

# “When order matters”

## A quantum formalization for perspective changes during the communication of route instructions

Jürgen Hahn   Paul Weiser

Department of Geodesy and Geoinformation  
Vienna University of Technology

ETH Zürich  
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## About me

- **PhD** Geoinformation at Vienna University of Technology
- **work** Consultant and developer at IQSOFT, projects for ÖBB (railway) and Frequentis (air traffic)
- **study** Geoinformation at UZ Rottenmann Styria
- **research goal** an information system **MUST** provide appropriate information
- **how to reach goal** formalize cognitive processes while human interaction
- **formalization technique** use mathematic model of quantum mechanics to model cognitive processes

# Outline

- 1 **Motivation and Analysis**
  - Exchange of route instructions
  - Communication coordination process
- 2 **Quantum formalization**
  - Hilbert space model
  - Formalization
- 3 **Summary**
  - Summary

# Exchange of information

## Problem

### human information exchange

- interactive
- all speaker contribute to conversation
- taking another perspective into account
- adjust the level of detail

### information system information exchange

- restricted adoption to information needs of user
- is fixed to the perspective given by a developer

# navigation system's route instruction

## examples

- ① IS: start heading north ...
- ② IS: turn left in 500 meters ...
- ③ IS: take ..street ...

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# Human communication for route instruction

## motivating example

- ① Provider: [...] , and then you pass *Stephansdom* to your left, [...]
- ② Tourist: ... eum, wait, *Stephansdom*?
- ③ Provider: *Stephansdom*, that's a *cathedral* like Notre Dame in Paris ...
- ④ Tourist: ... Ah, ok
- ⑤ Provider: So, once you have passed the *cathedral* to your left, you ...



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## Analysis of the motivating example

### critical part of conversation

- Provider: *Stephansdom*, that's a *cathedral* like Notre Dame in Paris ...

### Provider adjusted the information

- Stephansdom was not present to the Tourist
  - cognitive process: find a term that the Tourist knows
  - estimate the knowledge of the Tourist
- referring expressions - linguistic selectors
  - cognitive process: change from instance to category

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## Suggested solutions for route instructions

### adjustment from instance to concept

- possible solution Gärdenfors conceptual spaces
  - a subspace of instances refers to a more general concept

Provider has to include the Tourist's knowledge/ perspective

- order of evaluation matters
- suggested solution: Quantum formalization



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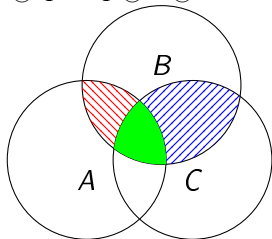
### Provider has to include the Tourist's knowledge/ perspective

- order of evaluation matters
- **suggested solution:** Quantum formalization

# Order effect- Why a quantum formalization?

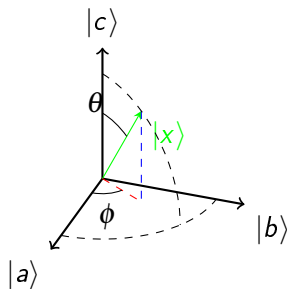
## Set theory

$$A \odot B \odot C = C \odot A \odot B$$



## Vector Spaces

$$A \odot B \odot C \neq C \odot A \odot B$$



# Quantum Formalization for route instruction

## assumptions

- adjustment from instance to concept not formalized
- information Provider is from Vienna
- Tourist is from Paris
- only two instances (Stephansdom, Notre Dame) included

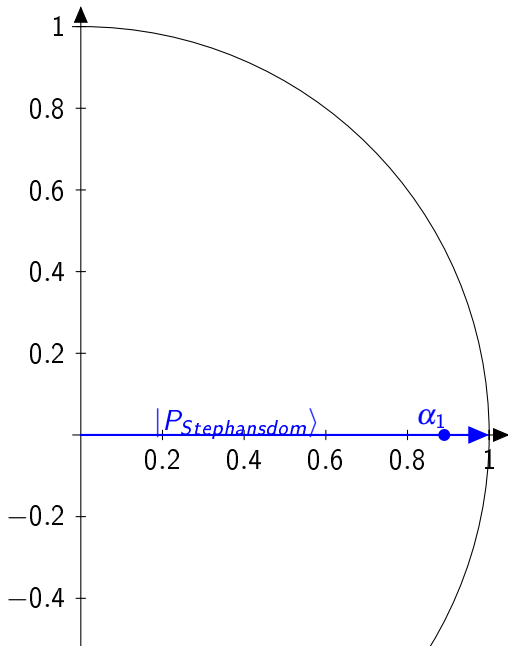
# Hilbert space formalization

## formalization

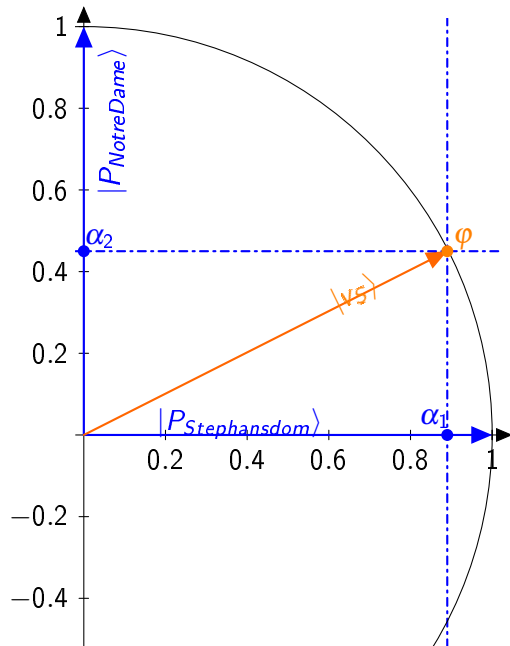
- two perspectives
  - set of base vectors for Provider
  - different set of base vectors for Tourist
- order effect
  - conversation from one base to the other
  - unitary matrix

$$\underbrace{\begin{pmatrix} \beta_1 |Tourist_{Stephansdom}\rangle \\ \beta_2 |Tourist_{NotreDame}\rangle \end{pmatrix}}_{\text{Tourist vector}} = \underbrace{\begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}}_{\text{unitary matrix}} \underbrace{\begin{pmatrix} \alpha_1 |Provider_{Stephansdom}\rangle \\ \alpha_2 |Provider_{NotreDame}\rangle \end{pmatrix}}_{\text{Provider vector}}$$

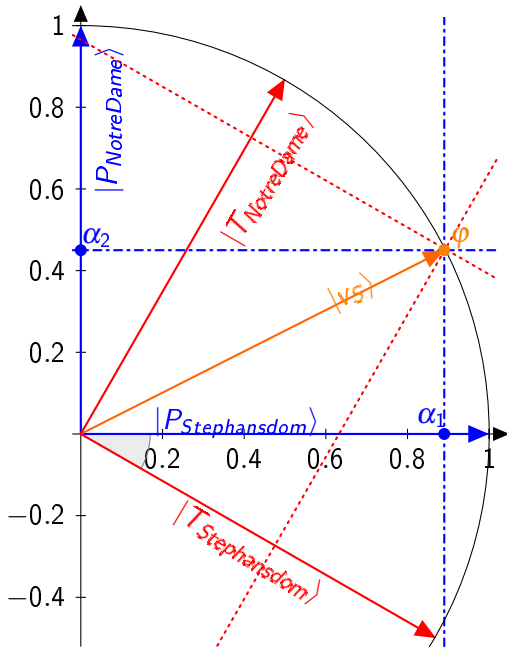
## Provider's perspective for route



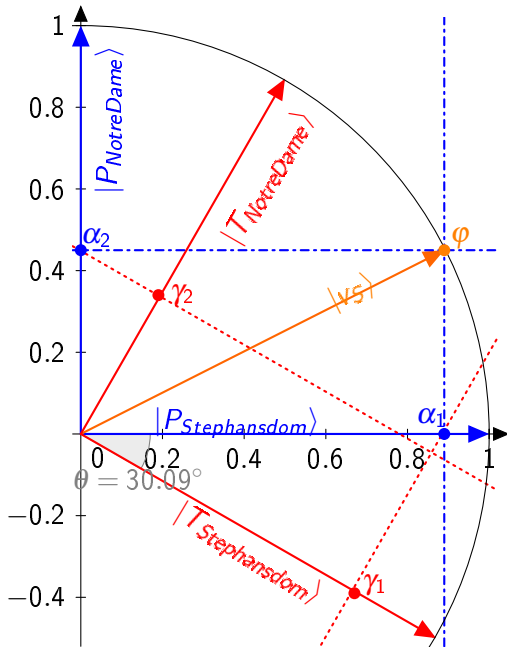
## Adjust the model for the Tourist



# Estimation of Tourist's knowledge

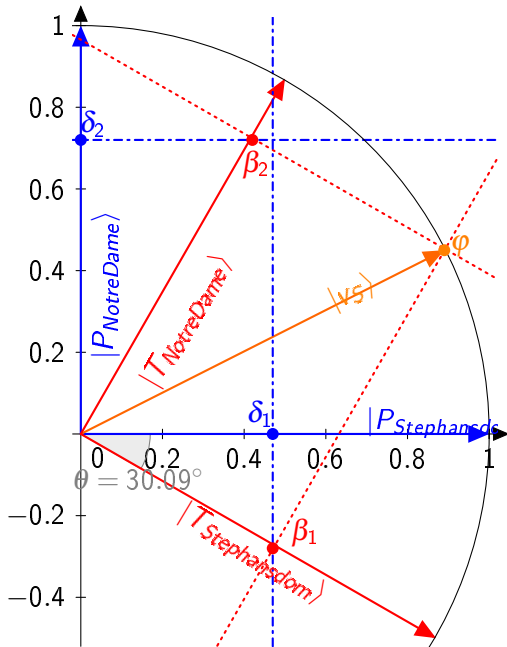


# Order effect, Provider to Tourist





## Order effect, Tourist to Provider



# Interactive Mode

Switch to GeoGebra

# Summary

- Outlook
  - unitary transformations for more than two instances

## take home message

- successful communication
  - take the others perspective into account
  - human route instructions include a perspective change
    - order effect
    - quantum model - Hilbert Space model

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## For Further Reading I

Citations, please refer to Quantum Interaction 2014 article