Spatio-Temporal Modeling and Analysis: Developments, Challenges, and Prospects for GIS

Wolfgang KAINZ

University of Vienna, Austria

and

Wuhan University, China

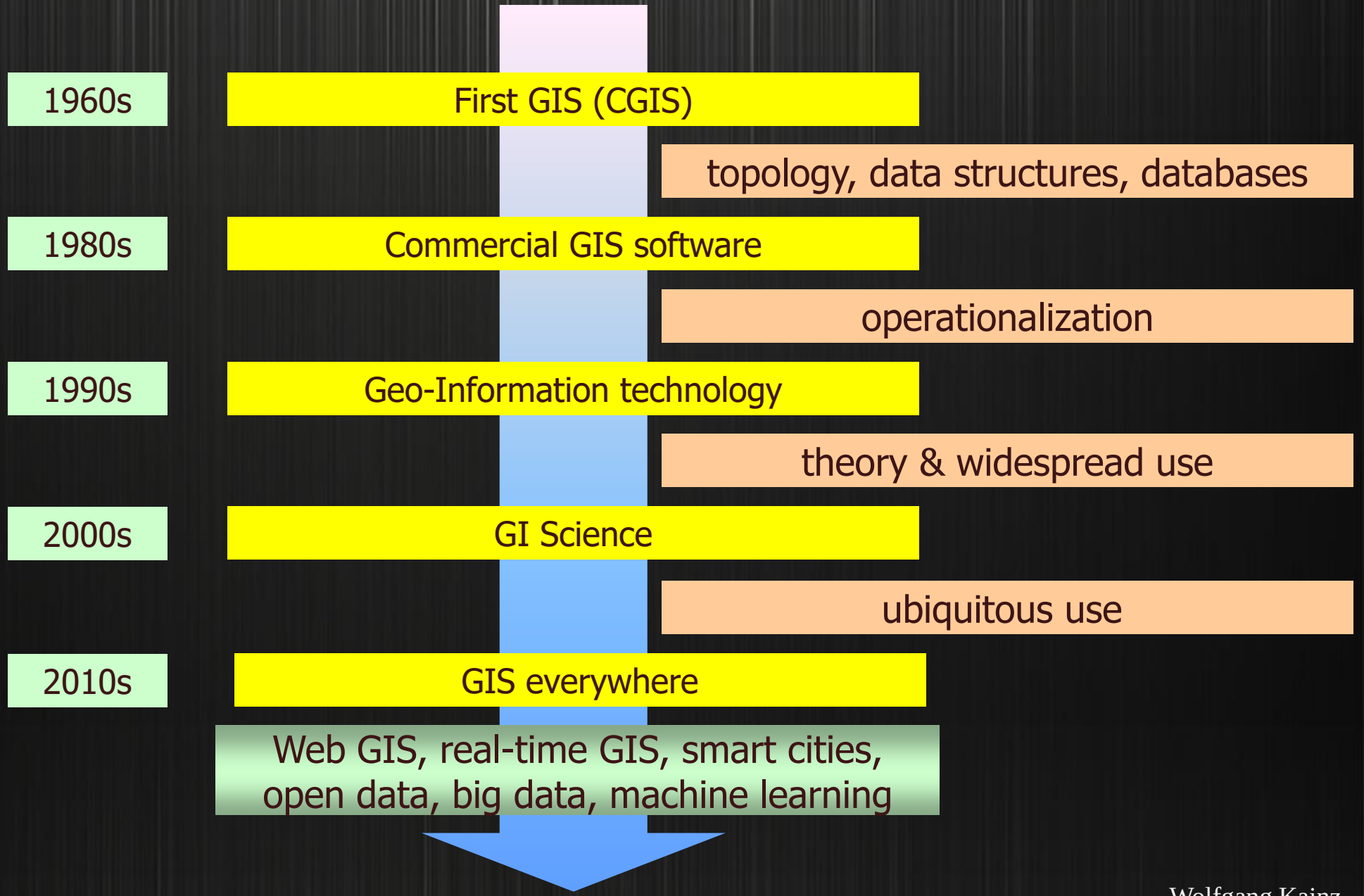
不出戶，知天下；
不窺牖，見天道。
（老子）

Without leaving home,
you can know the whole world;
without looking out of the window,
you can tell the ways of Heaven.
(Lao Zi)

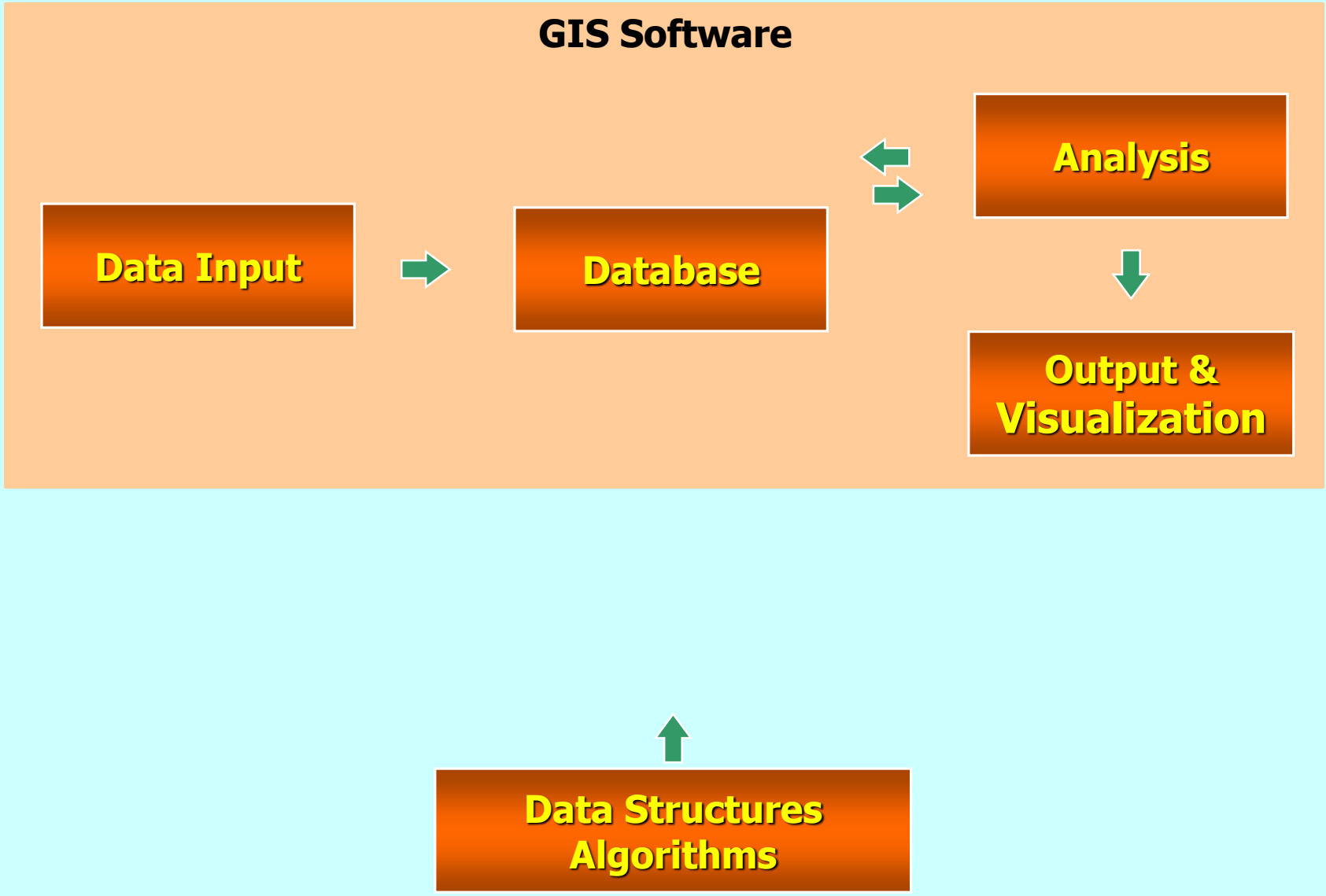
GIS and GIScience

Wolfgang Kainz

History of GIS



1980s


GIS Software
Data Input
Database
Analysis
Output & Visualization
Data Structures Algorithms

fzg
INSTITUT FÜR DIGITALE BILDVERARBEITUNG UND GRAPHIK

DIBAG - BERICHT No. 2

DESBOD - SYSTEMSPEZIFIKATION

M.RANZINGER, W.KAINZ, F.LEBERL

1981

DIGITALE ERFASSUNG, SPEICHERUNG UND BEARBEITUNG ORTSBEZOGENER DATEN

POJEKTBEGINN:
1. MAI 1981

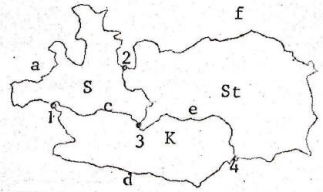
PROJEKTBEAUFTRAGTER :
FORSCHUNGSGESELLSCHAFT-
JOANNEUM

PROJEKTVERANTWORTLICHER:
F.LEBERL

GRAZ, 1.NOVEMBER 1981

4. Jede 1-Zelle liegt an der Grenze einer 2-Zelle.

Fig. B.3 veranschaulicht die topologische Beschreibung einer Karte. Es gibt drei 2-Zellen, sechs 1-Zellen und vier 0-Zellen.



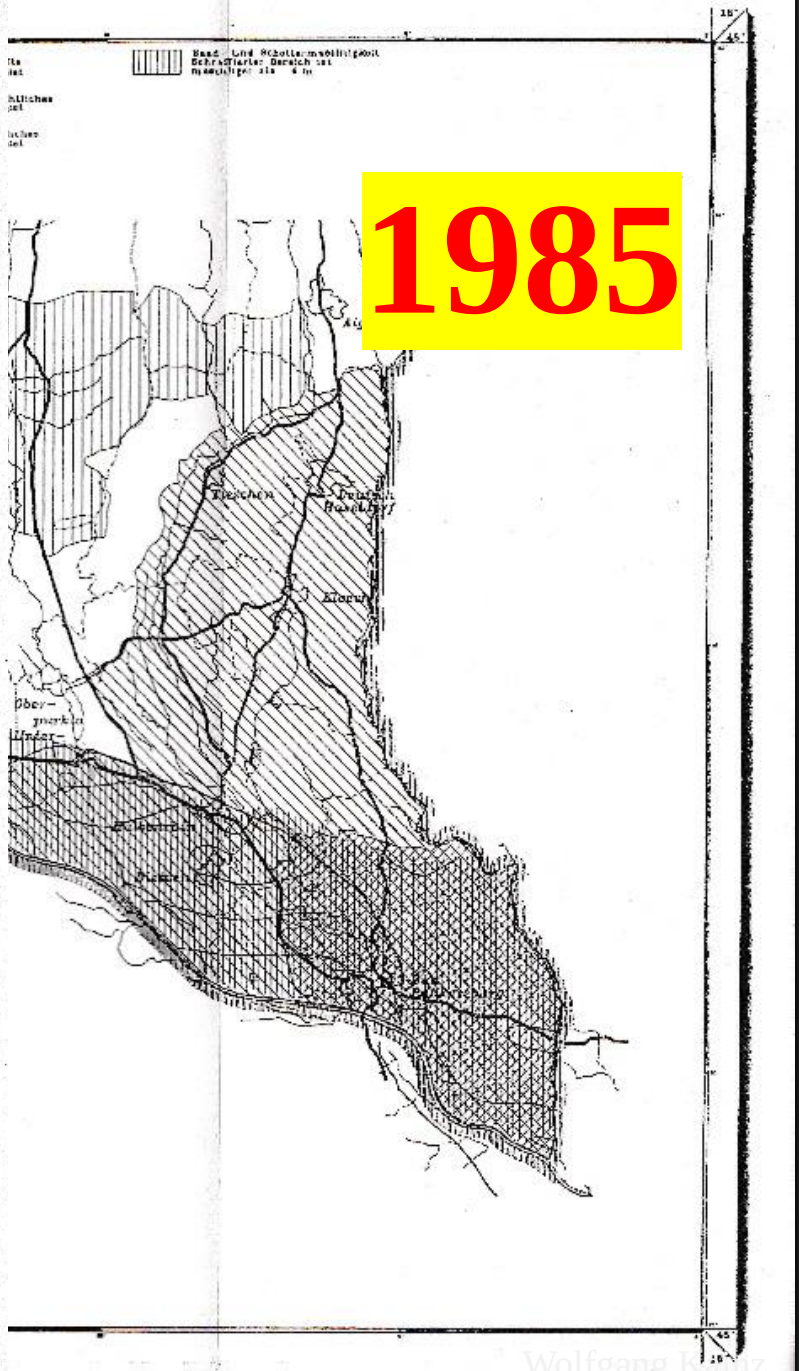
0-Zellen: 1,2,3,4
1-Zellen: a,b,c,d,e,f
2-Zellen: S,K,St

Fig. B.3

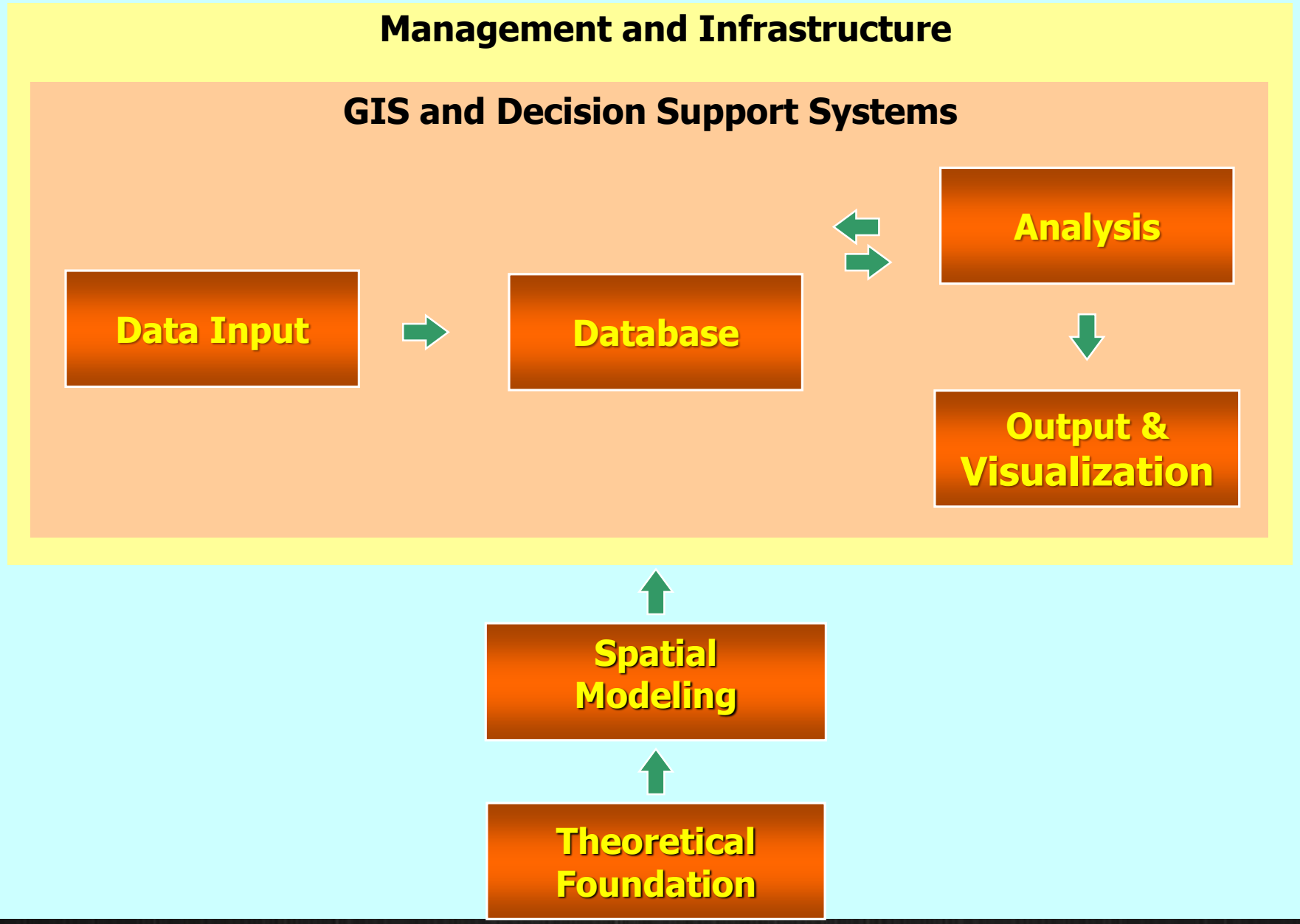
Durch diese Darstellung wird es möglich, die Struktur der Karte, z.B. die Beziehungen von Gebieten zueinander, in einem Computer darzustellen, wenn bestimmte Anforderungen erfüllt sind. Diese seien hier nur vage angedeutet:

F1. Jede 1-Zelle inzidiert mit genau zwei 2-Zellen.

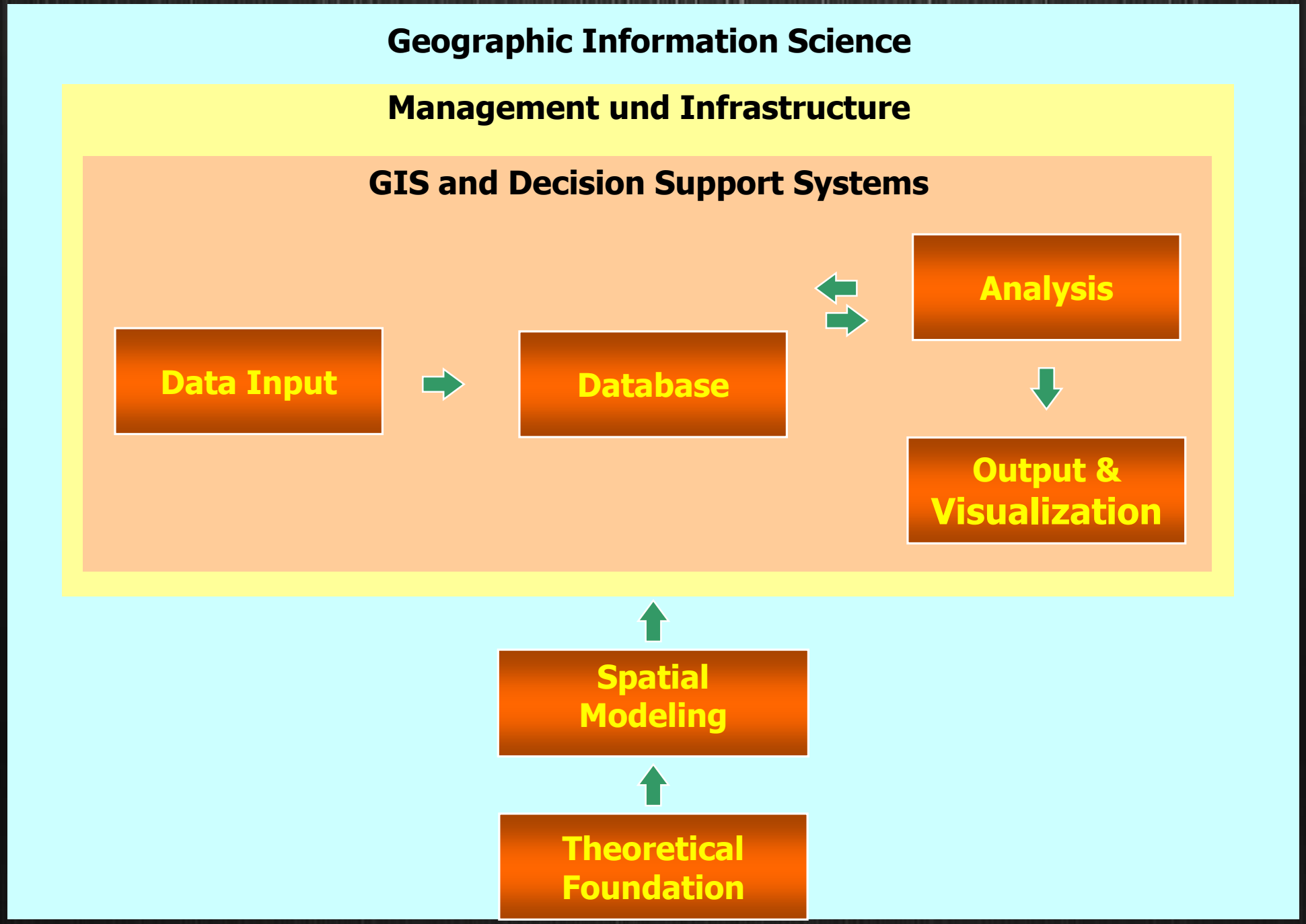
F2. Bei jeder 0-Zelle gibt es einen eindeutigen "Schirm", d.h. eine zyklisch abwechselnde Kette von 1-Zellen und 2-Zellen.



1990s


Management and Infrastructure
GIS and Decision Support Systems
Data Input
Database
Analysis
Output & Visualization
Spatial Modeling
Theoretical Foundation

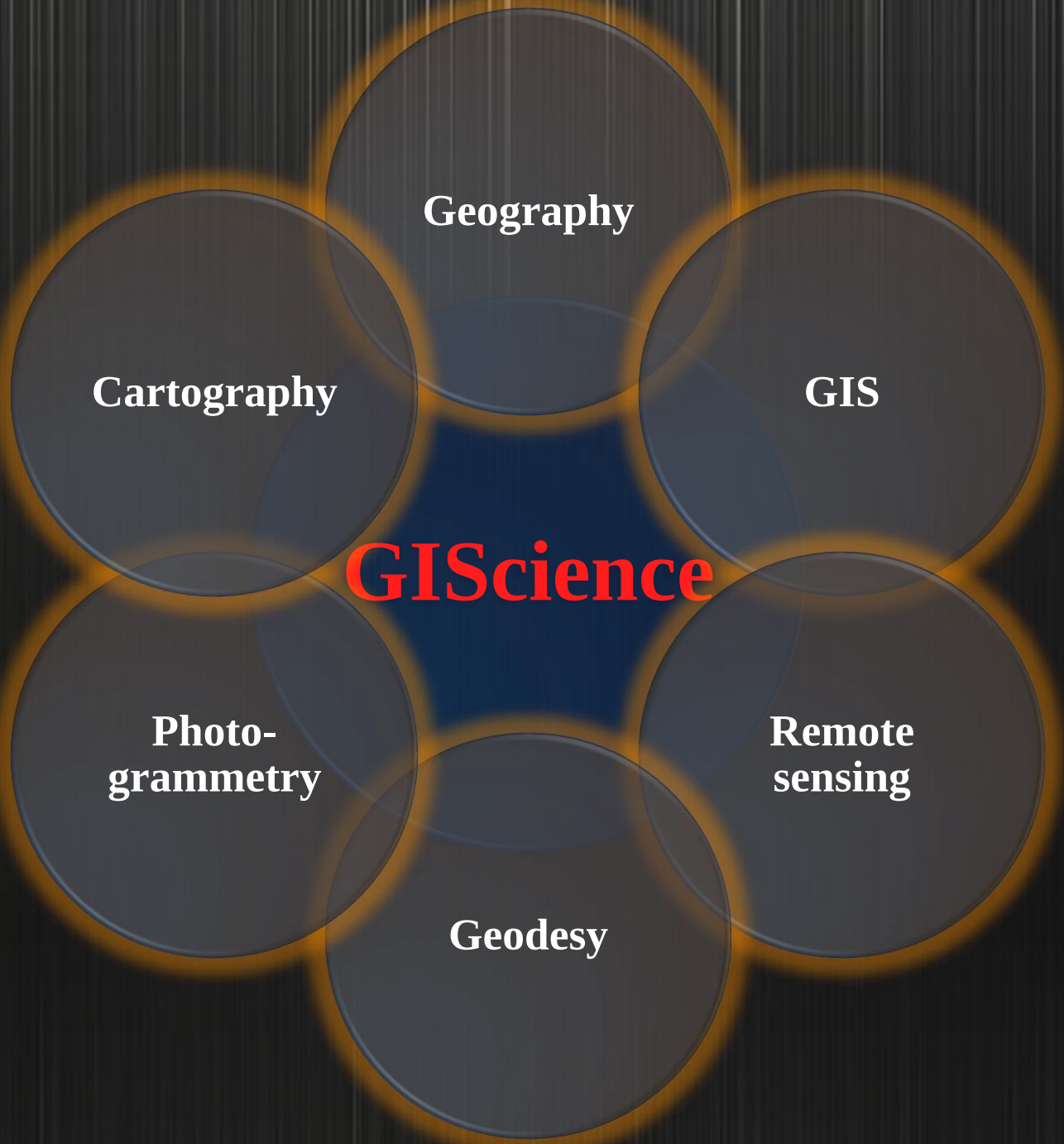
2000s

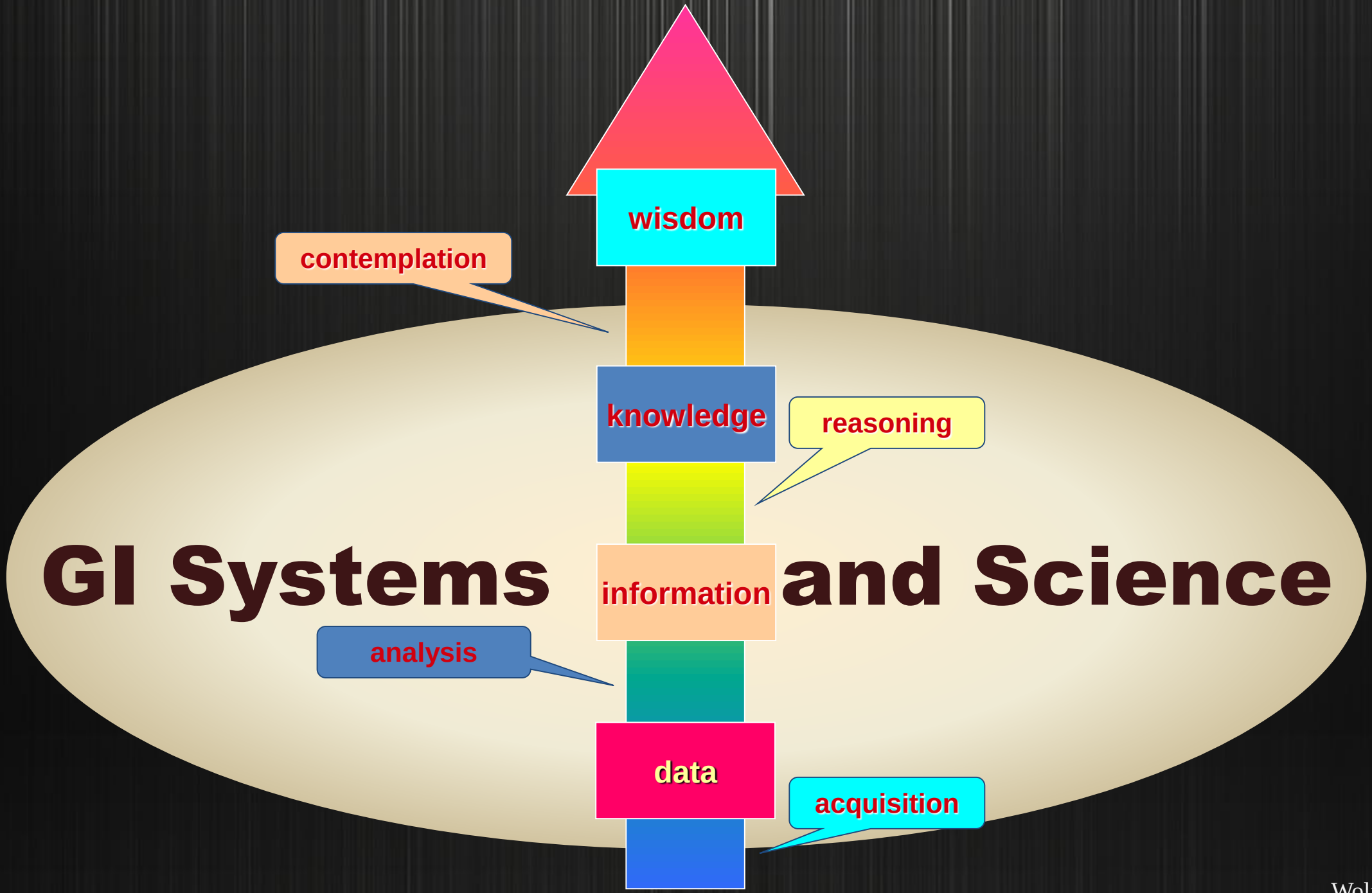

Geographic Information Science
Management und Infrastructure
GIS and Decision Support Systems
Data Input
Database
Analysis
Output & Visualization
Spatial Modeling
Theoretical Foundation

Geo-Information Science

Geo-Information Science is the integration of different disciplines dealing with spatial information.

- **Research on the generic issues that surround the use of GIS technology…**
- **Both "research about GIS" and "research with GIS"**


Geography
Cartography
GIS
GIScience
Photo-
grammetry
Remote
sensing
Geodesy



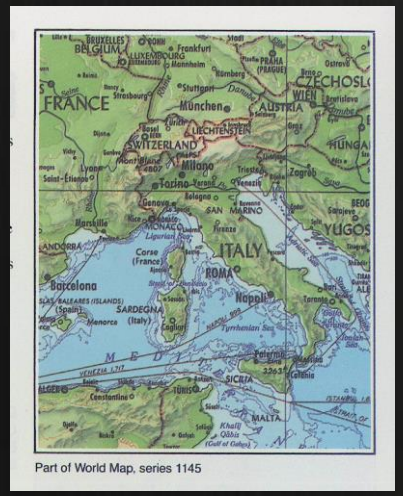
GI Systems and Science

Wolfgang Kainz

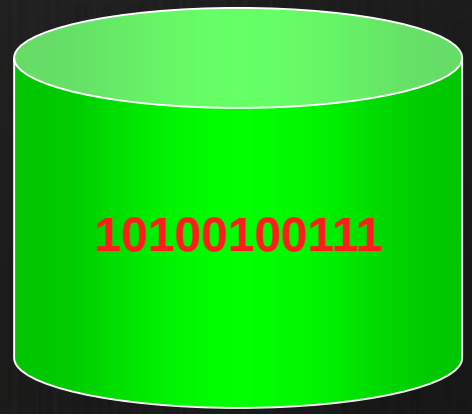
Modeling

Real (and Virtual) World Models

Maps

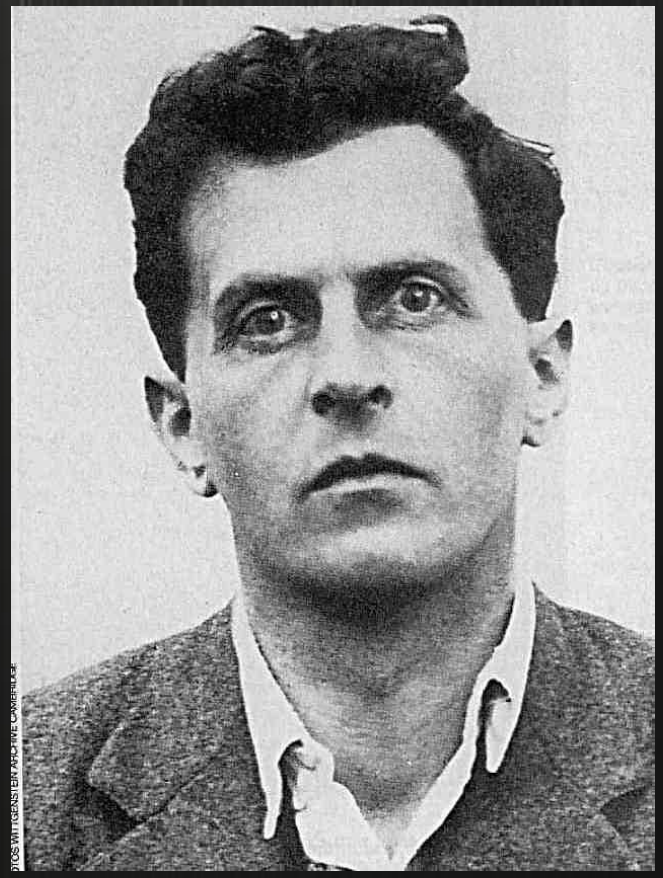


Databases



Ludwig Wittgenstein

- 1889 – 1951
- Austrian philosopher
- Mainly working on logic
- 1921: Tractatus logico-philosophicus (Logical-Philosophical Treatise)



Modeling

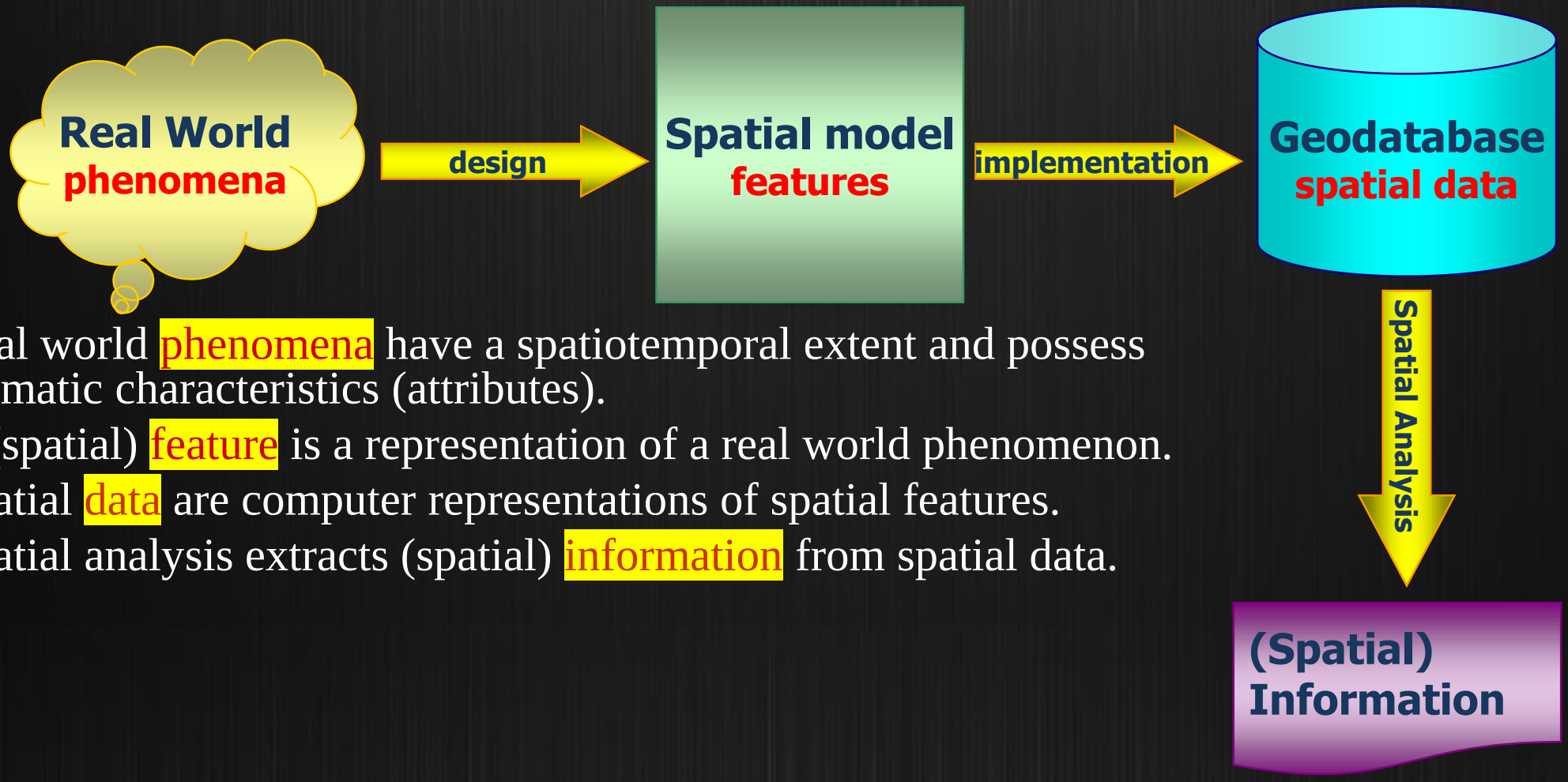
Quote from Wittgenstein

- 2.12 “A **picture** is a model of reality.”
- 2.14 “What constitutes a picture is that its **elements** are **related** to one another in a determinate way.”
- 2.15 “The fact that the elements of a picture are related to one another in a determinate way represents that **things** are **related** to one another in the same way.”

Concept of a map or database

- 2.12 “A **map/database** is a model of reality.”
- 2.14 “What constitutes a map/database is that its **features/objects** are **related** to one another in a determinate way.”
- 2.15 “The fact that the features/objects of a map/database are related to one another in a determinate way represents that **phenomena** are **related** to one another in the same way.”

Spatio-temporal Modeling & Analysis

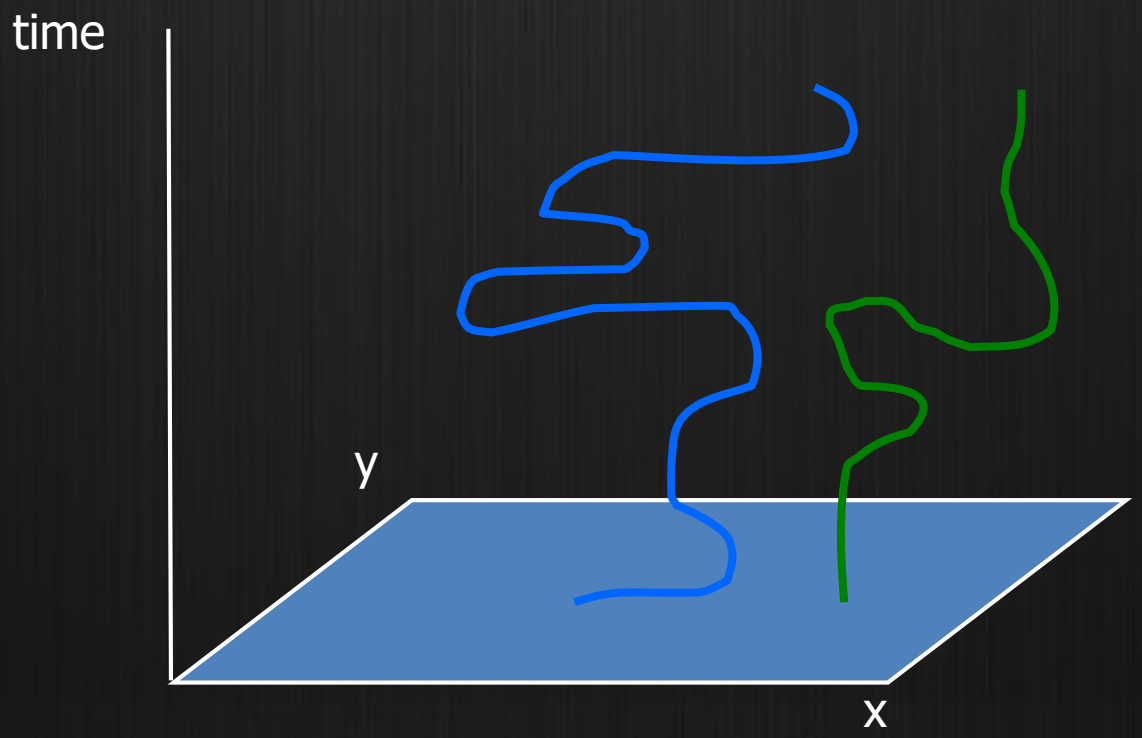


- Real world phenomena have a spatiotemporal extent and possess thematic characteristics (attributes).
- A (spatial) feature is a representation of a real world phenomenon.
- Spatial data are computer representations of spatial features.
- Spatial analysis extracts (spatial) information from spatial data.

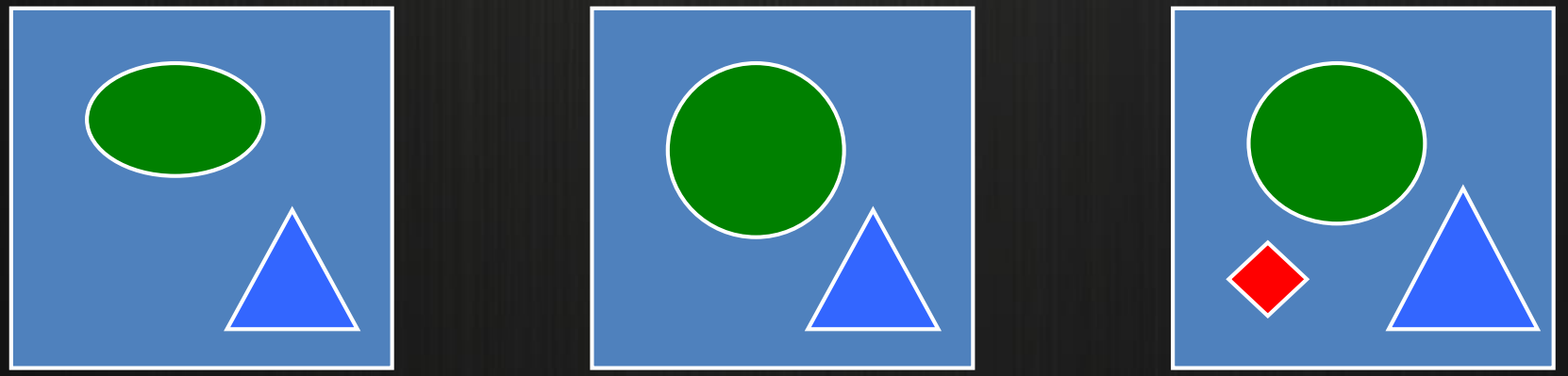
Temporal Modeling

- Modeling space and time
  - Mainly space-time cube and
  - Spatio-temporal object model (versioning)

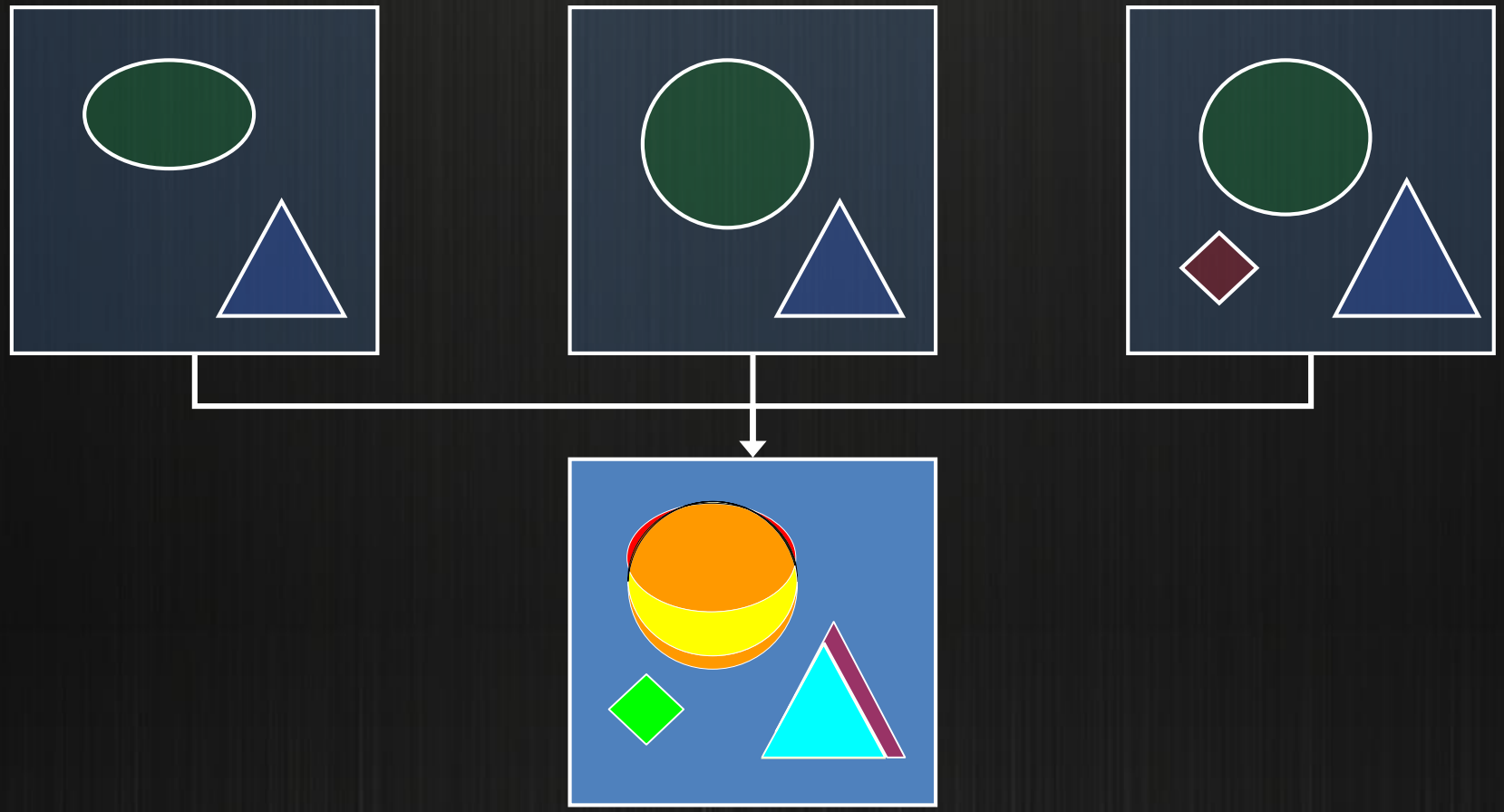
Space-Time Cube



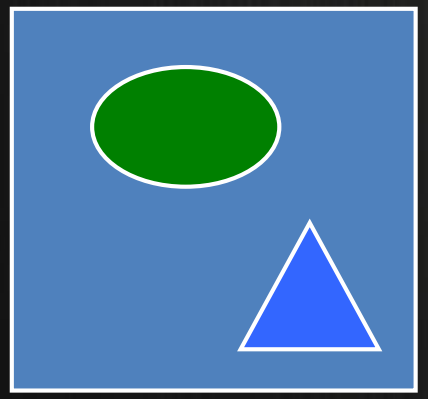
Snapshot Model



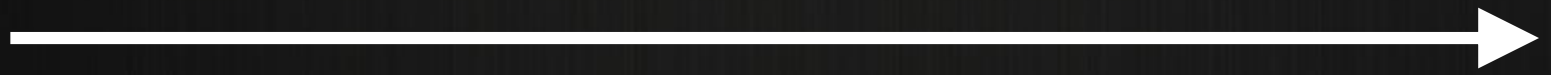
Space-Time Composite Model



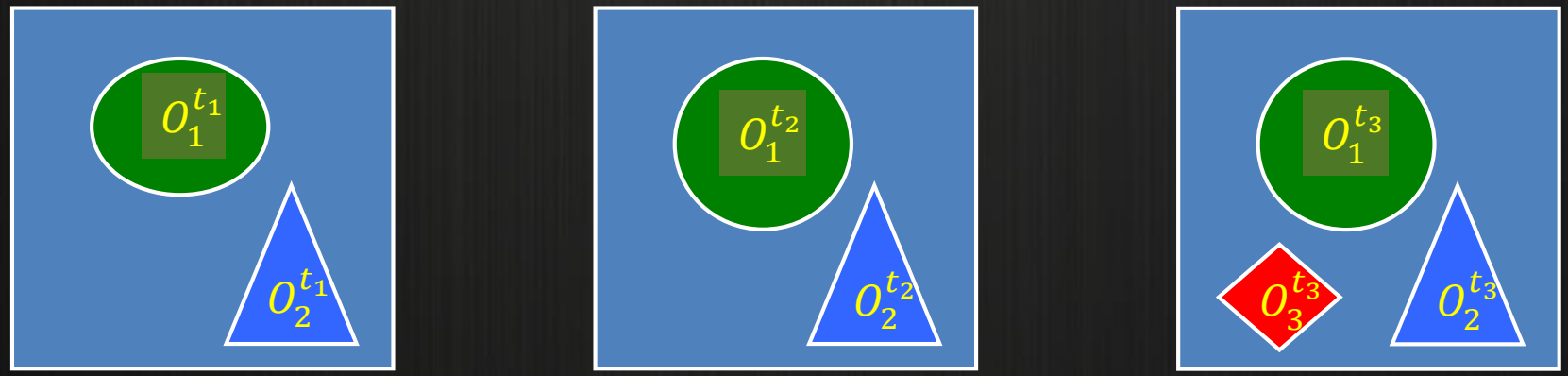
Event-Based Model



$Event_1$ $Event_2$ ... $Event_n$

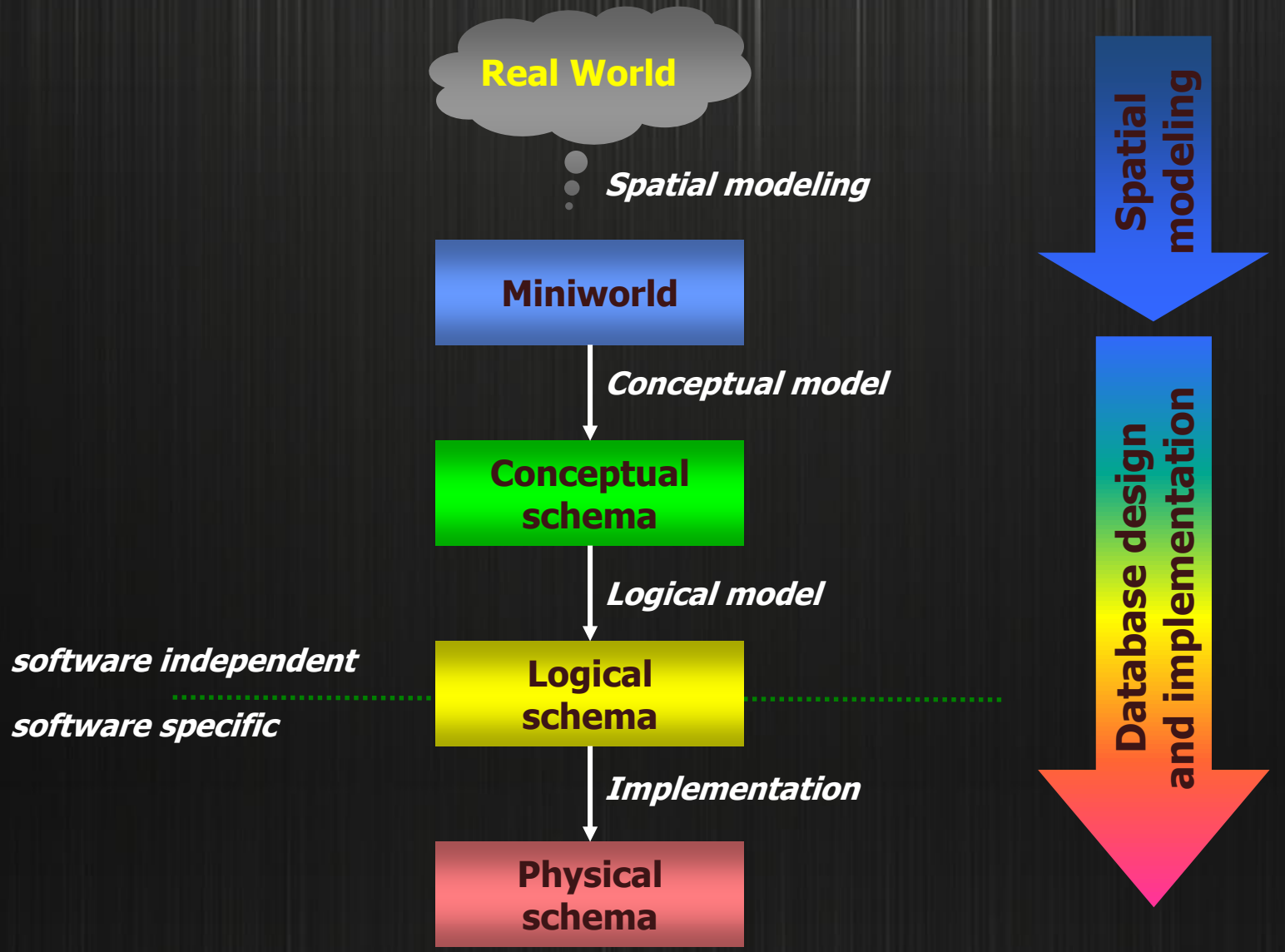


Spatiotemporal Object Model



- Object representation (versioning)
- Problem of object identity
- Comprehensive approach

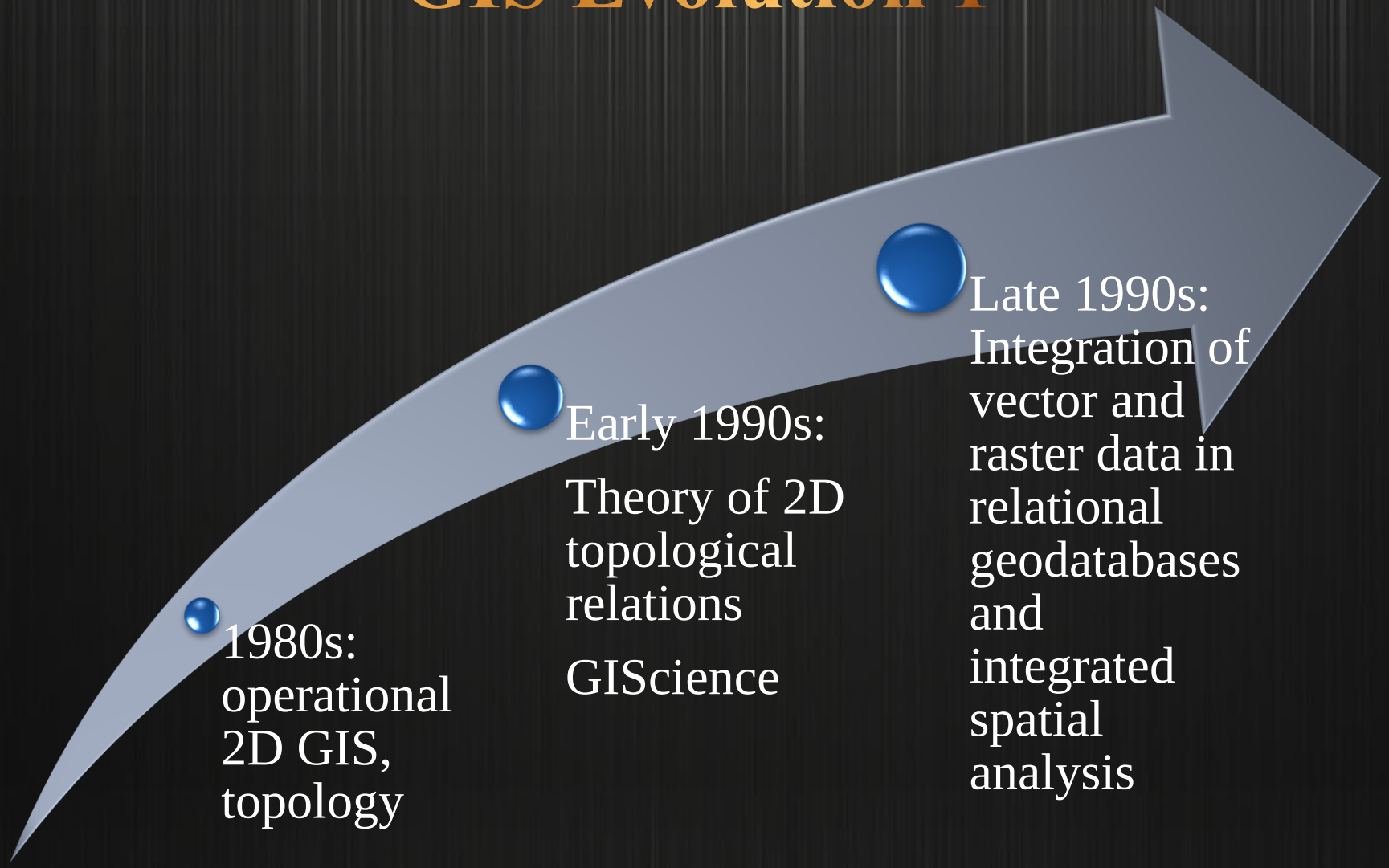
Traditional Relational Database Design



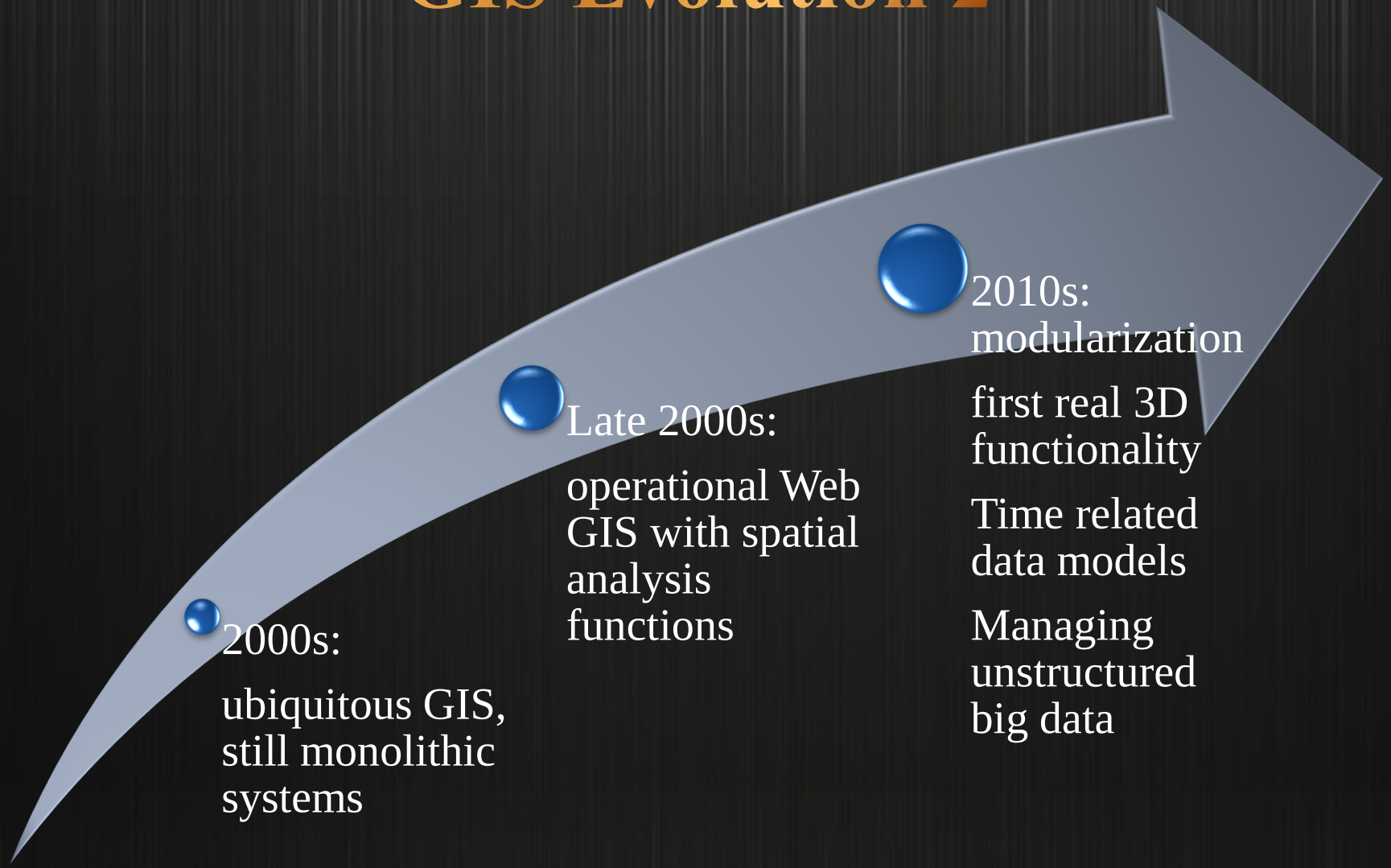
GIS Evolution

Wolfgang Kainz

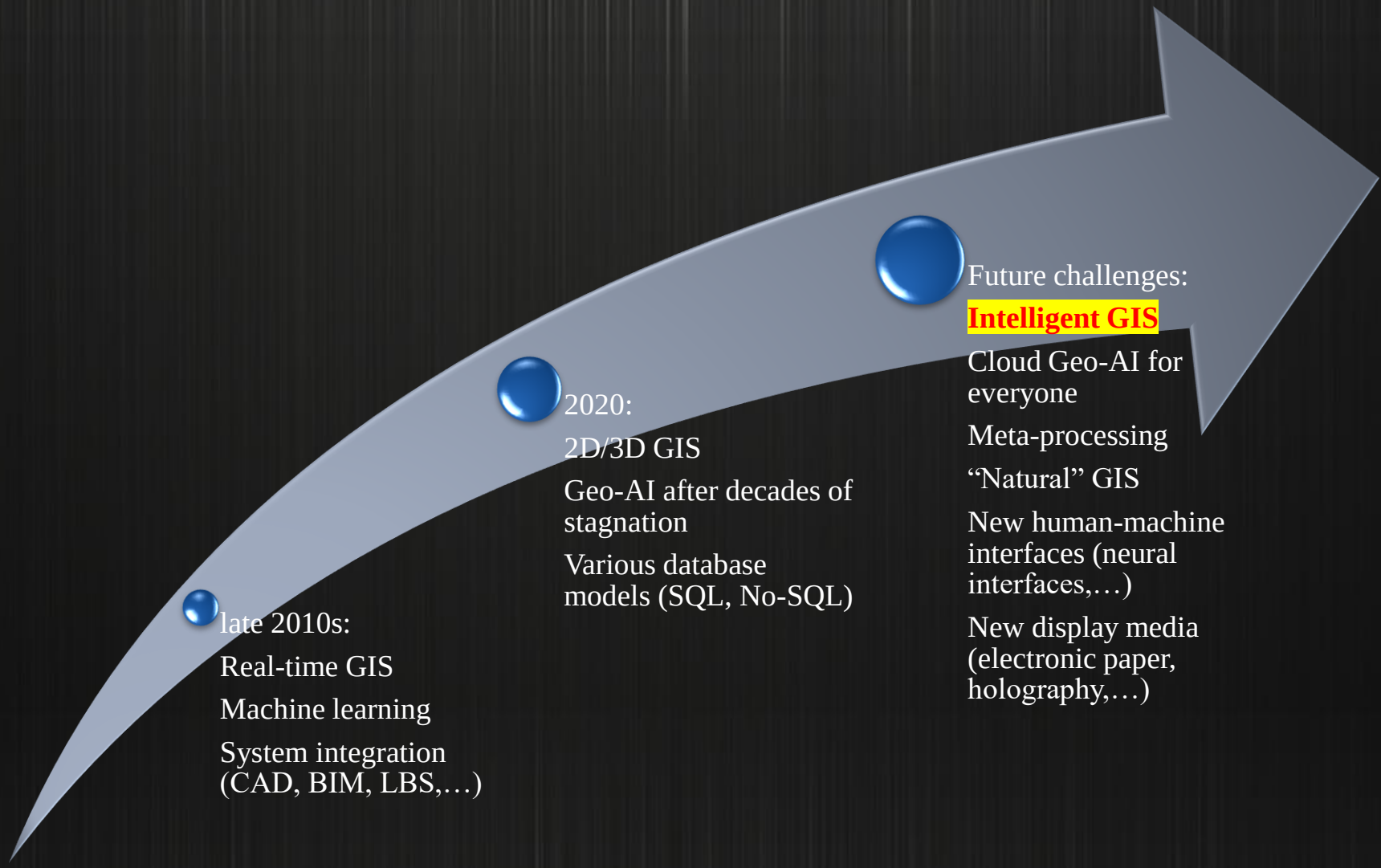
GIS Evolution 1



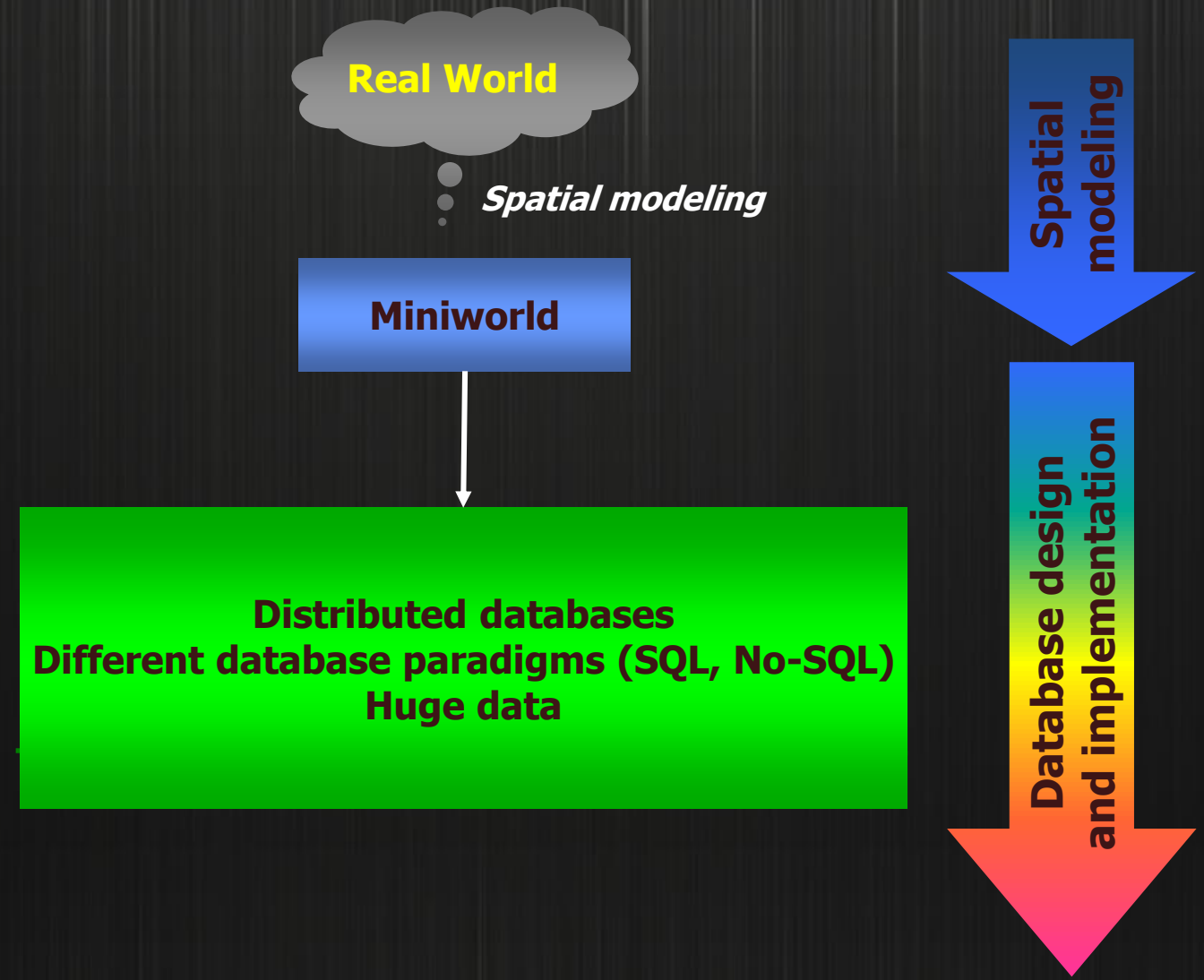
GIS Evolution 2



GIS Evolution 3 and beyond



New Database Concepts



Artificial Intelligence

- Work started in 1956
- Some progress (game strategies, theorem solving, etc.) in the following 20 years
- Slow down in the 1970's
- Expert system hype in the early 1980's followed by a decline until the late 1990's and early 2000's.
- Strong increase in activities and funding from the early 21st century on due to increase in computing power and availability of huge amounts of data (data mining, machine learning, deep learning)

Component-Based Systems and cloud AI

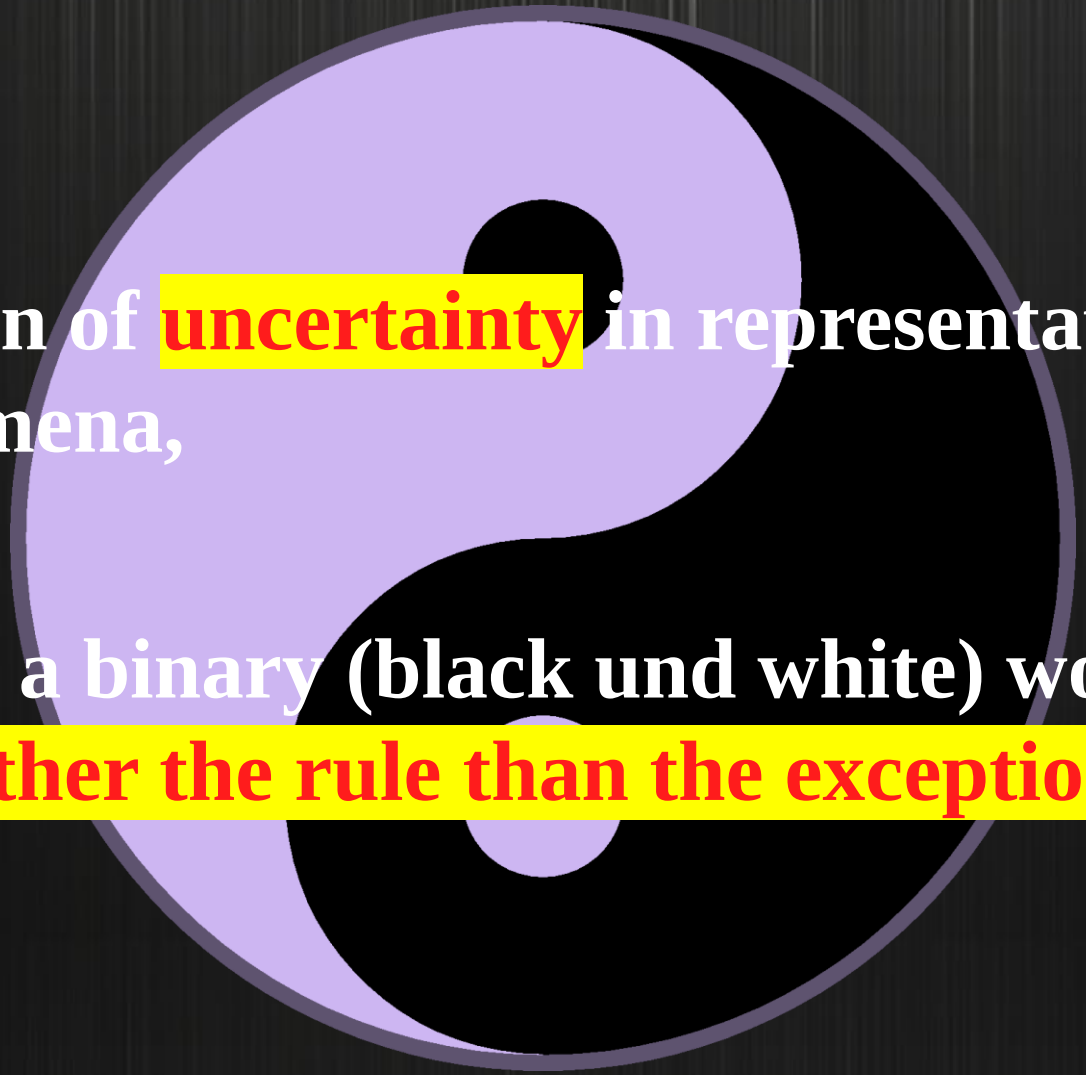
- Functional components on the web and in the cloud
- Tool repositories
- Thin clients with “thick” functionality
- Machine learning
- A kind of Geo-Siri, Geo-Alexa, or Geo-WolframAlpha

Better Use of Metadata

Meta-processing

- **Look at the metadata and decide whether a certain operations makes sense**
- **“Quality propagation”**

“Natural” GIS



Full consideration of uncertainty in representation and analysis of spatial phenomena,

because…

We do not live in a binary (black und white) world, and uncertainty is rather the rule than the exception.

不出户，知天下

如果你有 一个智能地理信息系统。

“Without leaving home, you can know the whole world”—

if you have an intelligent GIS.

谢谢

Wolfgang Kainz