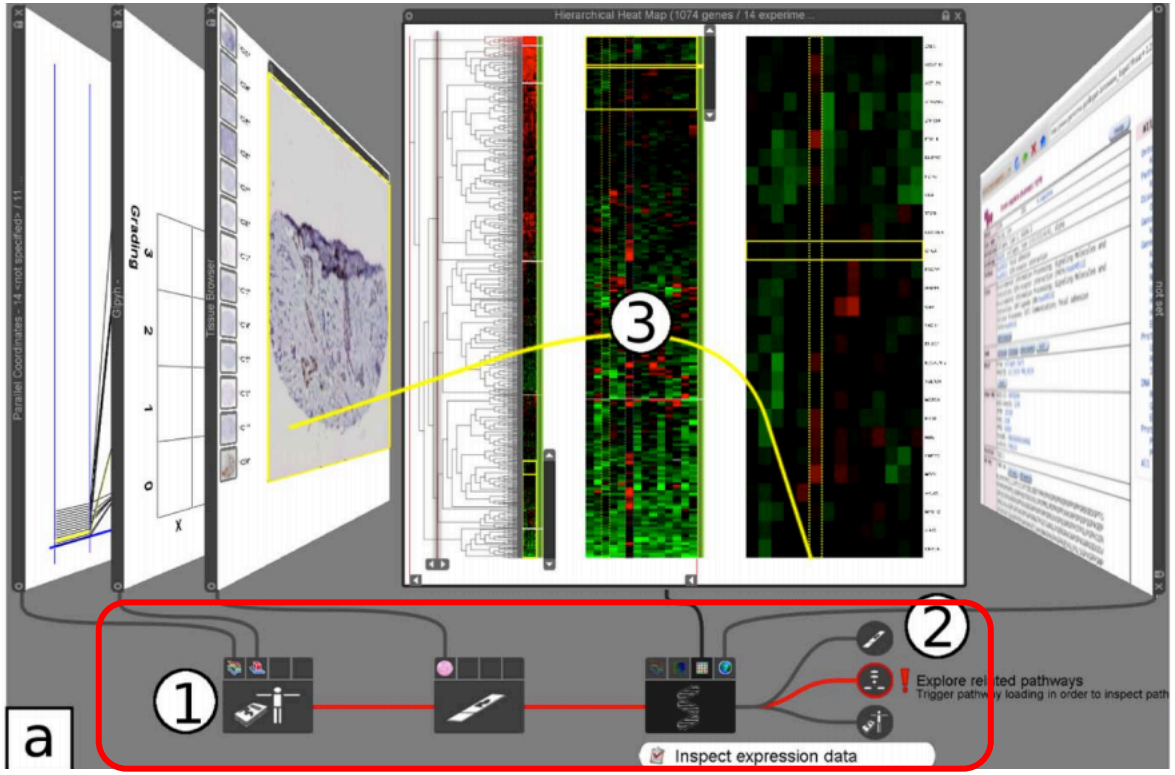
…find interesting data cases

Defining Guidance

Some Examples



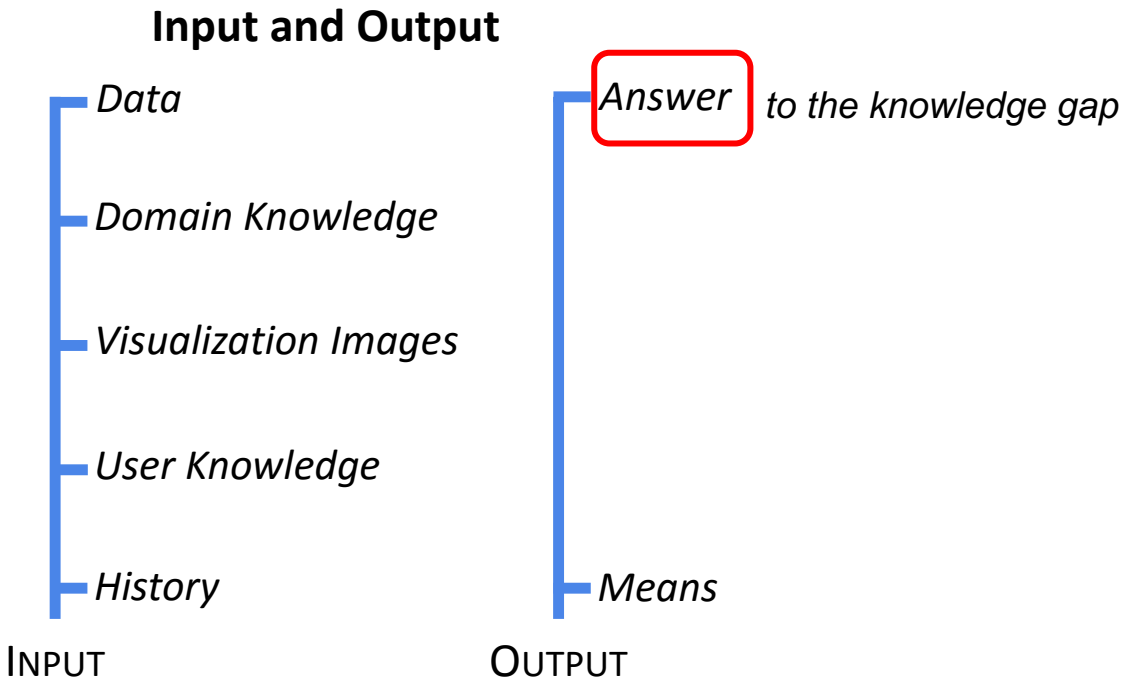
[Streit et al.2012]



…assist task resolution

Defining Guidance

Some Examples

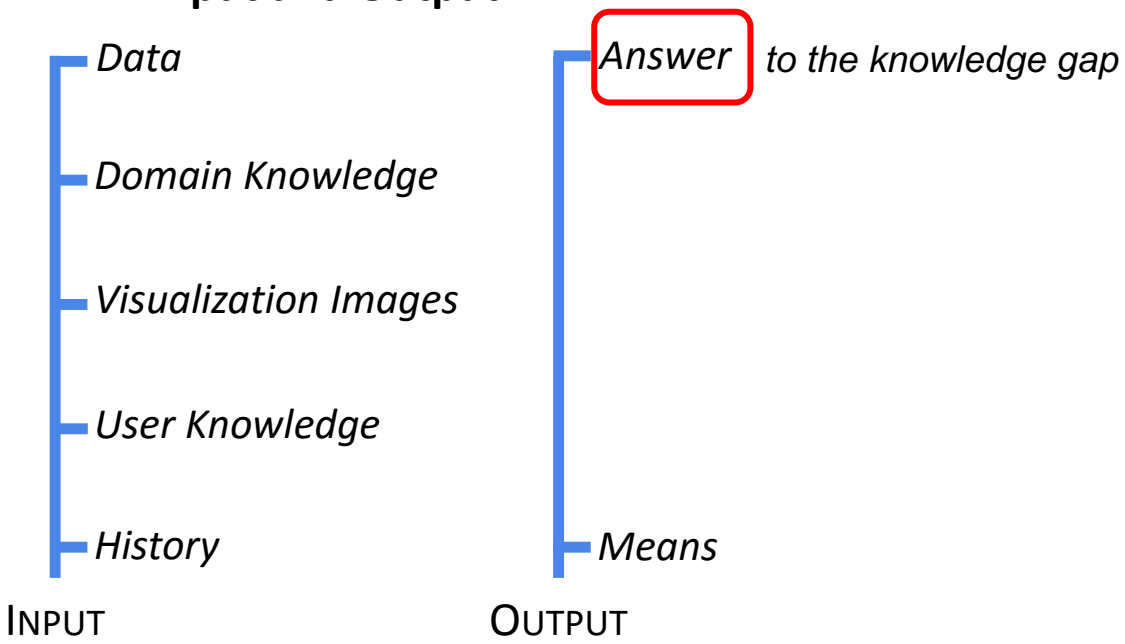


Guidance(gap, input) → *answer*

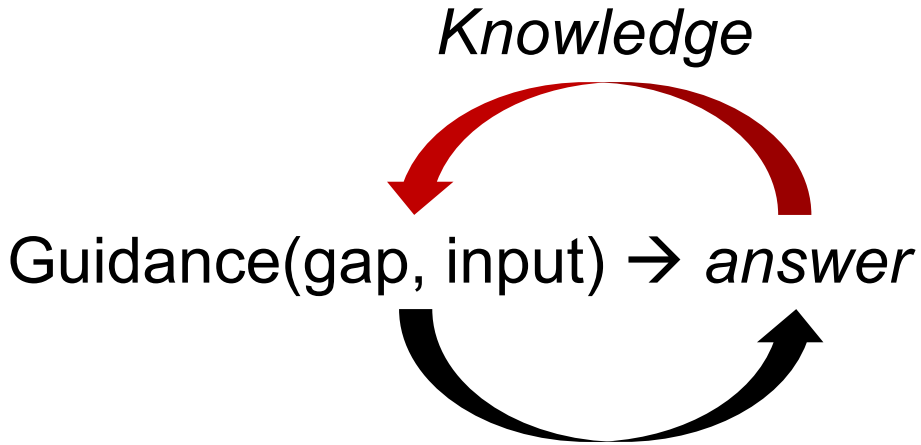
Defining Guidance

Some Examples

Input and Output



Goal → Solve Knowledge gap



Defining Guidance

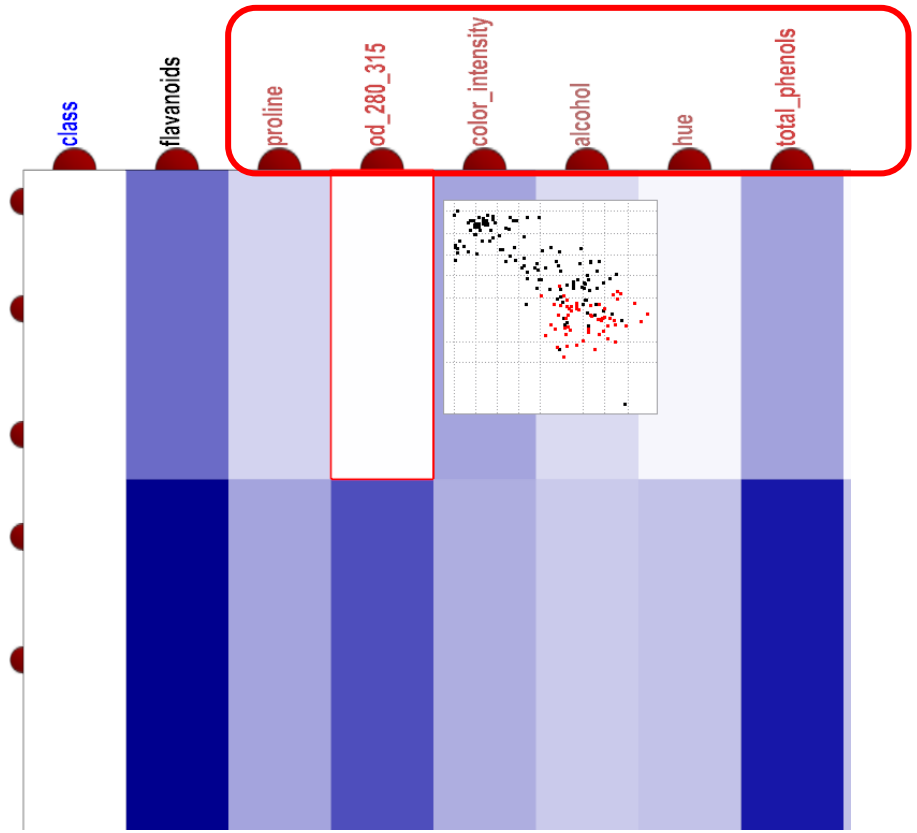
Some Examples

Input and Output

- INPUT
  - *Data*
  - *Domain Knowledge*
  - *Visualization Images*
  - *User Knowledge*
  - *History*
- OUTPUT
  - *Answer*
  - *Means* *to convey guidance*

Highlighting

[Ceneda et al.2019]
[May et al., 2011]



Defining Guidance

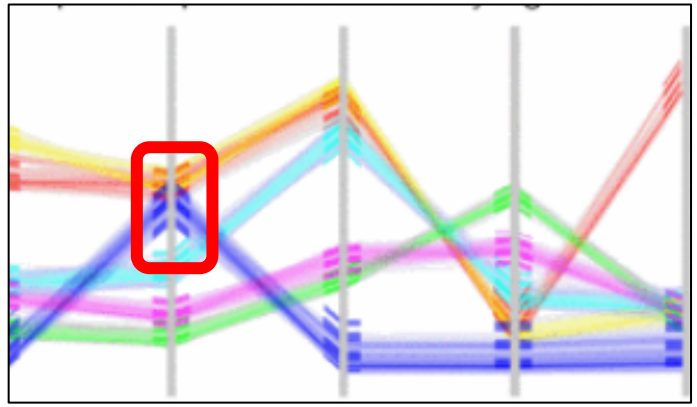
Some Examples

[Ceneda et al.2019]
[Johansson et al., 2005]

Input and Output

- INPUT
  - *Data*
  - *Domain Knowledge*
  - *Visualization Images*
  - *User Knowledge*
  - *History*
- OUTPUT
  - *Answer*
  - *Means* *to convey guidance*

Motion



Defining Guidance

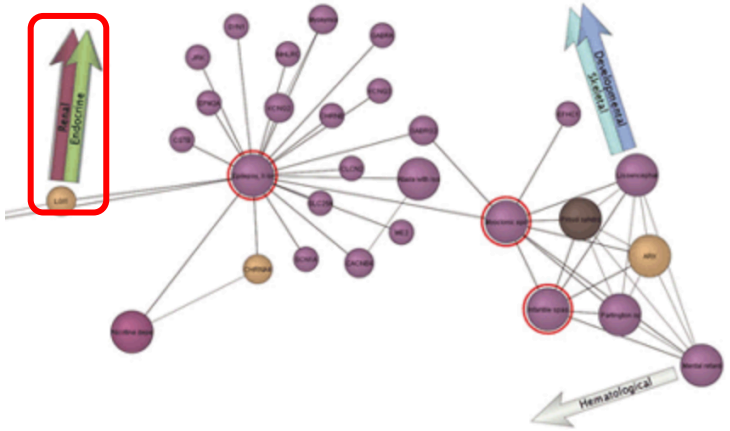
[Ceneda et al.2019]
[May et al., 2012]

Some Examples

Input and Output

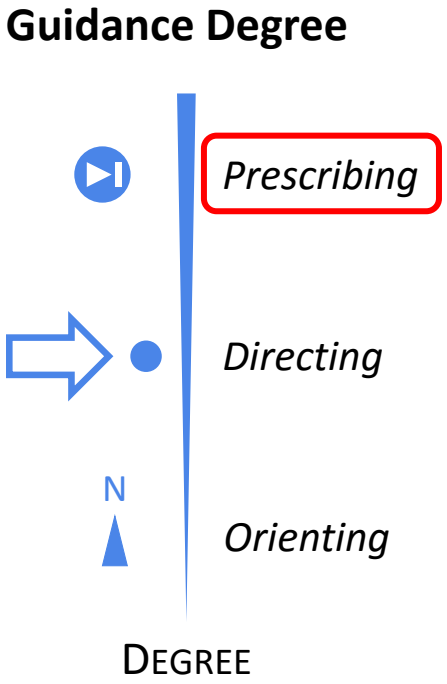
- INPUT
  - *Data*
  - *Domain Knowledge*
  - *Visualization Images*
  - *User Knowledge*
  - *History*
- OUTPUT
  - *Answer*
  - *Means* *to convey guidance*

Glyphs/Forms

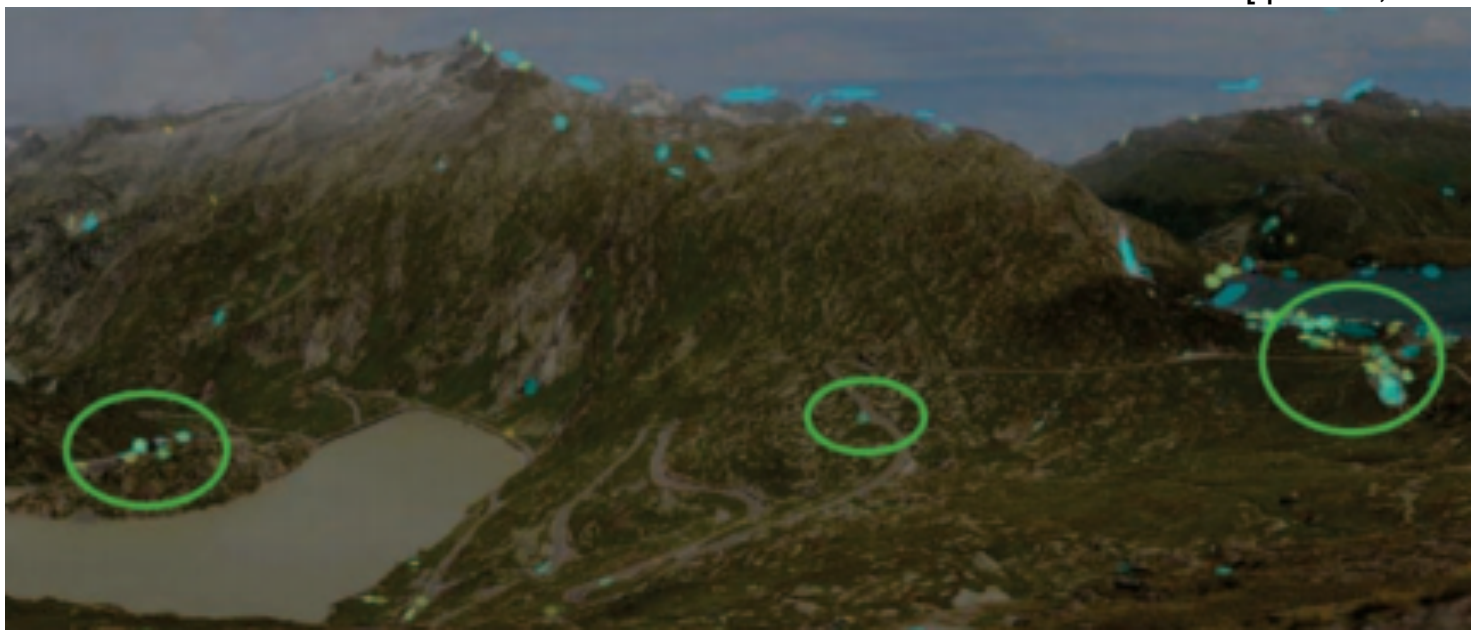


Defining Guidance

Some Examples



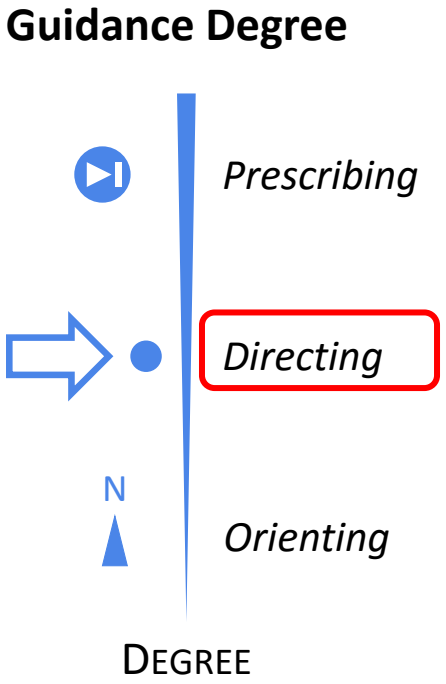
[Ip et al., 2011]



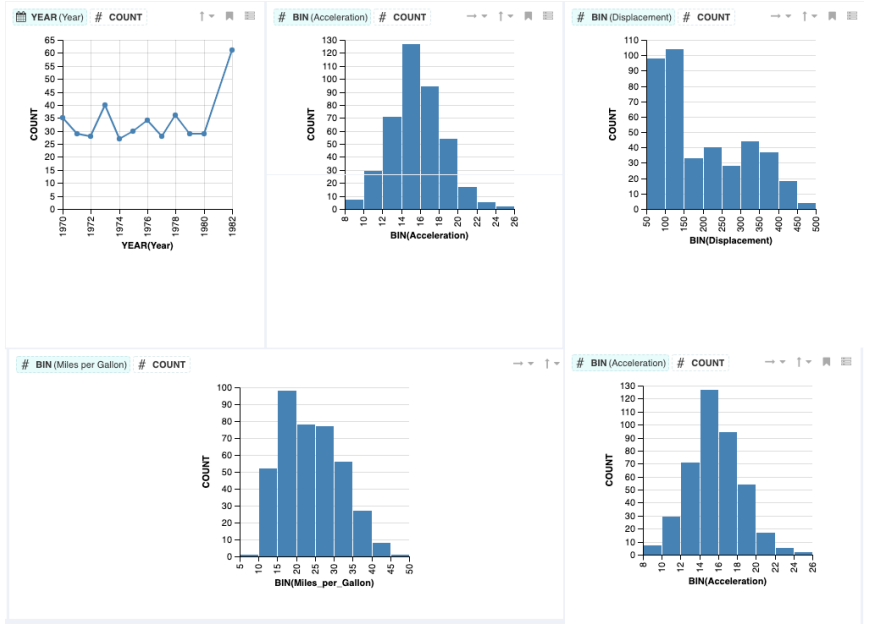
Step-by-step exploration of the most interesting viewpoints

Defining Guidance

Some Examples



[Wongsuphasawat et al., 2016]

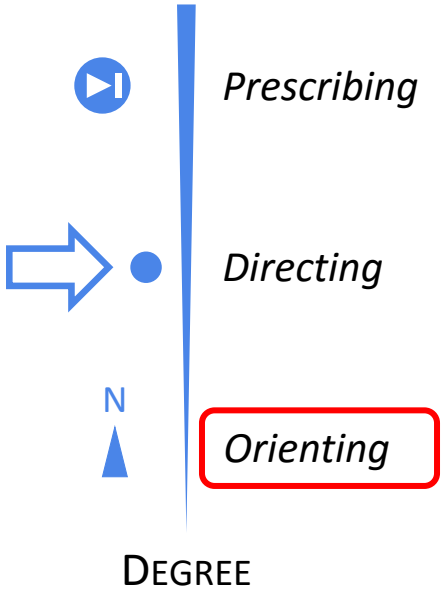


Recommendation of appropriate visualizations

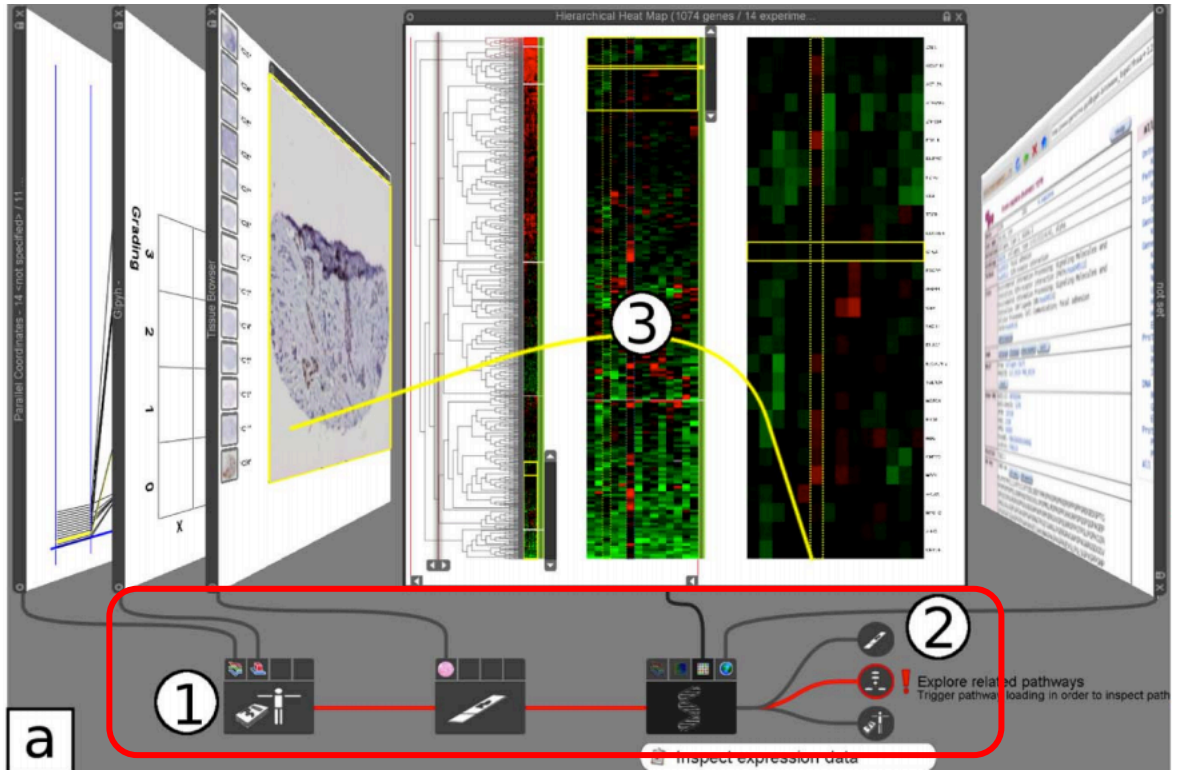
Defining Guidance

Some Examples

Guidance Degree

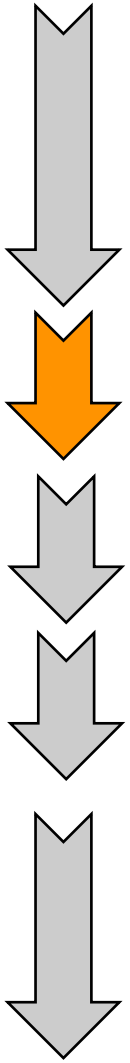


[Streit et al., 2012]



Alternative actions

Table of Contents



Defining Guidance - Overview

Answering **S1**:

«Is it possible to devise a general framework and a common guidance definition embodying the current state-of-the-art approaches and literature?»

Findings condensed in a framework and a definition → **computer side of guidance**

What about the user side of guidance?

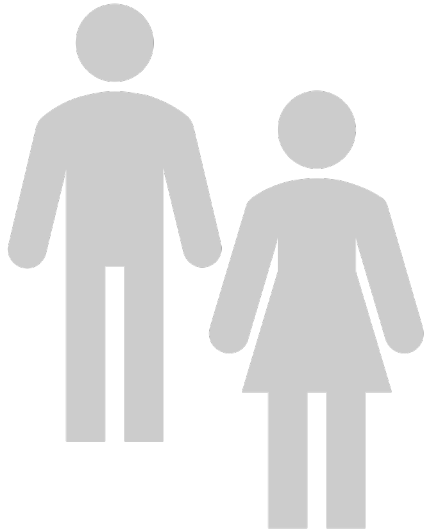
D. Ceneda, T. Gschwandtner, M. Streit, S. Miksch and C. Tominski. „***Guidance or No Guidance? A Decision Tree Can Help***“ In: Proc. of the International Workshop on Visual Analytics (EuroVA). Euro-graphics Digital Library, 2018, 19–23

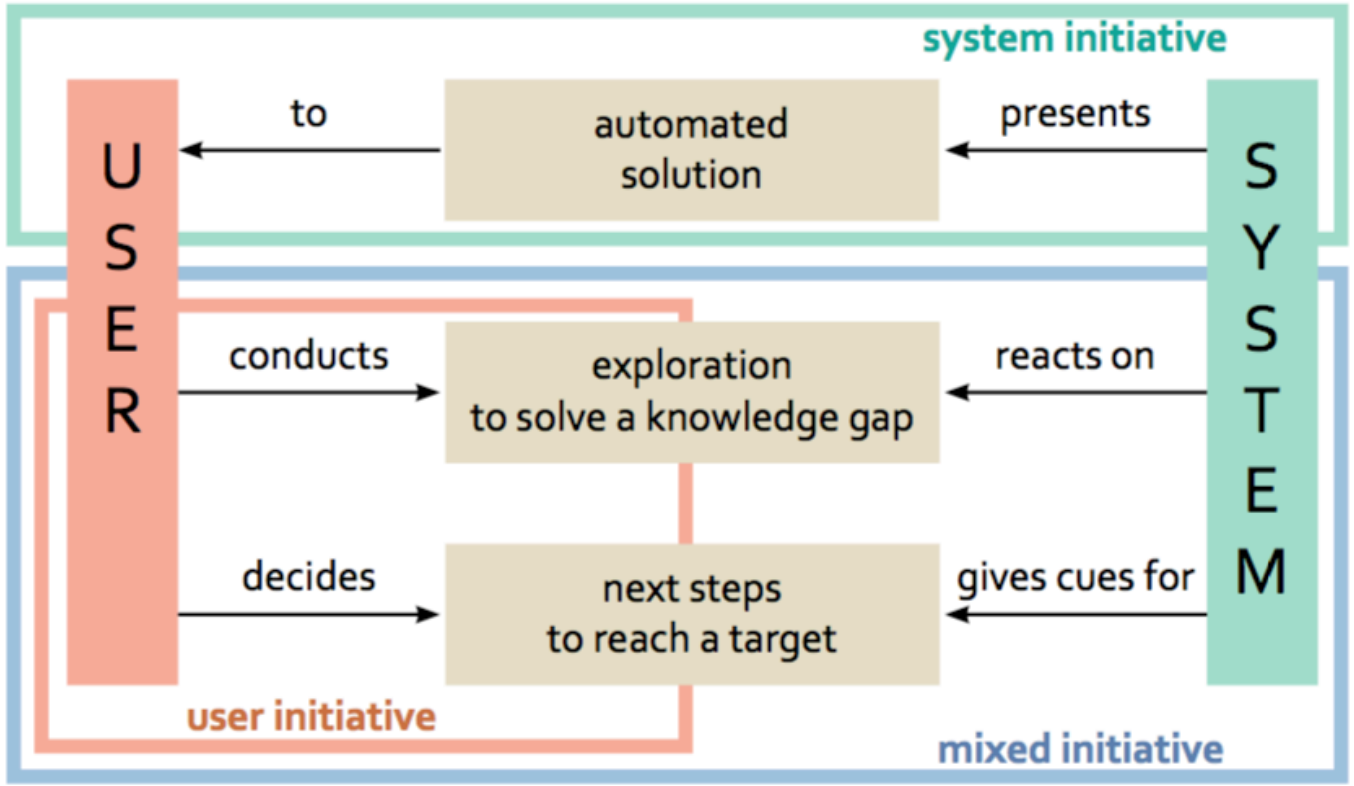
D. Ceneda, T.Gschwandtner and S. Miksch „***A review of guidance approaches in visual data analysis: A multifocal perspective***“. In: ComputerGraphics Forum 38.3 (2019), pp. 861–879.

Defining Guidance

[Horvitz, 1999]
[Ceneda et al., 2018]

Guidance is a **mixed-initiative** process

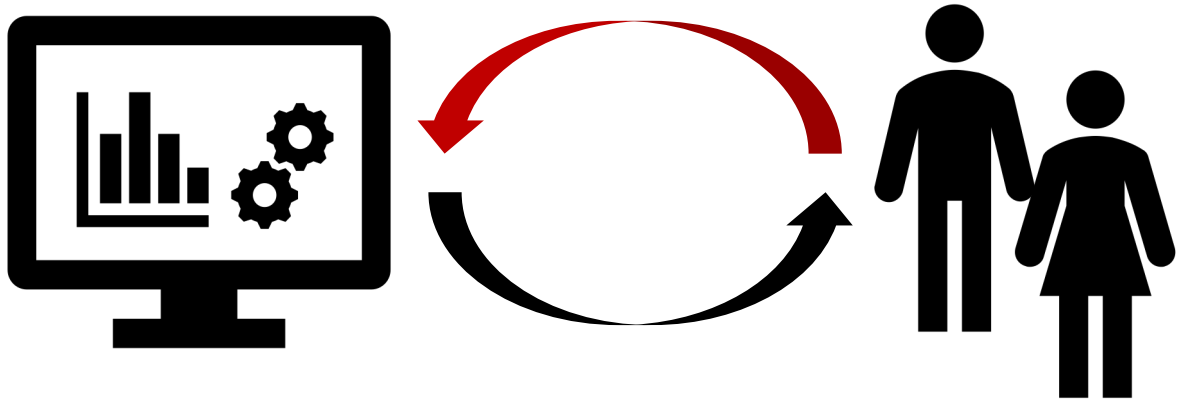




Defining Guidance

Let’s talk about «User Guidance»

[Ceneda et al.,2019]



Guidance Direction

Feedforward
Directed towards future guidance

Feedback
Directed towards future guidance

Guidance Inference

Direct Actions

Indirect Actions

Defining Guidance

Let’s talk about «User Guidance»

Guidance Direction

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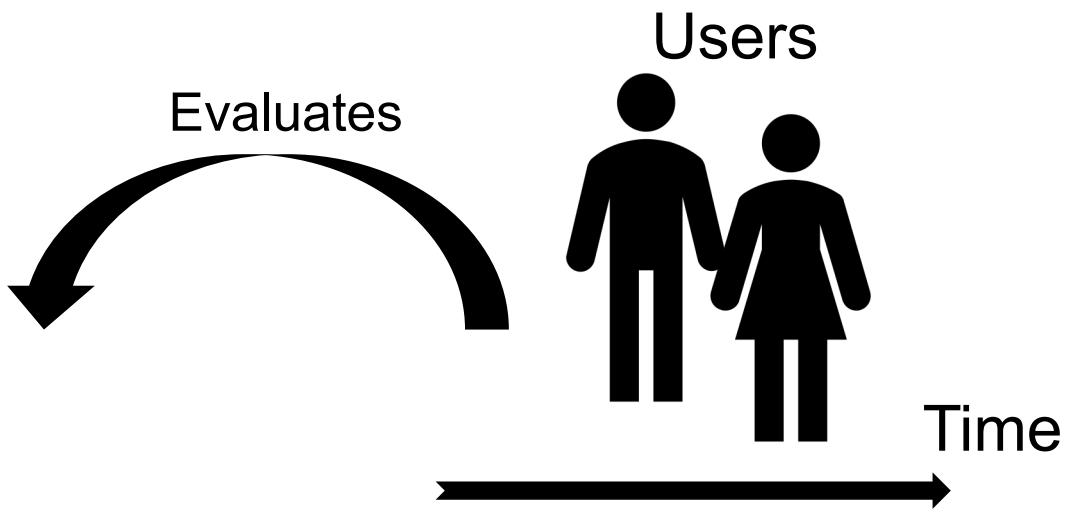
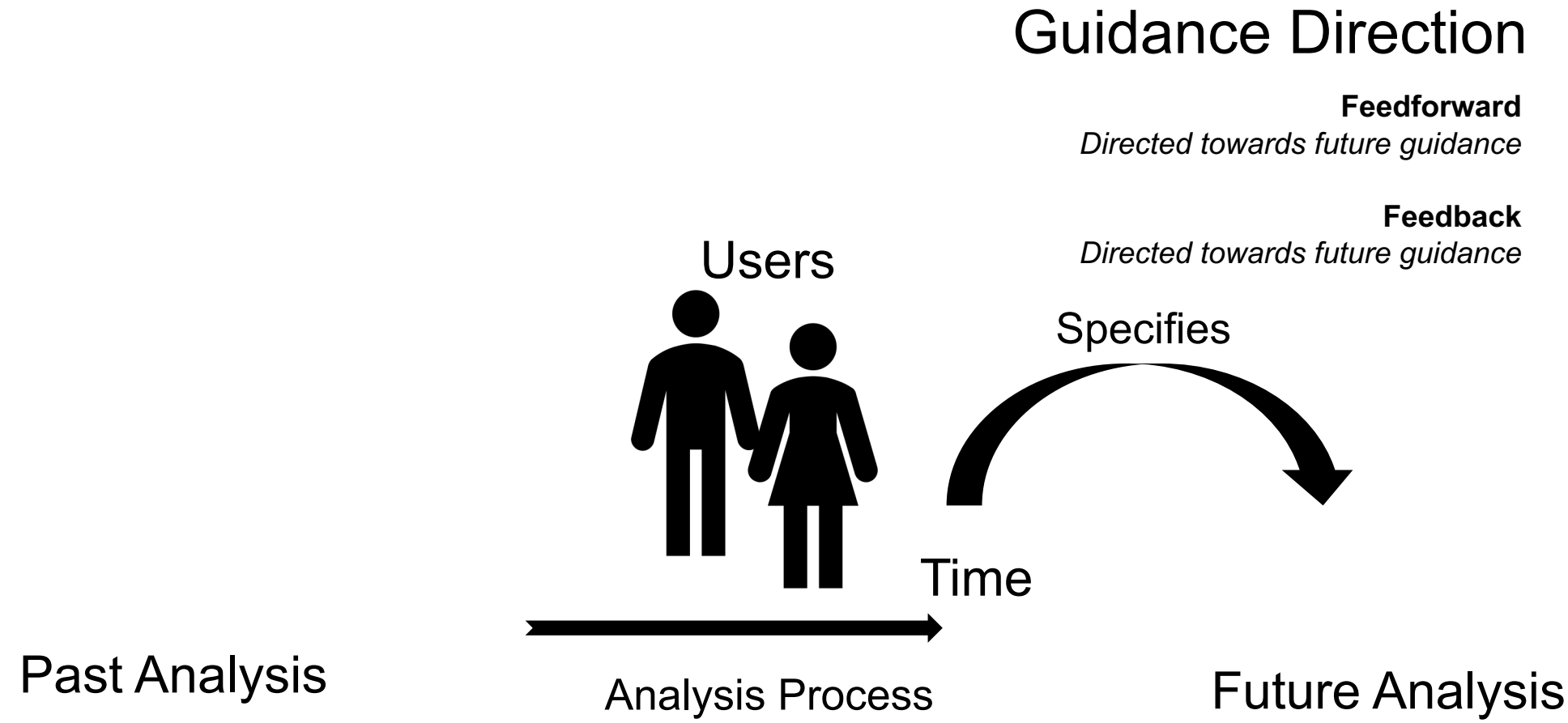
Directed towards future guidance

Feedback
Directed towards future guidance



Defining Guidance

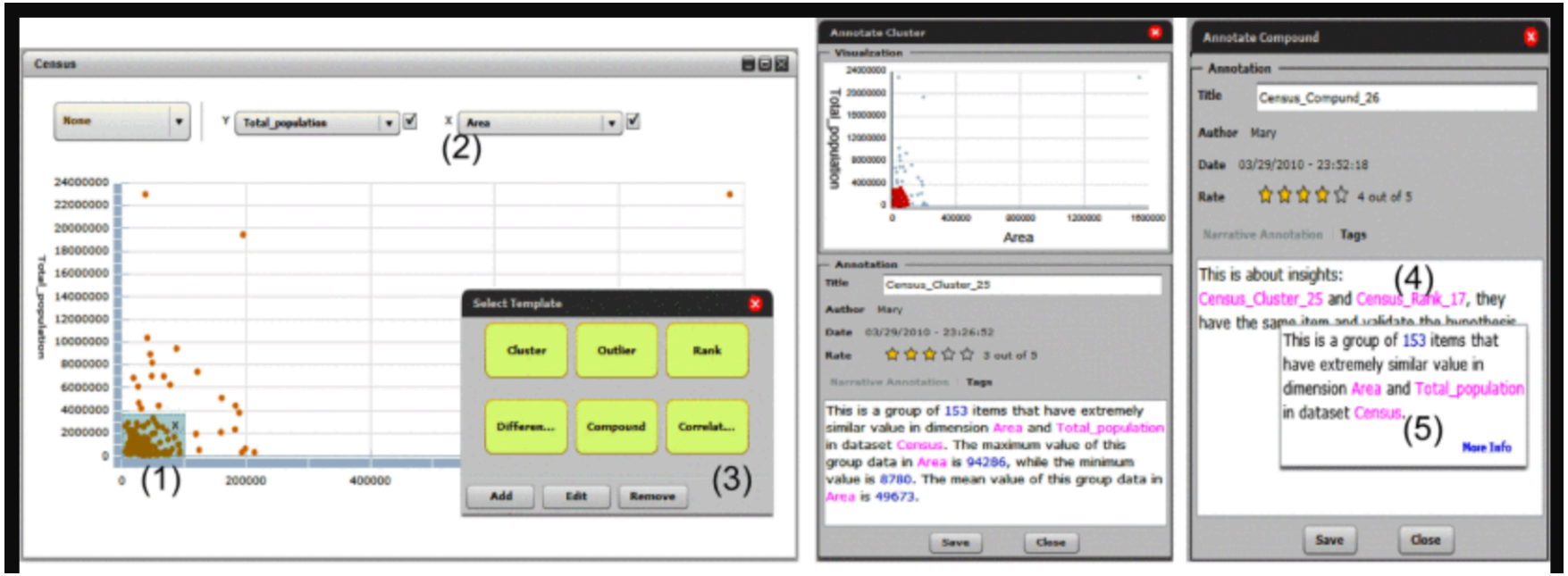
Let’s talk about «User Guidance»



Defining Guidance

Feedback

[Chen et al., 2010]



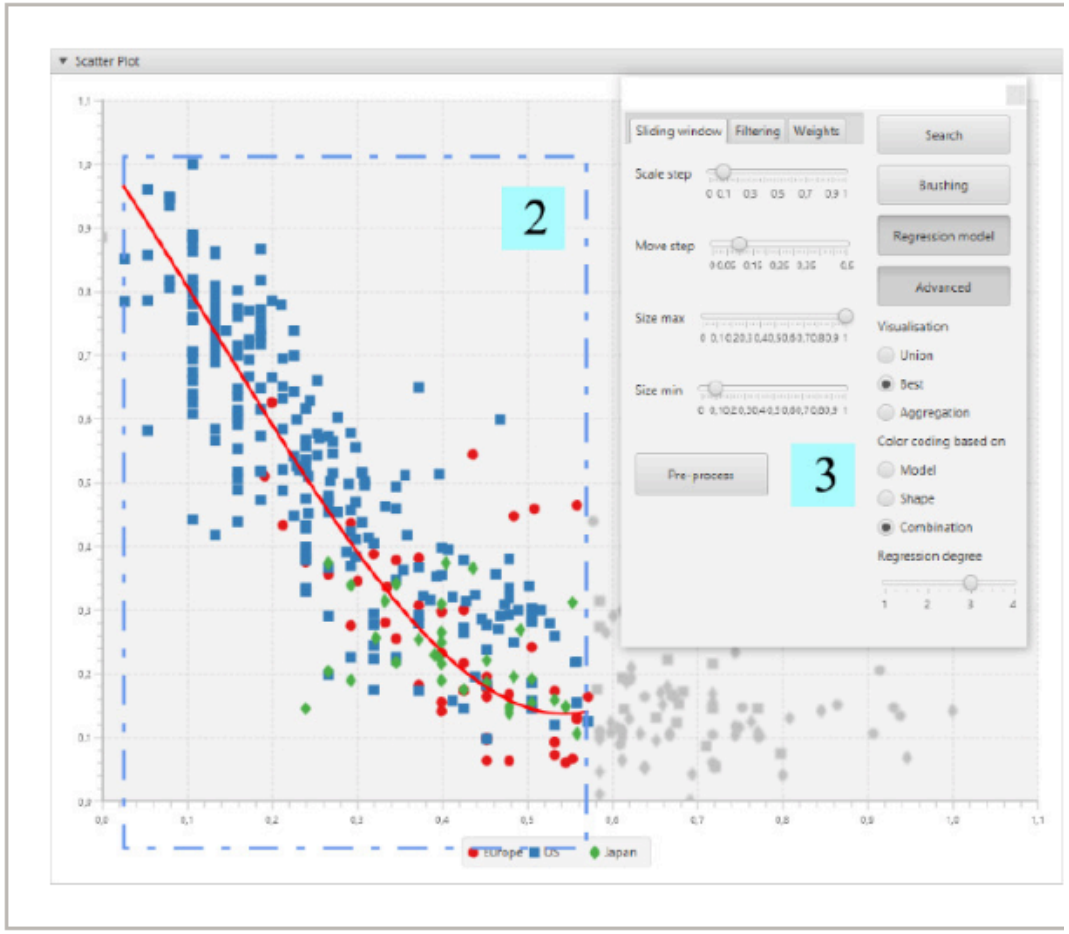
System suggests annotations →

User can evaluate/change them

This changes future suggestions

Defining Guidance

Feedforward



[Chegini et al., 2018]

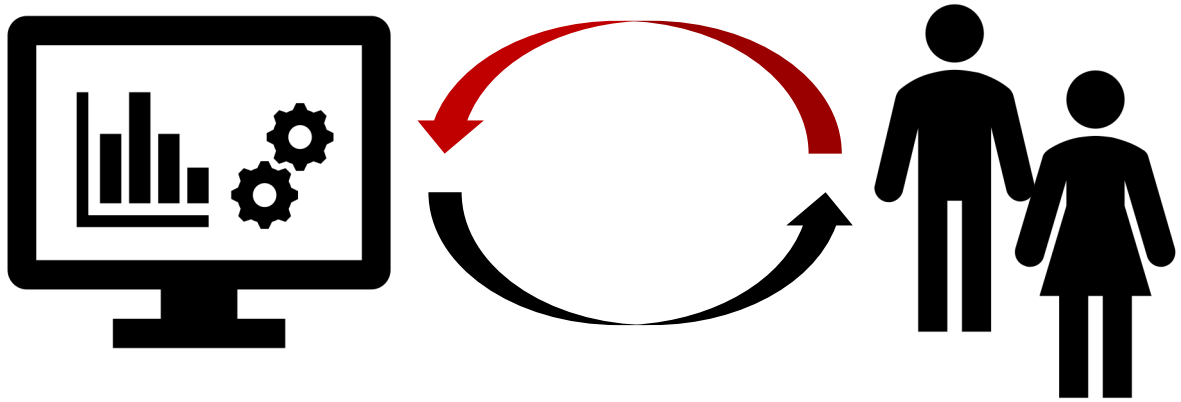
Users can input what they are looking for

e.g., draw the pattern representing the searched output

Defining Guidance

Let’s talk about «User Guidance»

[Ceneda et al.,2019]



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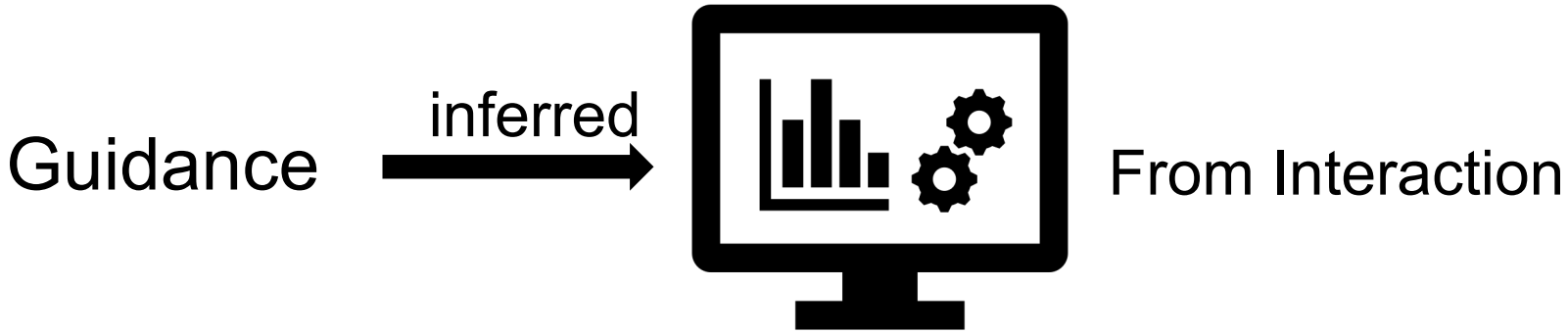
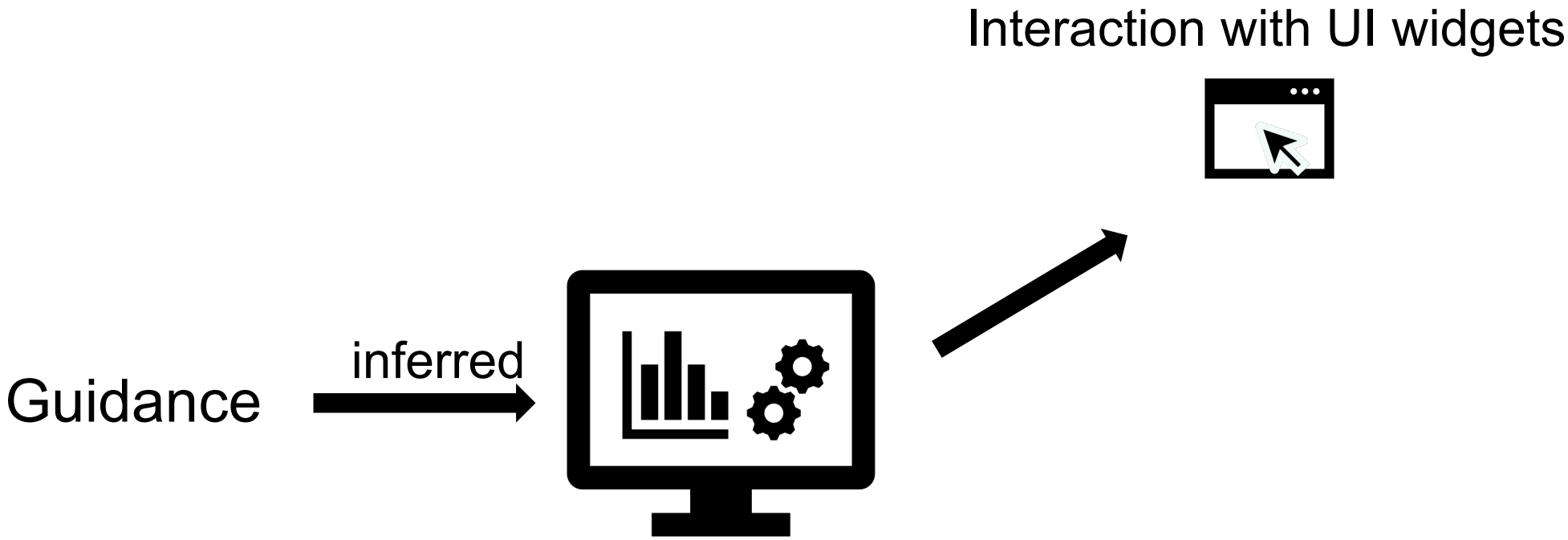


Defining Guidance

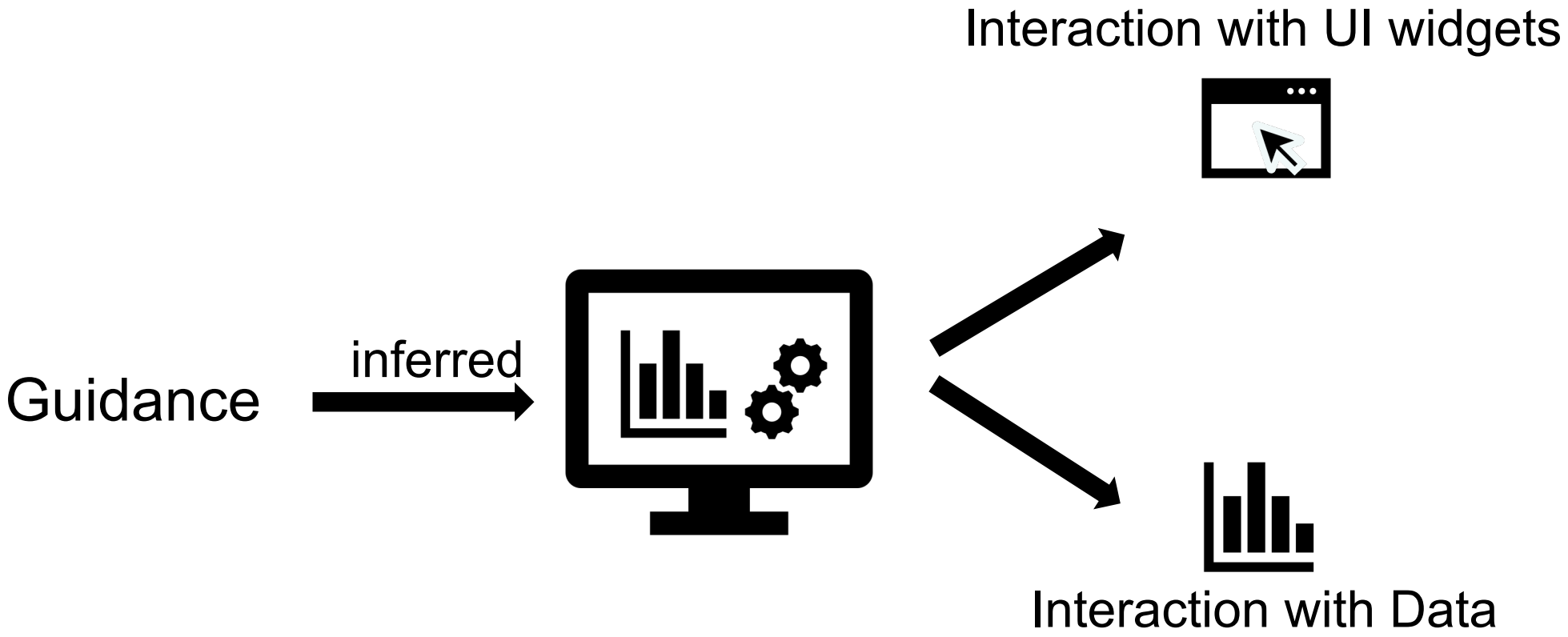
Guidance Inference



What does it mean in terms of Guidance?

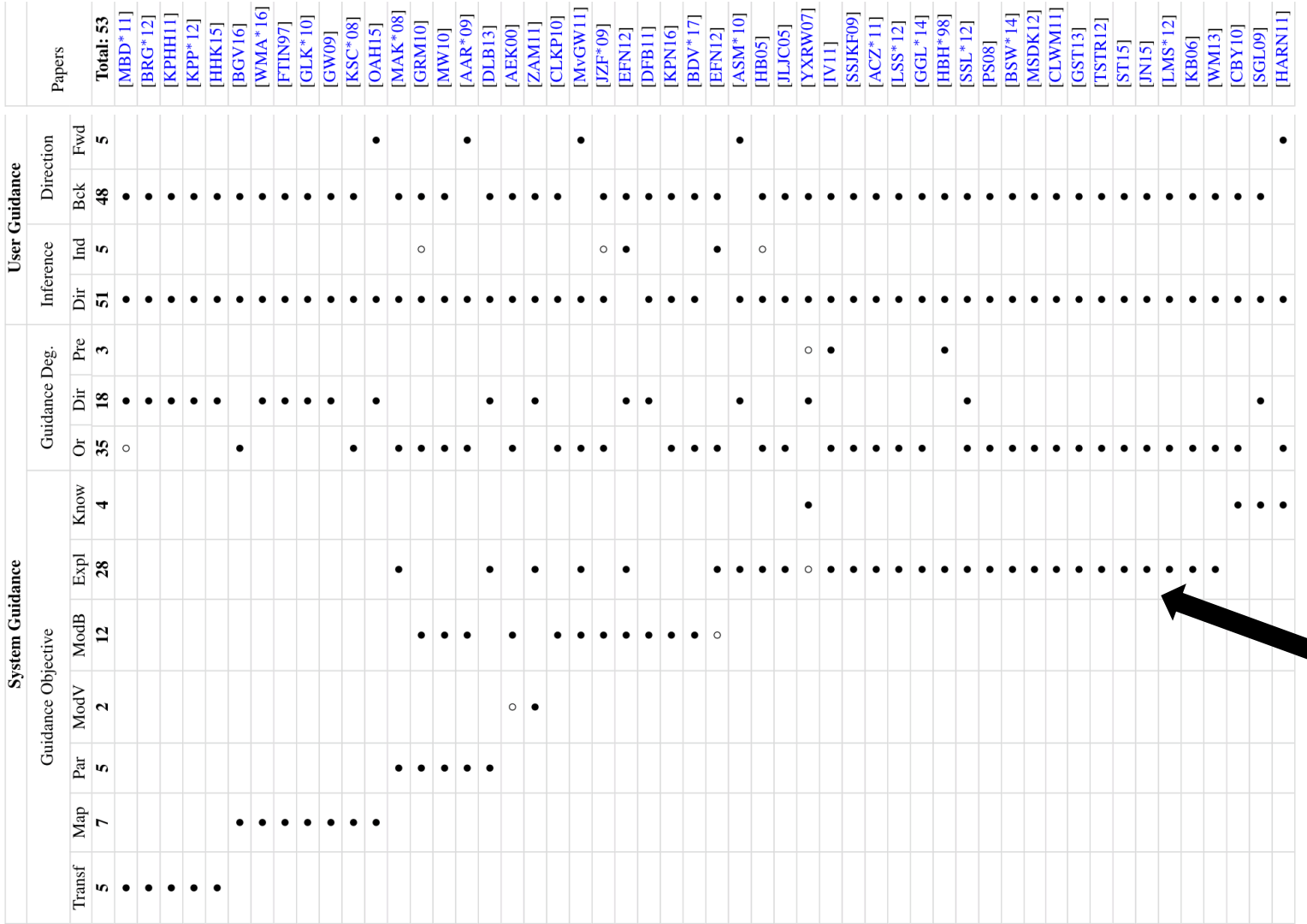
Defining Guidance

Guidance Inference



Defining Guidance

Guidance - State of the Art



Papers

Dimensions

[Ceneda et al., 2019]

Defining Guidance

What did we learn?

No single approach provides guidance in a comprehensive way to the whole analysis process

Typically, single/simple tasks are supported with guidance
Mostly, guidance for exaploration tasks
Not many approaches supporting knowledge generation tasks

No approach provides more than one guidance degree at a time

Mostly, orienting guidance
Only a few prescribing guidance

The aim of Guidance is to enable a better human-computer collaboration
However, ***effective human-computer collaboration is far from being realized***

[Ceneda et al., 2019]

Table of Contents

The Effects of Guidance - Overview

Answering **S2**:

«What are the benefits (if any), and in general what are the effects of using guidance during visual analytics*?*»

how users with different knowledge and expertise reacted to multiple types of guidance

how guidance influences the way users solve tasks

D. Ceneda, T. Gschwandtner, and S. Miksch. „**You get by with a little help: The effects of variable guidance degrees on performance and mental state**“. In: Visual Informatics 3.4 (2019), pp. 177–191

D. Ceneda, T.Gschwandtner, S. Miksch and C. Tominski „**Guided Visual Exploration of Cyclical Patterns in Time-series**“ Visualization in Data Science (VDS at IEEE VIS 2018)

The Effects of Guidance

User Study 1 - Assumptions

Assumptions: *3 dimensions influence guidance design*

Type of Task

Knowledge of the User

Type/Degree of Guidance

Aim: we alternatively varied one of these factors and analyzed if and how users were able to complete the given tasks and what was their reaction to the guidance received

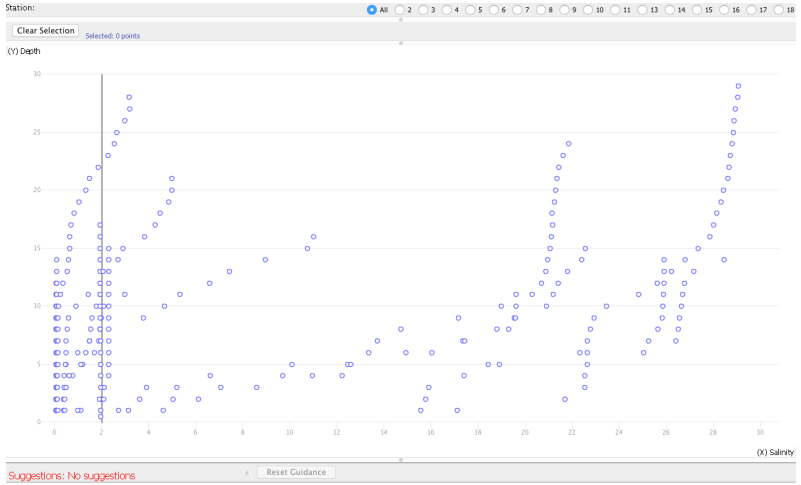
The Effects of Guidance

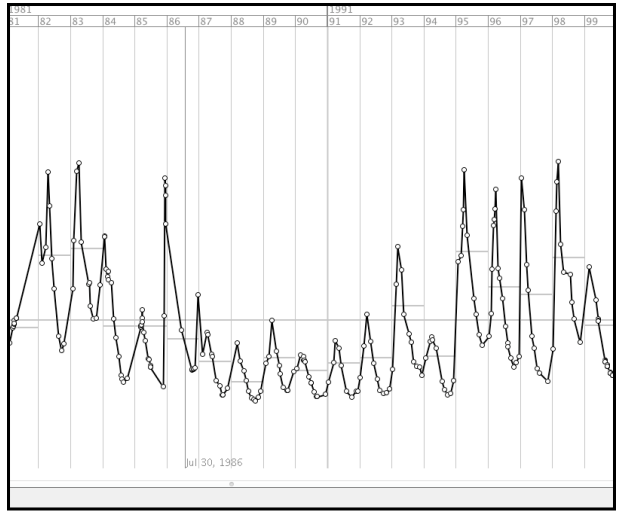
User Study 1 – Task Types

[Chen et al., 2008]

Operational Knowledge → Exploratory Tasks

Operational knowledge needed but no need to know domain concepts



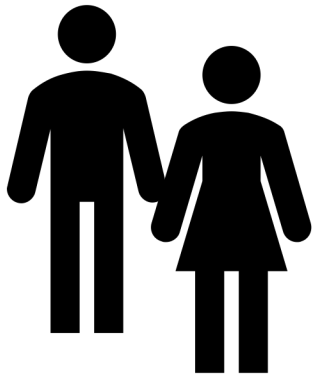


Domain Knowledge → Domain Tasks

Domain knowledge needed but no need to explore

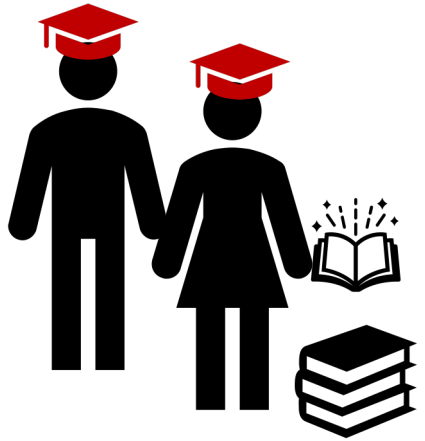
The Effects of Guidance

User Study 1 – Knowledge of the User



Novice Users

No previous knowledge

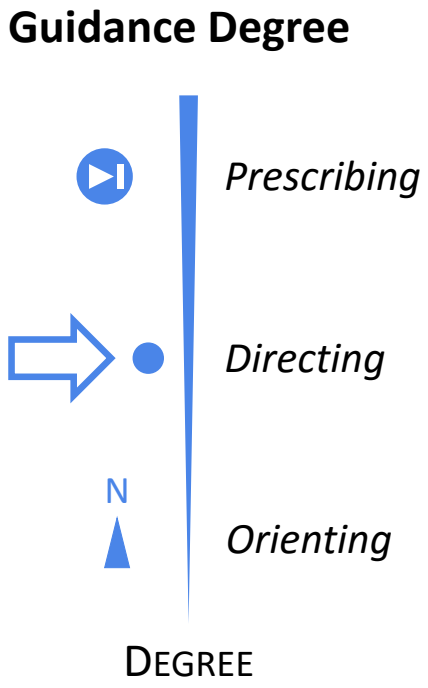


Knowledgeable Users

Previous Knowledge

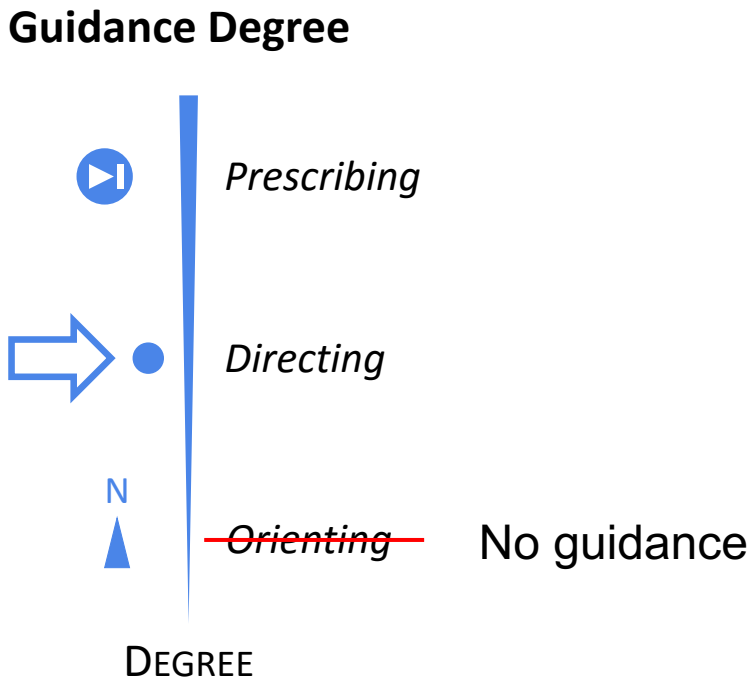
The Effects of Guidance

User Study 1 – Guidance Degree



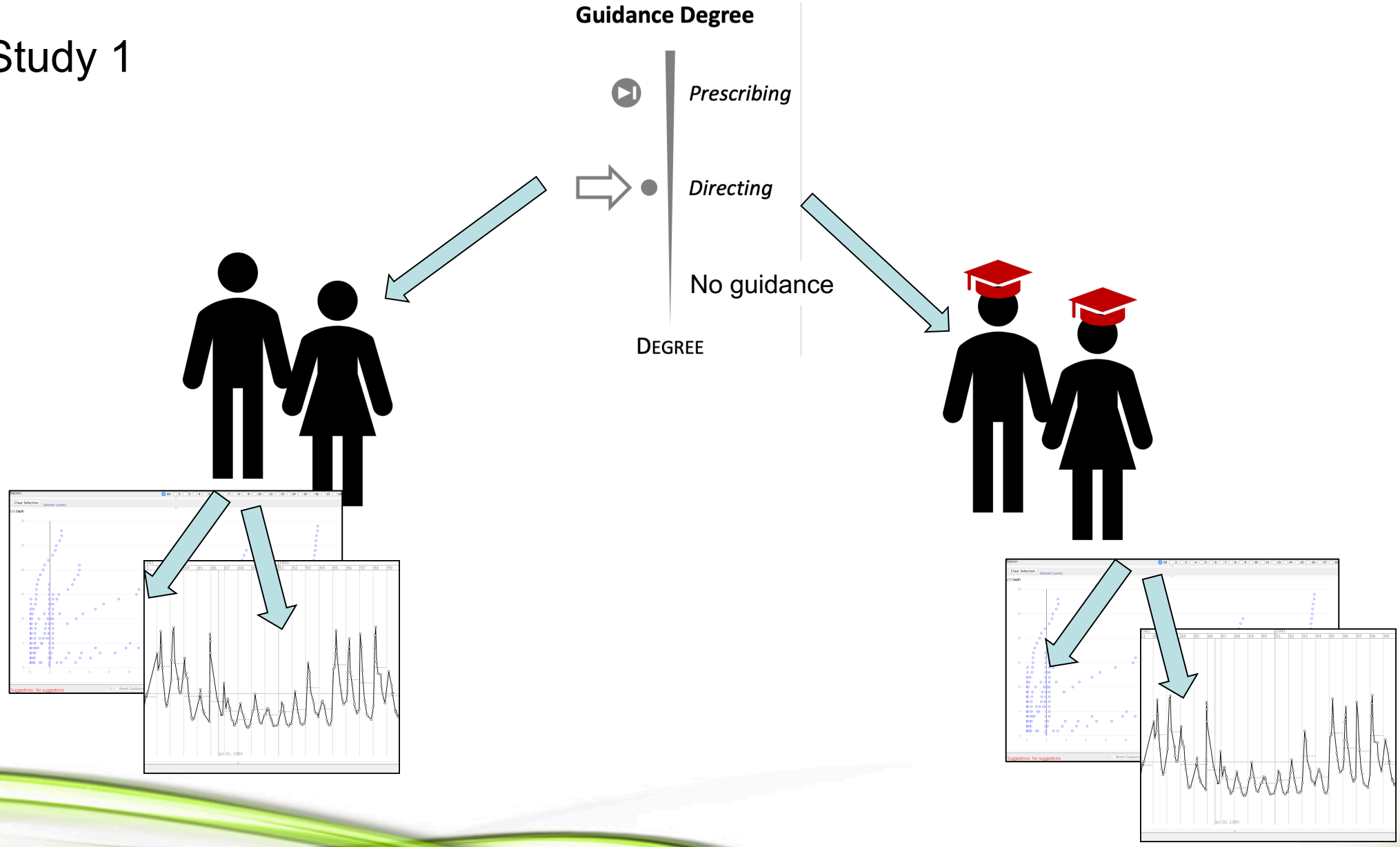
The Effects of Guidance

User Study 1 – Guidance Degree



The Effects of Guidance

User Study 1



The Effects of Guidance

User Study 1 – Evaluation

Performance	Description
Completion Time	A timer measured the interval between the start of the task and the submission of an answer.
Correctness	A real number in [0,1]. This value is a weighted ratio between correctly selected data items and all selected data items.
Distance	A real number in [0,1], measuring the semantic distance of the selected data items from the correct ones.
Total Steps	The total number of actions (clicks, filter, etc.) required by a user to complete a task.

Mental State	Description
Lost	We asked the participants how lost they felt while executing the task.
Frustrated	We asked the participants how frustrated they felt while executing the task.
Confident	We asked the participants how confident they felt about the correctness of the submitted result.
Easy	We asked the participants to evaluate how easy the task was.
Guidance Appropriate	We asked the participants if they considered the guidance they received appropriate to solve the task.

The Effects of Guidance

User Study 1 – Outcome

Positive effect on users' performance and mental state

Guidance is useful for novice users solving exploratory tasks

Novice users/Domain tasks needed more guidance

i.e., guidance can only compensate partially for domain knowledge

The guidance degree must match user's knowledge

increased errors – too much trust

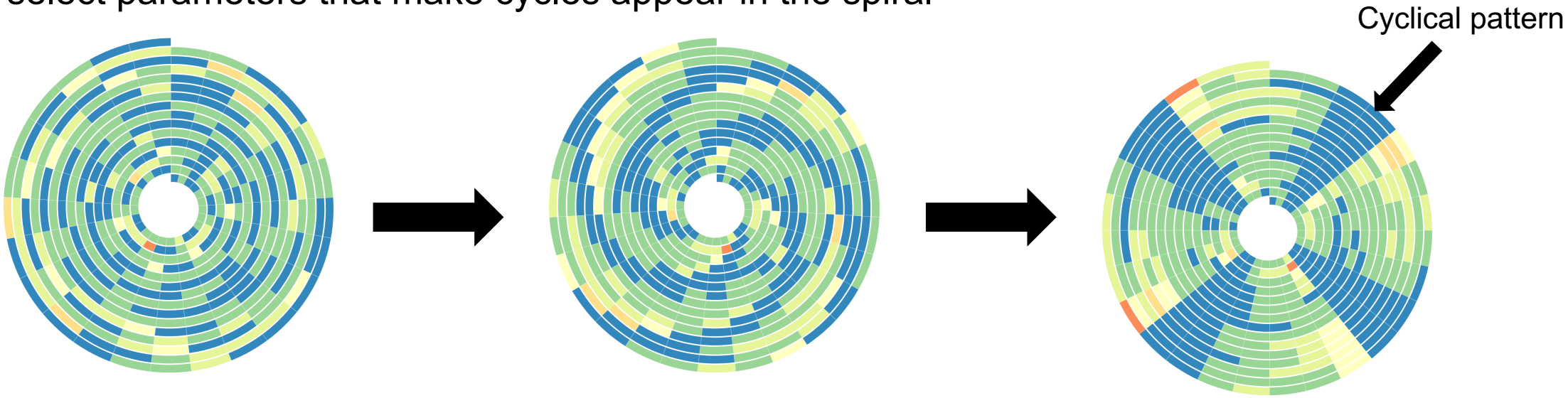
Guidance affects positively users' self assessment and confidence

The Effects of Guidance

User Study 2 – Overview

Guidance to support **detection of cycles using a spiral plot**

select parameters that make cycles appear in the spiral

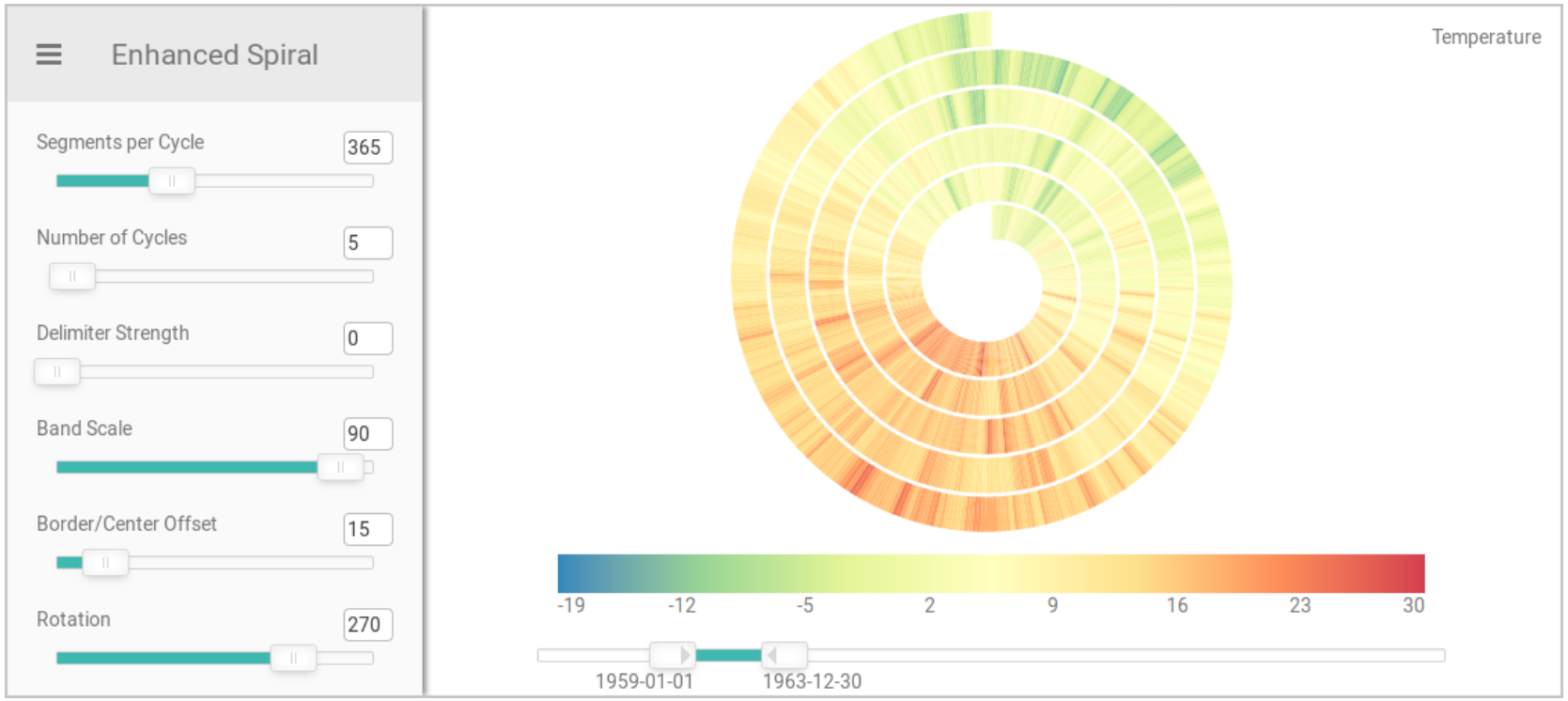


Aim: Check if guidance affect the way users solve tasks, i.e., users' strategy

The Effects of Guidance

User Study 2 – Changes of Strategy

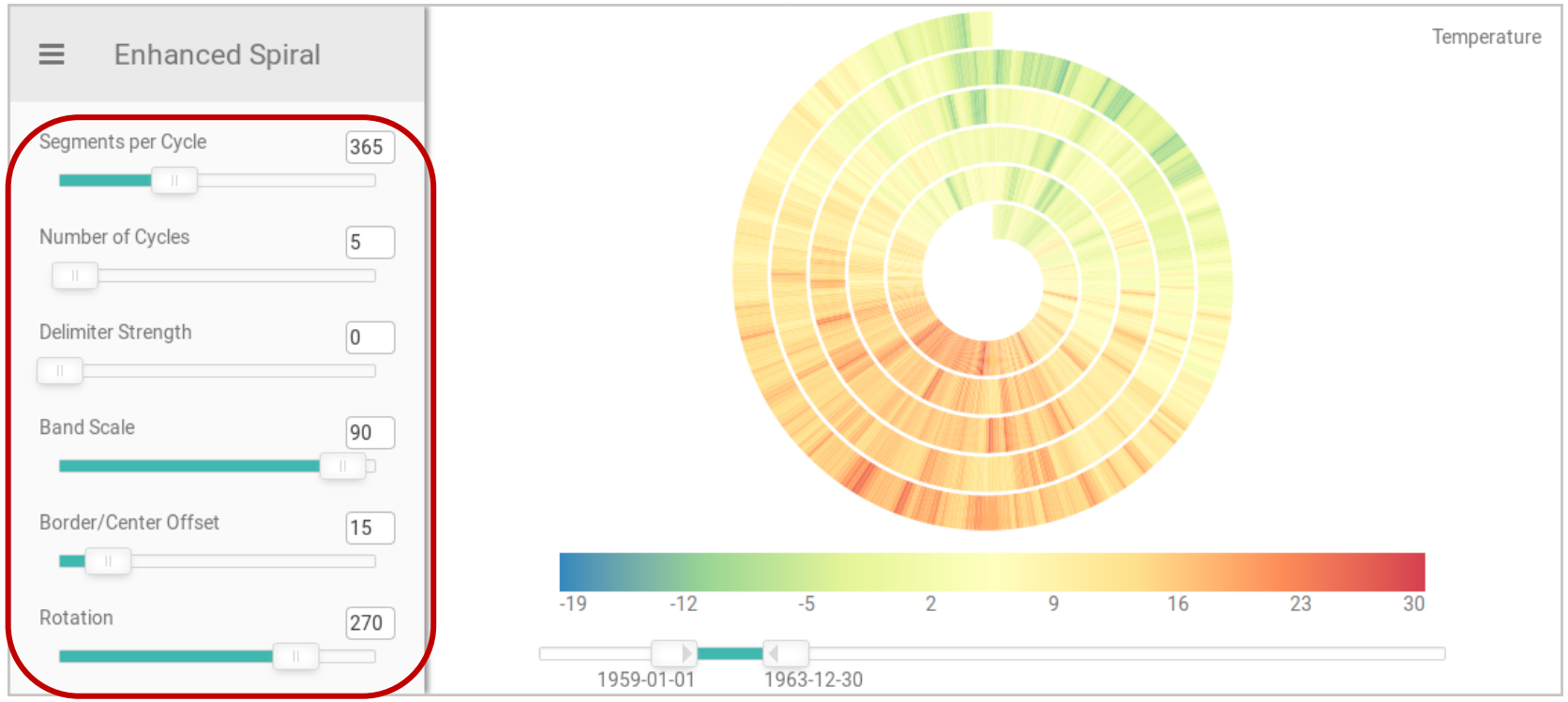
Task: Find cycles in the data (but **without guidance)**



The Effects of Guidance

User Study 2 – Changes of Strategy

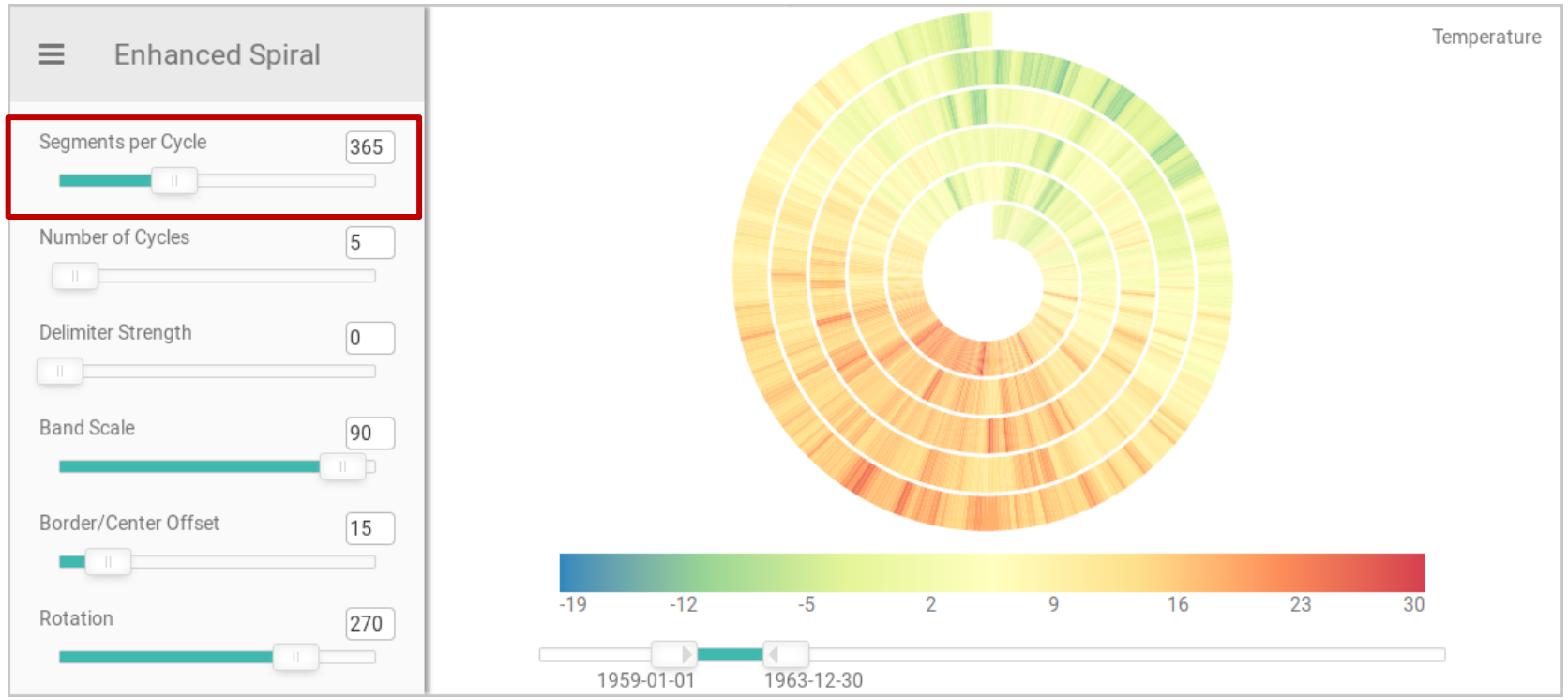
Task: Find cycles in the data (but **without guidance)**



The Effects of Guidance

User Study 2 – Changes of Strategy

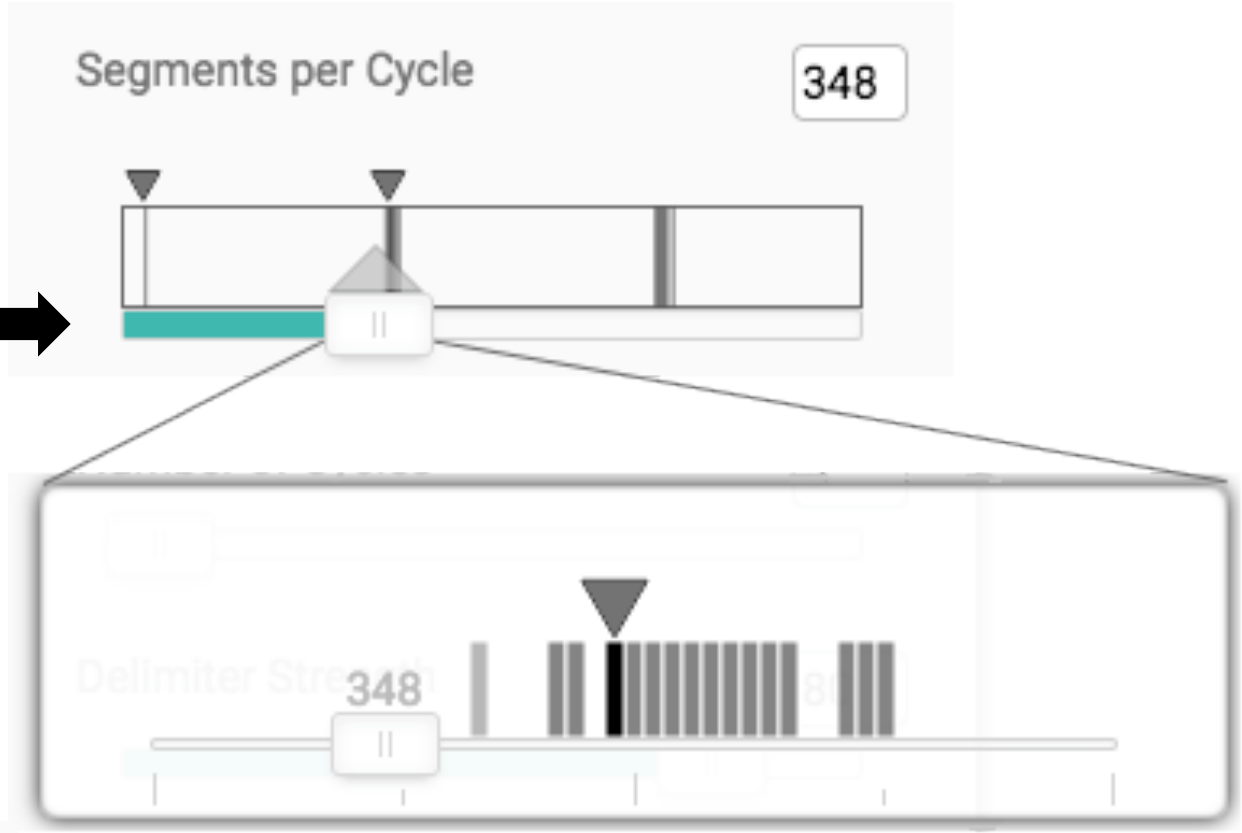
Task: Find cycles in the data (with **guidance)**



The Effects of Guidance

User Study 2 – Changes of Strategy

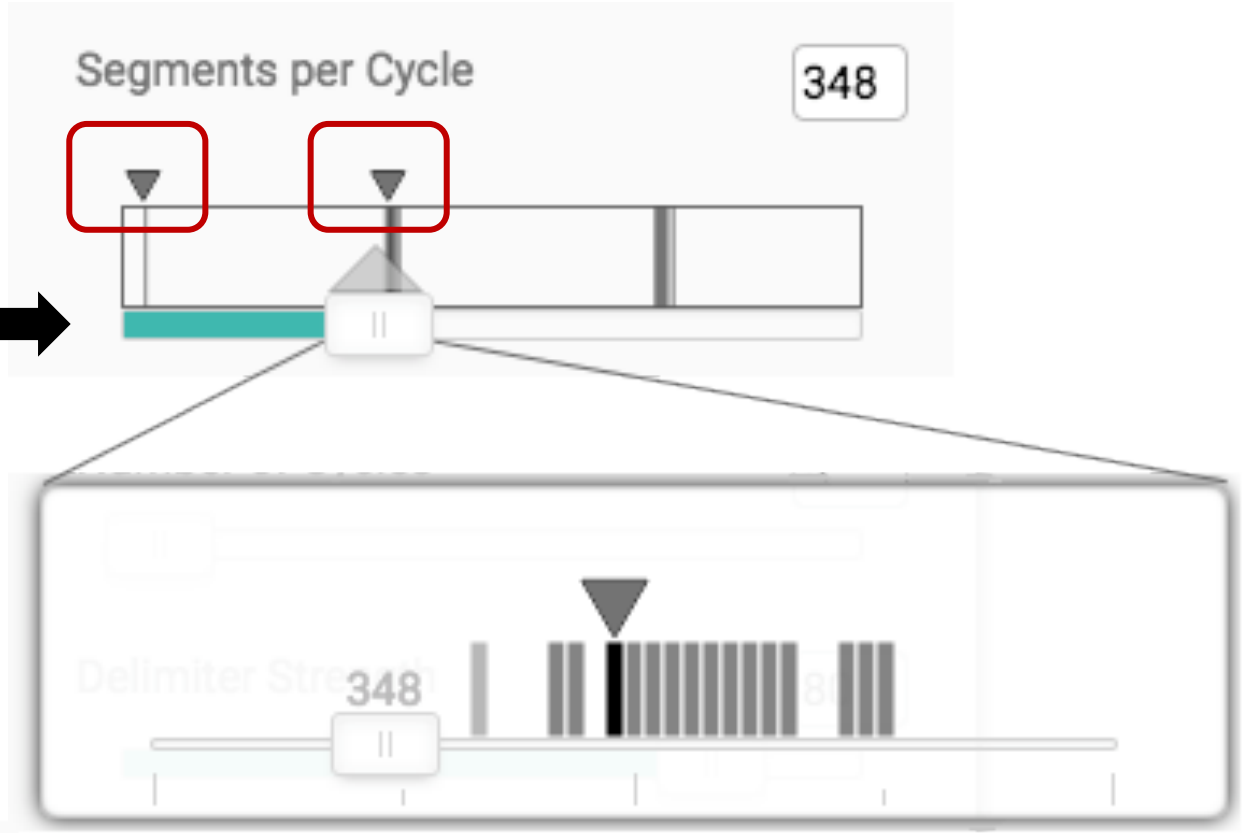
Task: Find cycles in the data supported with **guidance**



The Effects of Guidance

User Study 2 – Changes of Strategy

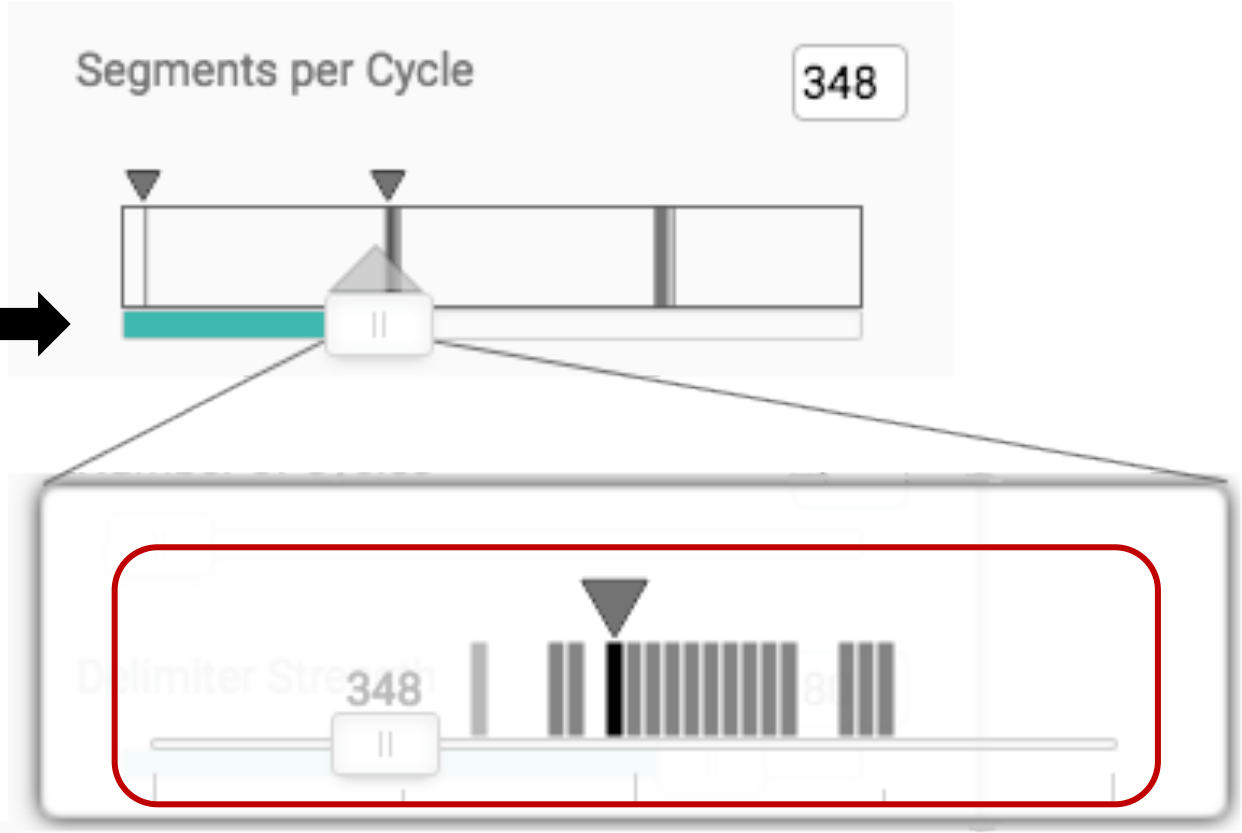
Task: Find cycles in the data supported with **guidance**



The Effects of Guidance

User Study 2 – Changes of Strategy

Task: Find cycles in the data supported with **guidance**



The Effects of Guidance

User Study 2 – Outcome

With guidance

- *Users found more cycles and reasoned more about the results.*
- *Formulated more hypotheses about the phenomenon observed*
- *Rated the relevance of the cycles they found, ordered them*
- *Reasoned about recurrences and multiple cycles*
- *Users spent most of their time evaluating the cycles suggested by the algorithms*
- *The participants developed a deeper understanding of the data*

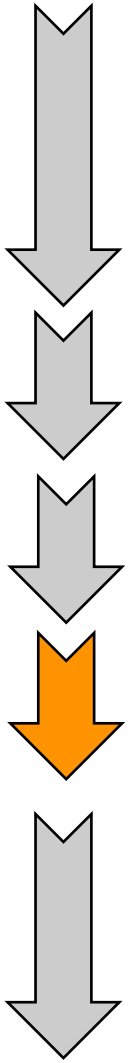
The Effects of Guidance

User Study 2 – Outcome

Without guidance

- *the participants followed quite closely a trial-and-error strategy.*
- *users explored all the different cycle length values.*

Table of Contents



Designing Effective Guidance - Overview

Answering **S3**:

«How is it possible to design effective guidance to support users throughout the visual analytics process?»

Meaning of «effective guidance»

Framework for guidance designers

D. Ceneda, N. Andrienko, G. Andrienko, T. Gschwandtner, S. Miksch, N.Piccolotto, T. Schreck, M. Streit, J. Suschnigg, and C. Tominski. „**Guide Me in Analysis: A Framework for Guidance Designers**“. In: Computer Graphics Forum 39.6 (2020), pp. 269–288

Designing Effective Guidance

Requirements

Effectiveness → the end goal of guidance-enriched visual analytics.

«mechanisms that should help analysts complete a given task while overcoming possible issues that could arise during the process»

The analysis is a complex process

Many factors play a central role in determining if guidance is effective

Designing Effective Guidance

[Ceneda et al., 2019]
[Ceneda et al., 2020]

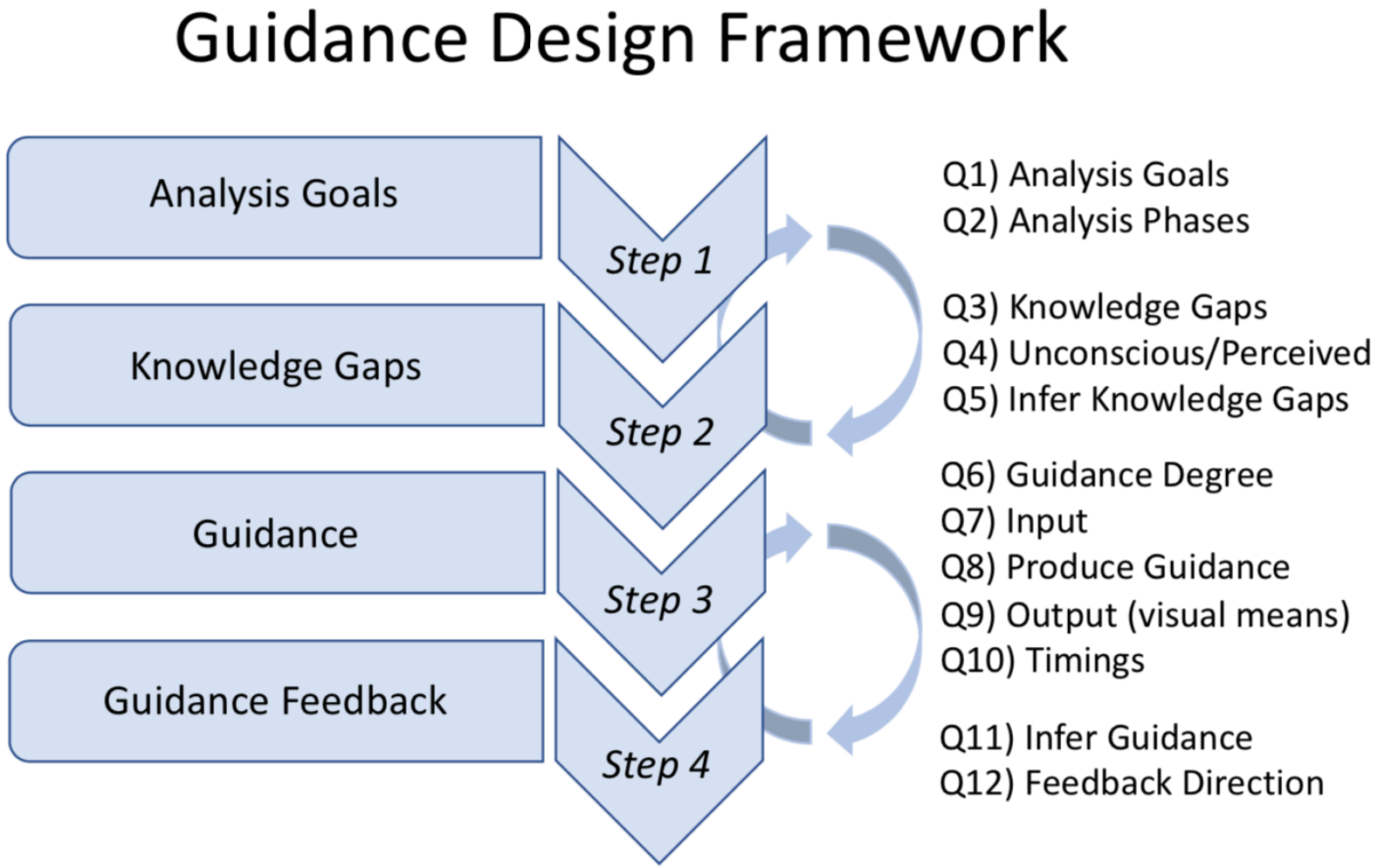
Qualitative Criteria

1. *Available* – Guidance is there for you
2. *Trustworthy* – Guidance will help you
3. *Adaptive* – Guidance will adapt to the situation
4. *Controllable* – Guidance can be tuned
5. *Non-disruptive* - Guidance will not mislead you

Designing Effective Guidance

Effective Guidance

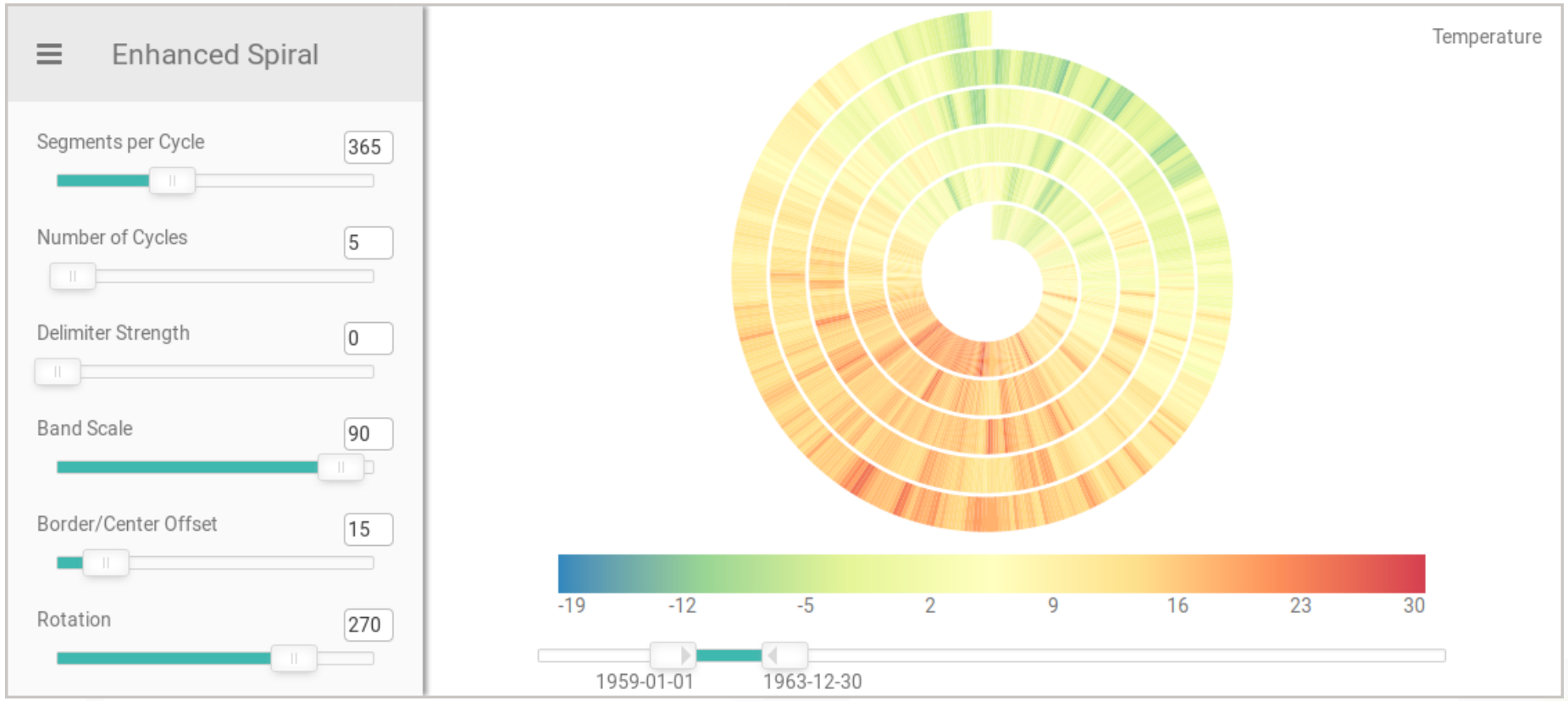
1. *Available*
2. *Trustworthy*
3. *Adaptive*
4. *Controllable*
5. *Non-disruptive*



Designing Effective Guidance

Step 1 – Analysis Goals

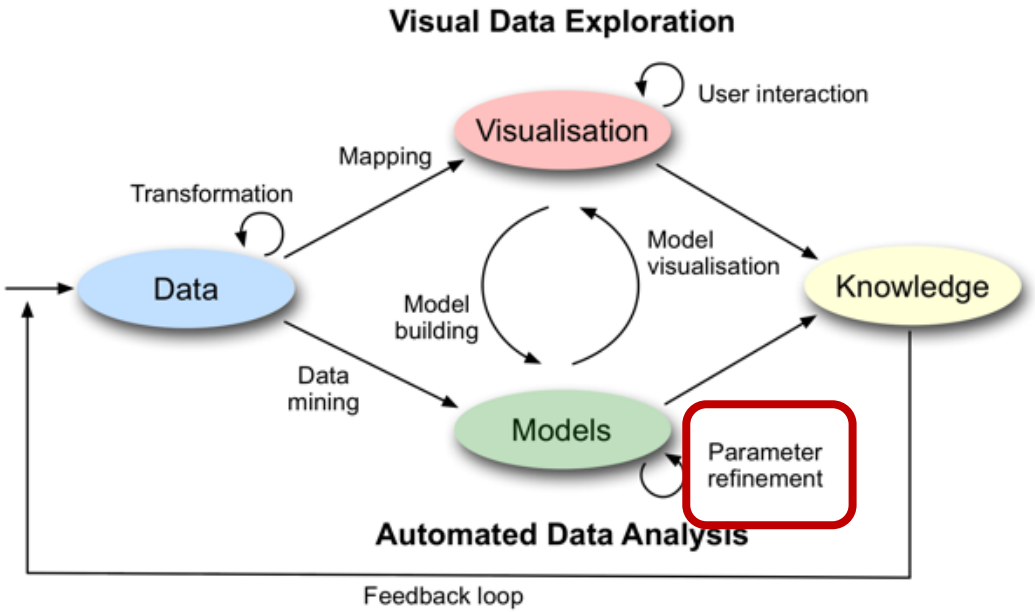
Q1: What are the analysis goals? *Find cycles in the data*

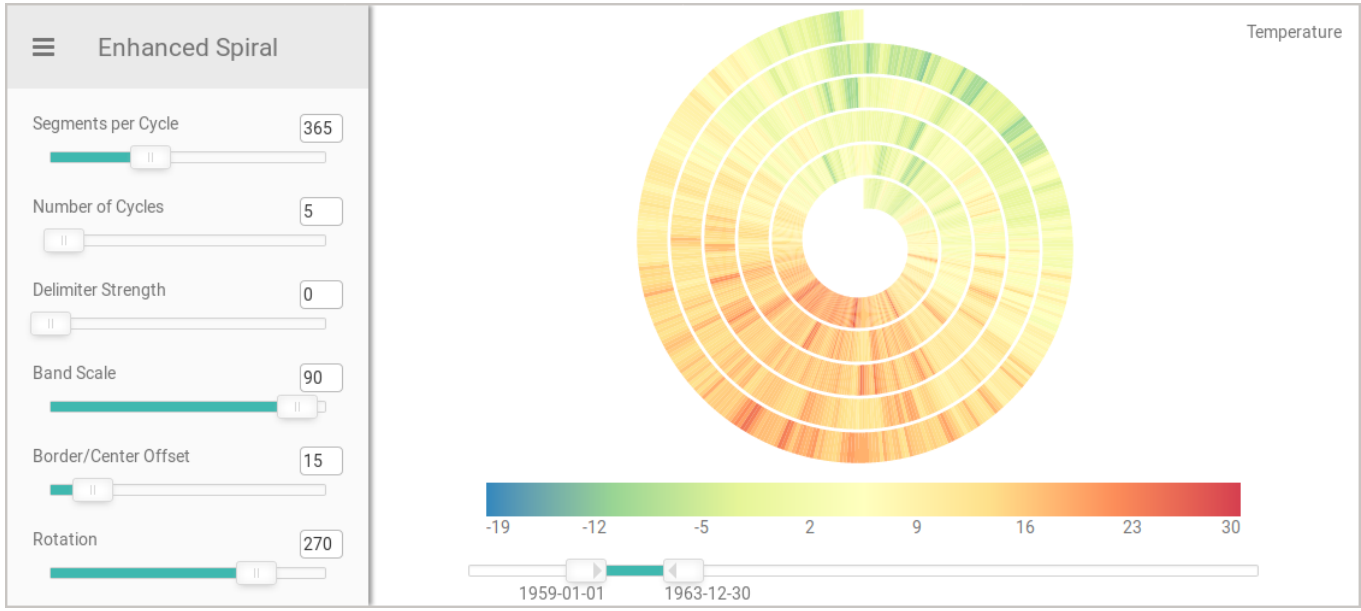


Designing Effective Guidance

Step 1 – Analysis Goals

Q1: What are the analysis goals? *Find cycles in the data*
Q2: In what analysis phases issues might occurr? *Mostly, during model building*





Designing Effective Guidance

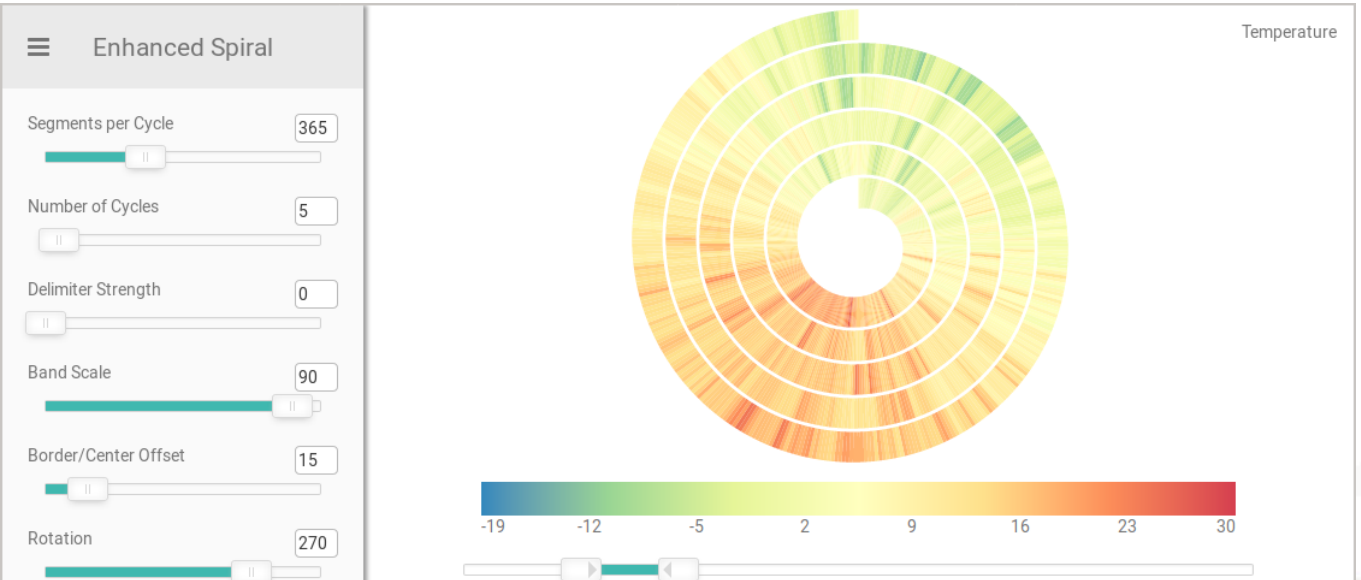
Step 2 – Knowledge Gaps

Q3: What are the knowledge gaps? *What parameters can be used to make cycles appear*

Q4: Are analysts aware or unaware of them? *Patterns in the data are not known in advance*

Q5: How can potential knowledge gaps be identified?

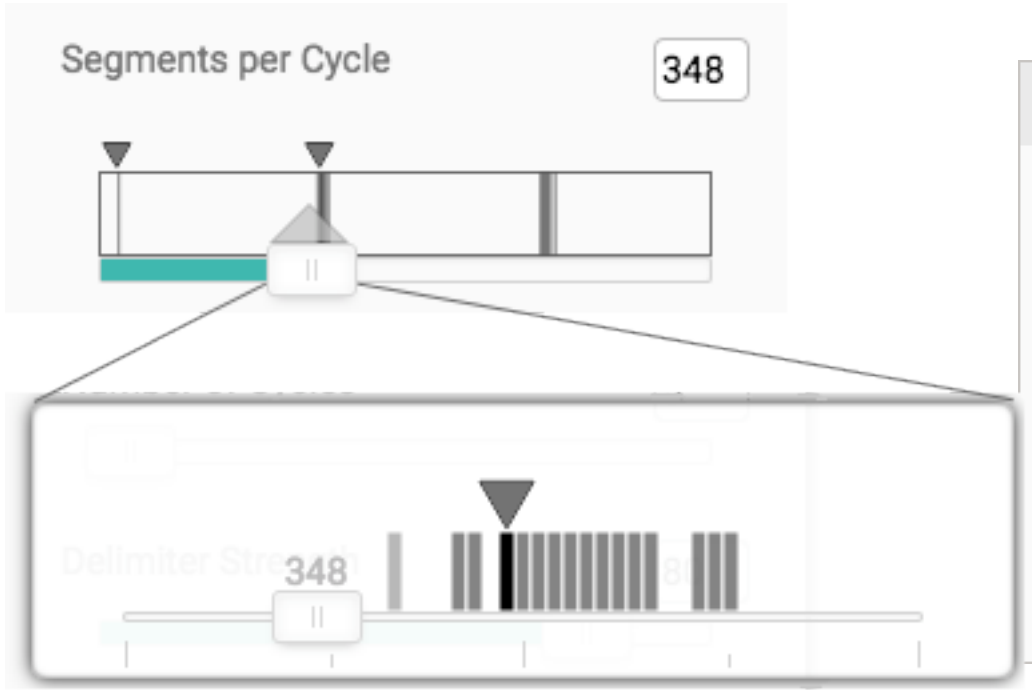
- Knowledge gap interface (users should be aware)
- Knowledge gap inference

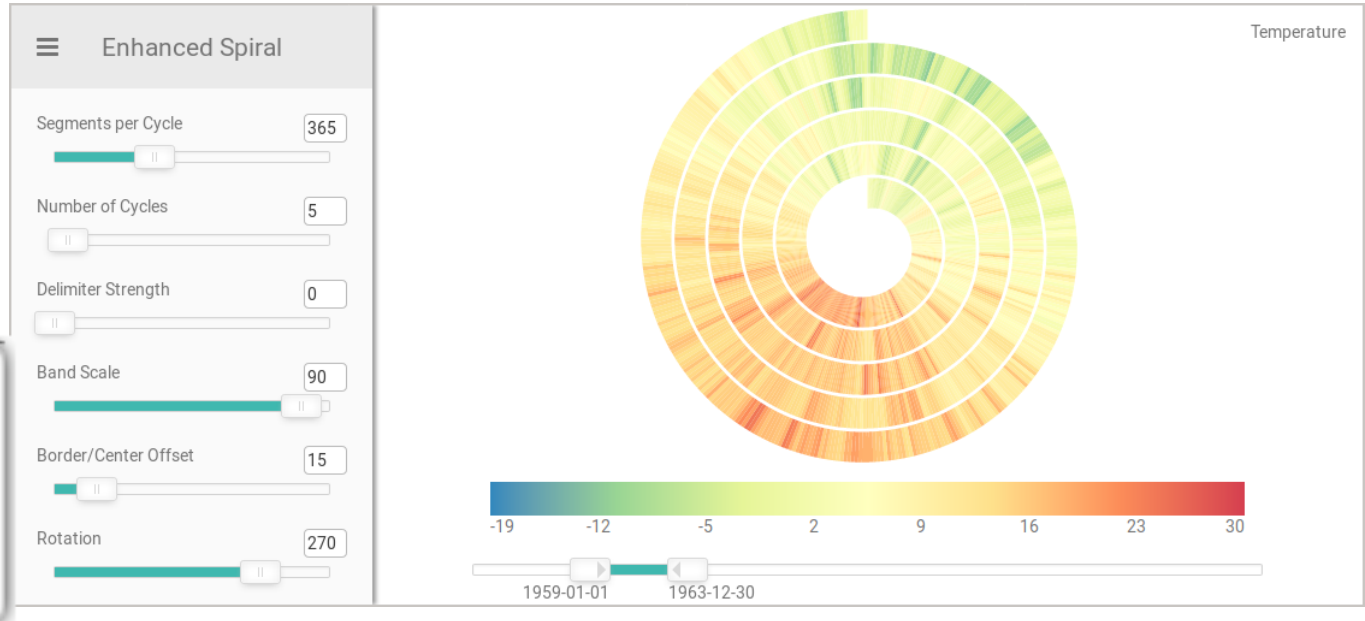


Designing Effective Guidance

Step 3 – Guidance

Q6: What degree of guidance is needed? *Orienting guidance*

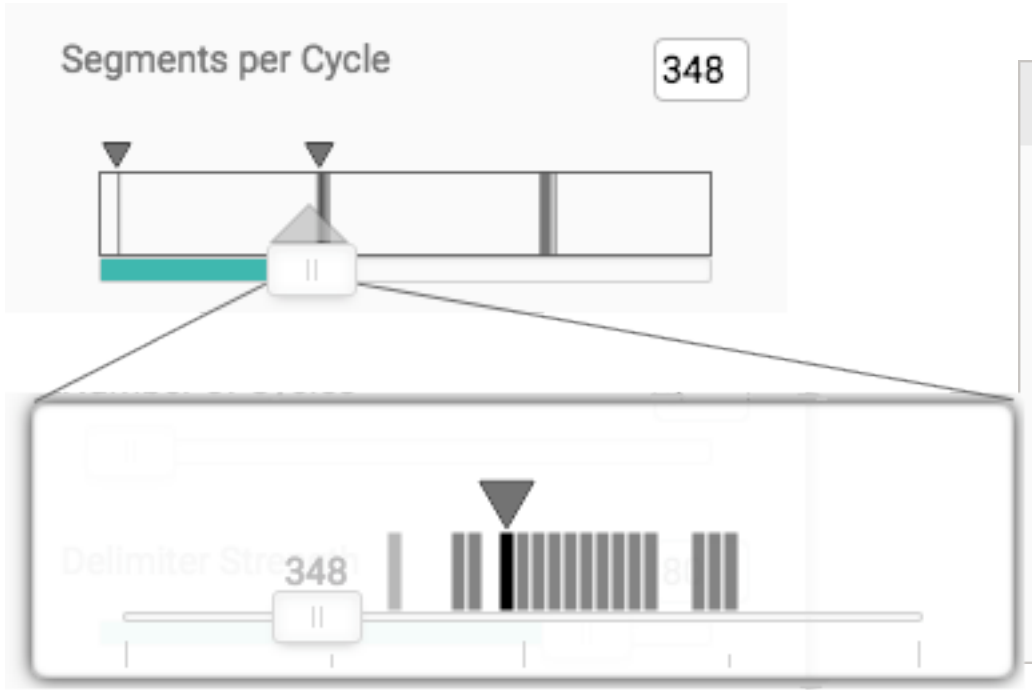


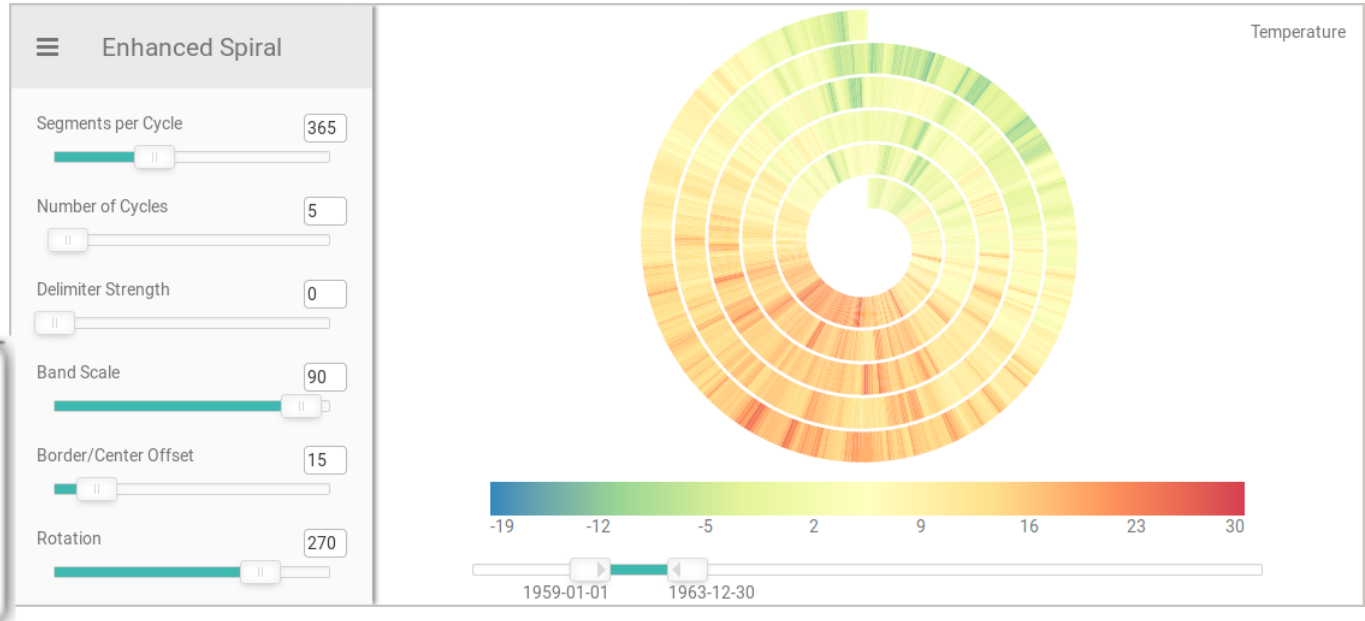


Designing Effective Guidance

Step 3 – Guidance

Q7: What input is available? *Only the data*



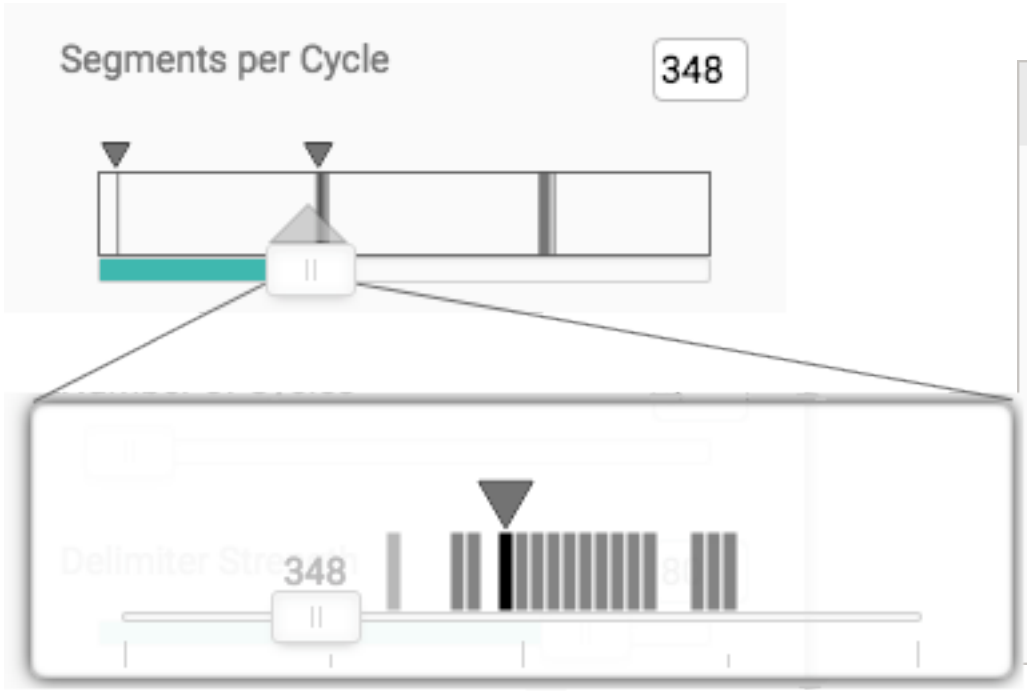


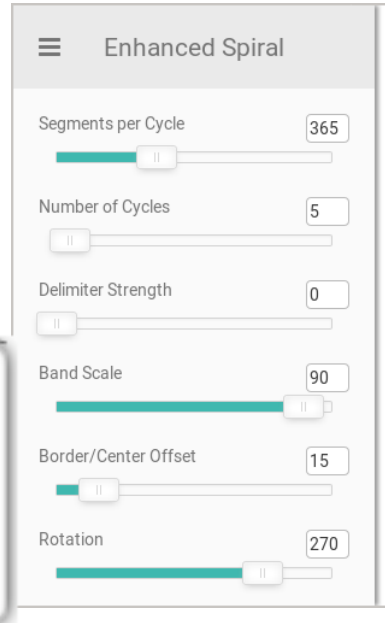
Designing Effective Guidance

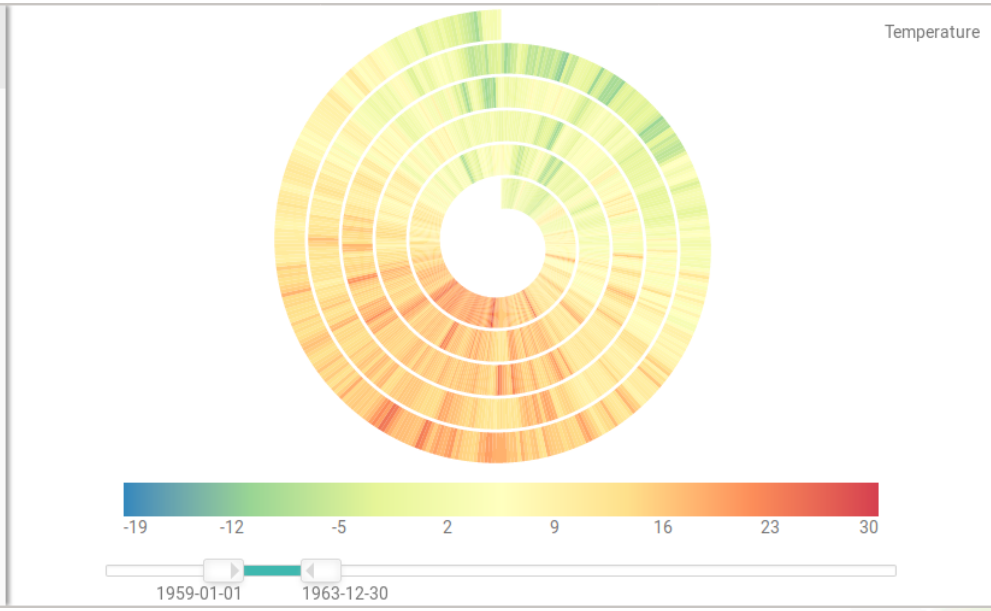
Step 3 – Guidance

Q8: What algorithms and procedures are needed to generate guidance?

- Discrete Fourier Transform
- Chi-sq Periodogram



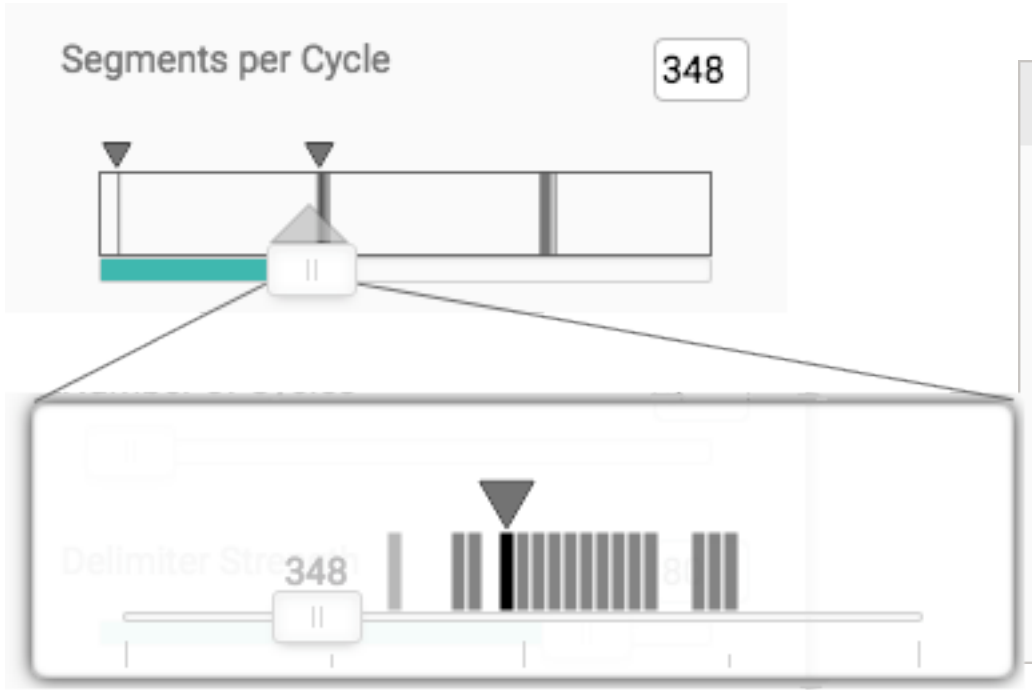


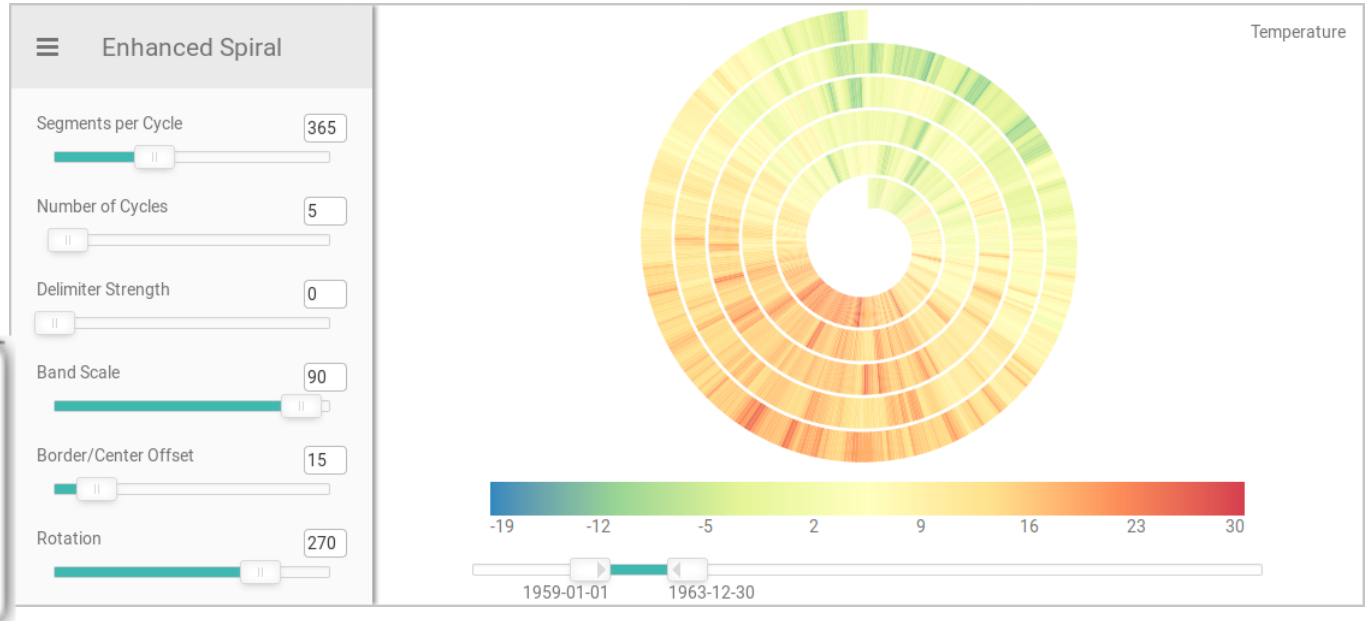


Designing Effective Guidance

Step 3 – Guidance

Q9: What are appropriate means to communicate the guidance? *Visualize guidance on the Sliders*



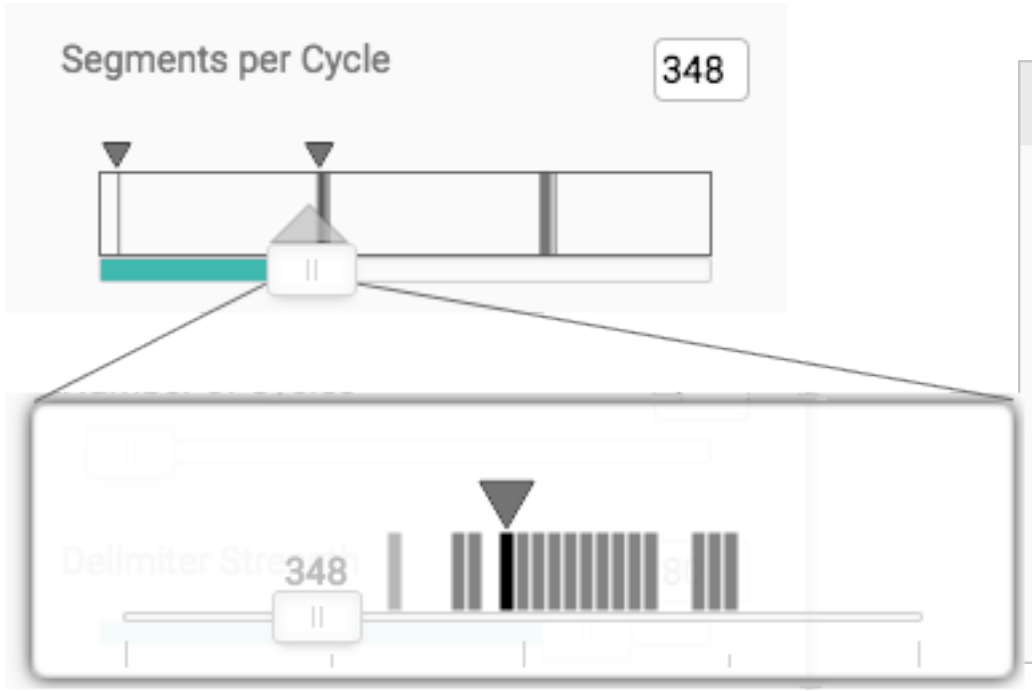


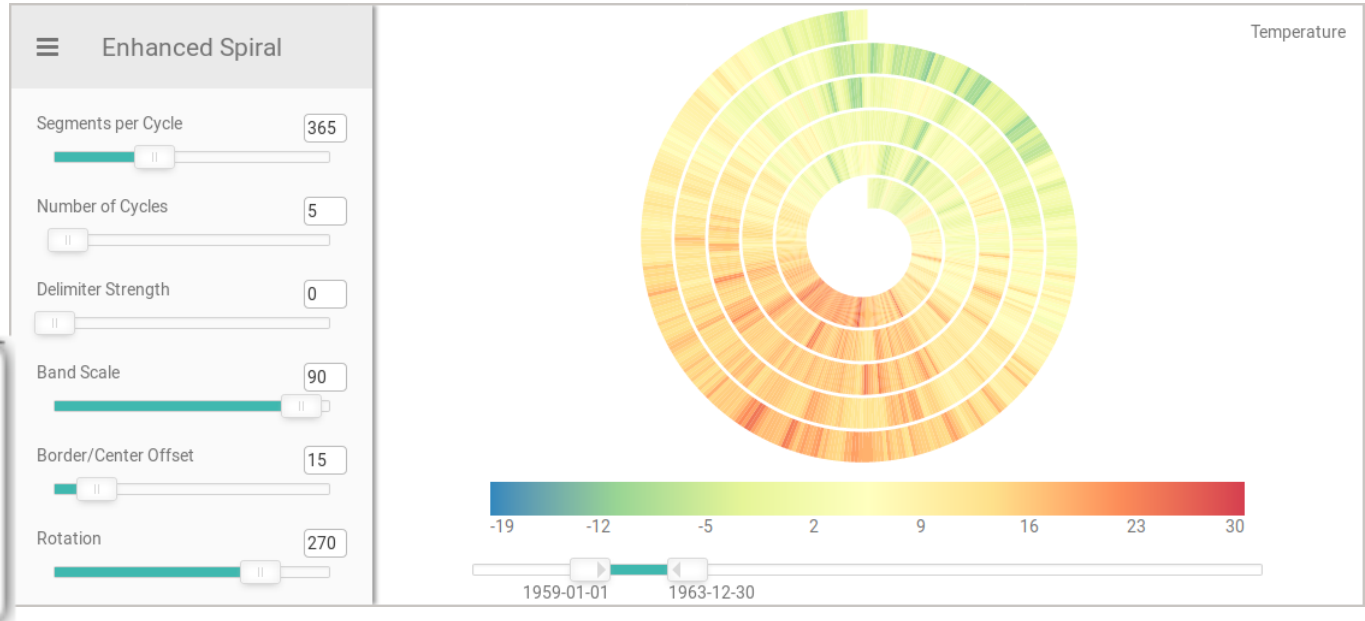
Designing Effective Guidance

Step 3 – Guidance

[Silver,1990]
[Battle et al., 2019]

Q10: When should the guidance be provided? *Look for «Decisional moments»*
«Cycles in the interaction graph»





Designing Effective Guidance

Step 4 – Guidance Feedback

Q11: How can the system derive guidance from the analyst's actions?

Direct or indirect Feedback

Q12: What is the direction of the analysts' feedback?

Future

Past

Table of Contents

Future Perspectives

Detecting the knowledge gap

Analysis of the interaction

Problems with exploratory analysis

Providing timely guidance

Inactivity?

What differentiate a stalled and a normal analysis?

Future Perspectives

Guidelines for guidance

first steps with our work

bridge theory and practice

Evaluating effectiveness

We know what means «effectiveness»

How do we measure it?

Future Perspectives

Comprehensive guidance in VA

No approach provides guidance to the whole analysis process

Bridge our design framework and VA design

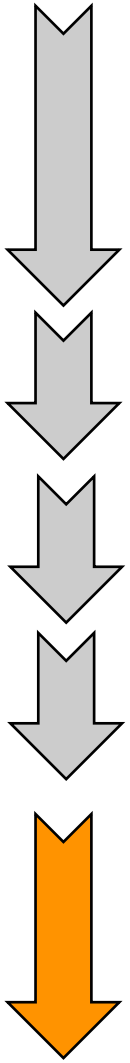
Related problems

How do we generate guidance? Process G is still a black-box

Find a suitable guidance degree?

How do we switch between degrees?

Table of Contents



Guidance-Enriched Visual Analytics

In summary – Answering the Research Questions

[S1] Is it possible to devise a general **framework** and a common **guidance definition** embodying the current state-of-the-art approaches and literature?

Definition
Framework
Guidance Characteristics
Guidance as a mixed-initiative process
User-side of guidance
How guidance can solve the knowledge gap

Guidance-Enriched Visual Analytics

In summary – Answering the Research Questions

[S2] What are the **benefits** (if any), and in general what are the **effects of using guidance** during visual analytics?

Two user studies

- *Guidance is beneficial*
- *Users are less frustrated*
- *Increased confidence and trust*
- *Changes of strategy due to introduction of guidance*

Guidance-Enriched Visual Analytics

In summary – Answering the Research Questions

[S3] How is it possible to **design effective guidance** to support users throughout the visual analytics process?

Effective guidance
Qualitative Criteria
Design Framework

Guidance-Enriched Visual Analytics

«How can we devise guidance methods for supporting users performing visual analytics tasks?»

We have paved the way for the adoption of effective guidance-enriched VA approaches

Publications

Journals

D. Ceneda, T. Gschwandtner, T. May, S. Miksch, H.-j. Schulz, M. Streit, and C. Tominski. „**Characterizing guidance in visual analytics**“. In: IEEE Transactions on Visualization and Computer Graphics 23.1 (Jan. 2017), pp. 111–120

D. Ceneda, T. Gschwandtner, and S. Miksch. „**You get by with a little help: The effects of variable guidance degrees on performance and mental state**“. In: Visual Informatics 3.4 (2019), pp. 177–191

D. Ceneda, N. Andrienko, G. Andrienko, T. Gschwandtner, S. Miksch, N.Piccolotto, T. Schreck, M. Streit, J. Suschnigg, and C. Tominski. „**Guide me in analysis: A framework for guidance designers**“. In: Computer Graphics Forum 39.6 (2020), pp. 269–288.

D. Ceneda, T. Gschwandtner, and S. Miksch. „**A review of guidance approaches in visual data analysis: A multifocal perspective**“. In: Computer Graphics Forum 38.3 (2019), pp. 861–879

Publications

Others

D. Ceneda, T. Gschwandtner, T. May, S. Miksch, M. Streit, and C. Tominski. „**Guidance or No Guidance? A Decision Tree Can Help**“. In: Proc. of the International Workshop on Visual Analytics (EuroVA). Eurographics DigitalLibrary, 2018, 19–23.

D. Ceneda, T. Gschwandtner, S. Miksch, and C. Tominski. **Guided Visual Exploration of Cyclical Patterns in Time-series**. Visualization in Data Science (VDS at IEEE VIS 2018).

D. Ceneda, W. Aigner, M. Bögl, T. Gschwandtner and S. Miksch. **Guiding the Visualization of Time-Oriented Data.** Poster at IEEE VIS 2016.

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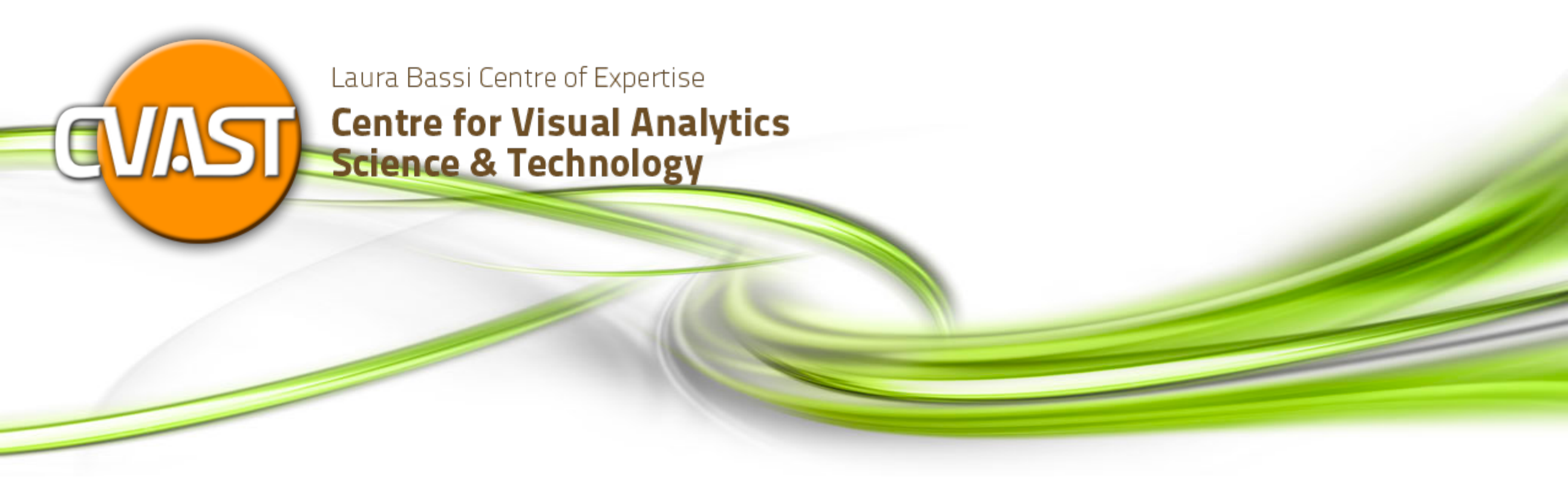

Guidance-Enriched Visual Analytics

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