社会与自然要素相互作用及其地理表达探讨

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2012.3.11

提要

- 近代地理学发展概述
- GIS发展
- 基于地理智能体的新表达框架
- 应用实例
- 未来发展探讨

What' geography?

- "Geography is what geographers do"
- "Geography is the study of the earth and its features and of the distribution of life on the earth, including human life and the effects of human activity."
- "Geography is the study of physical and human landscapes, the processes that affect them, how and why they change over time, and how and why they vary spatially. "
- Physical geography & human geography
  - Physical geography : geomorphology, hydrology, climate and meteorology , biogeography, soils, geology...
  - Human geography: urban, regional, environmental planning; cultural; economic; political; transportation …

近代地理学发展

- 20世纪中叶以前
  - 欧洲
    - 18世纪： Alexander von Humboldt: the systematic
    - Carl Ritter, 1820, 柏林大学地理主任
    - Oxford, 1899, School of Geography
    - Cambridge, 1919, BA degree
  - 美国：
    - 1870s 美国高校出现地理研究领域，1898 加州大学设置地理系
    - 1904年美国地理学会成立AAG
  - 学术发展：
    - Louis Agassiz, 哈佛 1848, 冰川理论
    - William Morris Davis,哈佛 1880s：地貌学，开设第一门自然地理课
    - Ratzel; 地缘政治，自然与文化
    - Semple 1903：环境决定论
    - Richard Hartshorne 1939: 空间变化,
    - Carl Sauer: 人类对环境影响
  - 1947：哈弗关闭地理系，“not a university subject”
    - Followed by Michigan, Northwestern, Chicago, and Columbia universities

近代地理学发展

- 20世纪中叶以后
  - 计量革命，1950s：“quantitative revolution”
    - 统计方法的广泛运用
    - 1980s后衰落
  - GIS及信息化
  - 哈弗地学回归，2006 ：The Center for Geographic Analysis (CGA)

近代地理学发展

- 中国地理系
  - 张相文，1901，上海南洋公学，《初等地理教科书》
  - 1920s后：东南大学地理系(1921)、北平师范大学地理系(1928)、清华大学地理系（1929）、中山大学地理系(1929)，浙江大学1936……，竺可桢、翁文灏、丁文江、曾世英、胡焕庸、王庸、李旭旦、任美锷、林超……
  - 中科院系统：地理所（1953）、南京地理研究所(1958)、长春地理研究所(1959)、广州地理研究所(1959)、新疆地理研究所(1961)、成都地理研究所(1965)、兰州冰川冻土研究所（1958）…….
  - 研究：地理资源考察，区划，自然地理体系、经济地理、人文地理、地图、遥感、GIS
  - 90年代前后：地理系改名

中国地理学发展

- 清华地学 **分久必合　合久必分**
  - 1929 清华大学地理学系成立
  - 1933 地理学系易名，清华大学地学系成立，下设地理、地质、气象三组
  - 1946 清华大学在北平复学，地学系恢复
  - 1947 地学系气象组独立，清华大学气象学系成立
  - 1950 地学系地质组独立，清华大学地质系成立
  - 1952 地学系、气象学系被调整出清华大学，迁到北京大学
  - 1952 地质学系被调整出清华大学，组建北京地质学院
  - 2009 03.01 清华大学地球系统科学研究中心成立
  - 2010 01.18 清华大学全球变化研究院成立

中国地理学发展

- 兰州大学始建地理系
  - 1946年 国立兰州大学始建地理系;
  - 1952年 设立自然地理学本科专业；
  - 1958年 设立地质学本科专业，并更名为地质地理系 ；
  - 1971年 设立气象学本科专业；
  - 1977年 设立水文地质与工程地质本科专业；
  - 1984年 从地质地理系分出地质学系；
  - 1986年 设立大气物理与大气环境学、经济地理学本科专业；
  - 1987年 从地理系分出大气科学系;
  - 1994年 由地理科学系、地质学系、大气科学系组建成资源环境学院;
  - 1996年 设立环境科学本科专业;
  - 1999年 在地理科学系、地质学系、大气科学系、环境科学系等基础上重组，成立实体的资源环境学院;
  - 2002年 成立水文与水资源工程系;
  - 2003年 成立地质工程与岩土工程系;
  - 2004年 大气科学系分出建院;
  - 2005年 地质工程与岩土工程系分出，并入土木工程与力学学院。

The nature of geographic knowledge

— R. Golledge (2002)

"In the latter part of the 20th century there has been a substantial change in the nature of geographic knowledge. Throughout most of the history of the discipline, geographic knowledge has been declarative — i.e., it has focused on collecting and representing the physical and human facts of existence. In the latter part of this century there has been a change from inventory dominated activity to the creation of knowledge generated by emphasizing cognitive demands, such as understanding 'why' and 'how' in addition to 'what' and 'where'. This has required a change from an emphasis on form to an emphasis on process."

"Understanding Human-Environment Relations (HER) has been a constant theme throughout the history of geography."

The nature of geographic knowledge

— R. Golledge (2002)

Purposes of developing geographic knowledge

1. increasing our understanding of place-to-place relations and variations;

2. obtaining a more complete base for interpreting human-environment relations at scales ranging from personal to global spaces;

3. assisting us to think about the spatial arrangement or organization of features, interactions, and relationships;

4. facilitating the performance of efficient and effective spatial behaviors.

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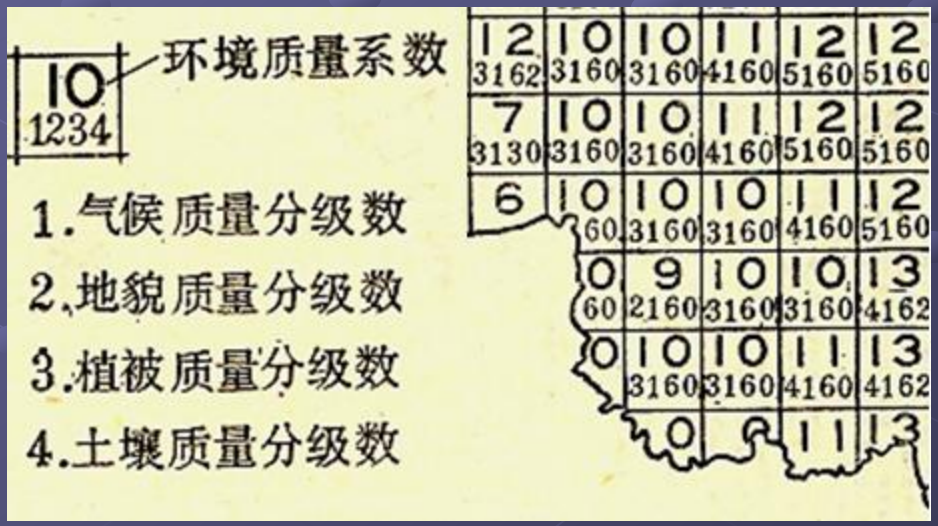
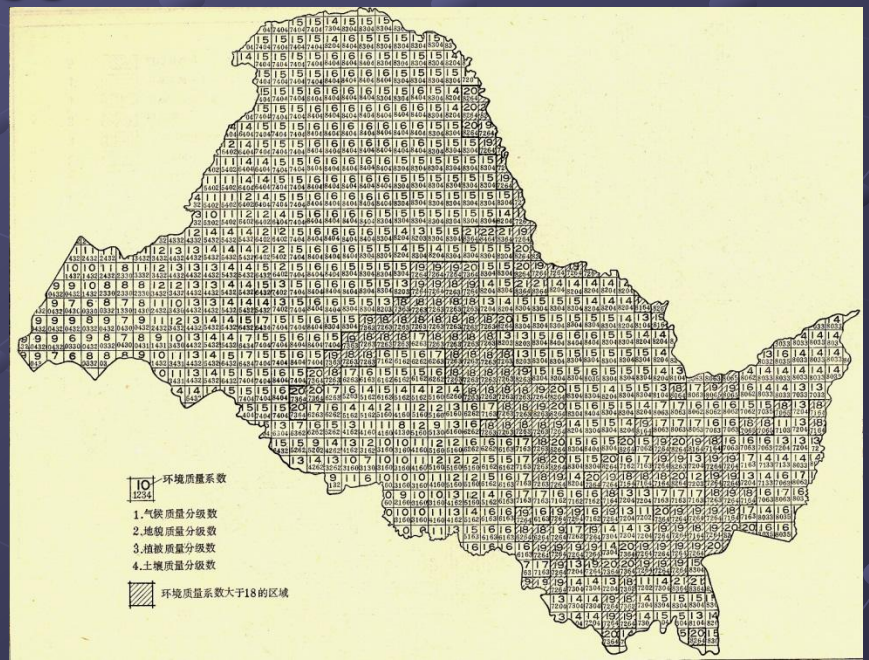
GIS

- Roger Tomlinson 1967: CGIS
- *Jack* Dangermond and his wife, 1969: ESRI
- 1982, ARC/INFO
- Goodchild 1992: GIScience

中国：空间分析
1972，李长生等，
克山病研究



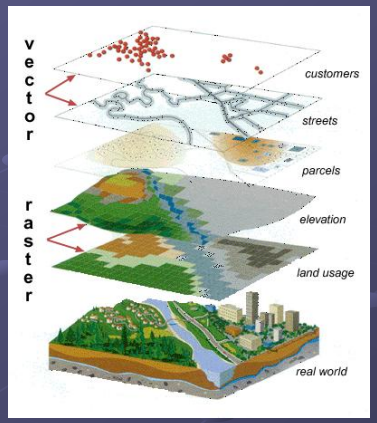


Geographic representation

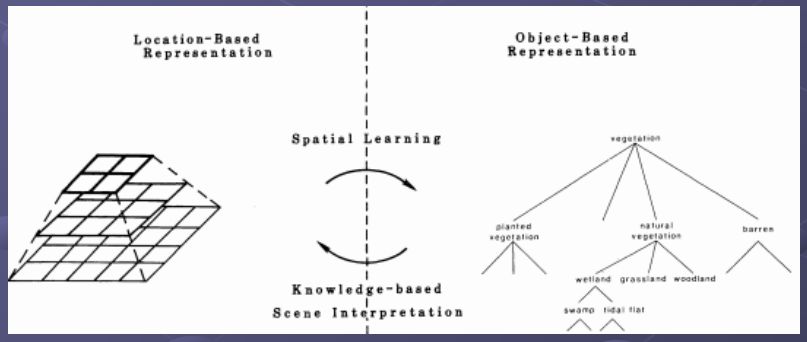
Geographic representation plays a central role to establish correspondences between theories and the world (Raper 1999) and to guide human actions within the world (Peuquet 2002)

GIS：80年代后的理论思考

- 1980s: Raster vs. vector
- 1988, Langran: Time in GIS
- 1992， Couclelis:
  - 对象(object)：独立非连续现象
  - 场（field)：连续现象
- 1988,1994: Peuquet



Form
vs.
process



1988

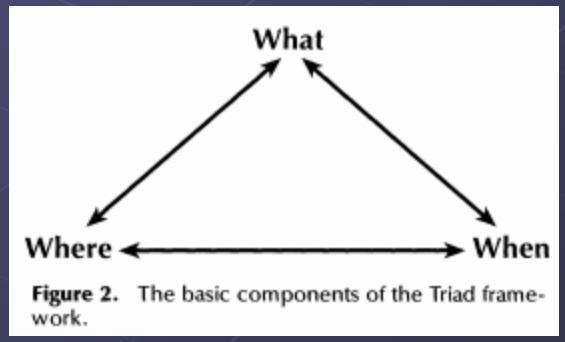


Figure 2. The basic components of the Triad framework.

1994

What/where/when
vs.
How/Why

GIS -> GIScience

- 1992, Goodchild: Geographic information Science
- UCGIS long-term research agenda : Spatial Ontologies, Geographic Representation, Spatial Data Acquisition and Integration, Remotely Acquired Data and Information in GIScience, Scale, Spatial Cognition, Space and Space/Time Analysis and Modeling, Uncertainty, Visualization, GIS and Society, Geospatial Data

“…the growth of GIScience has led to an increased interest in form, leaving inference about process entirely outside the system.”

—Goodchild (2004)

地图

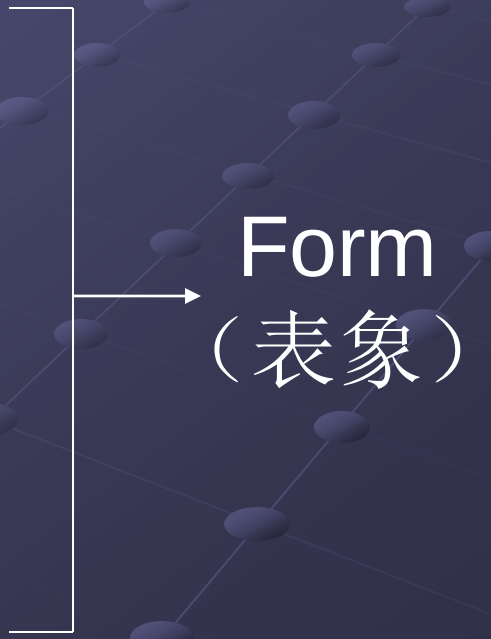
GIS 数据库

时空数据模型

本体论（ontology）

模糊论（uncertainty and fuzziness)

数据挖掘（data mining）



什么是过程？

Christopherson (2002）：

Process: “a set of actions or mechanisms that operate in some order, governed by physical, chemical, and biological laws.”（一系列按一定秩序，机制，和规律进行的活动）

Goodchild (2004）：

Form: “how the world looks” (表象)

Process: “how the world works” （运作）

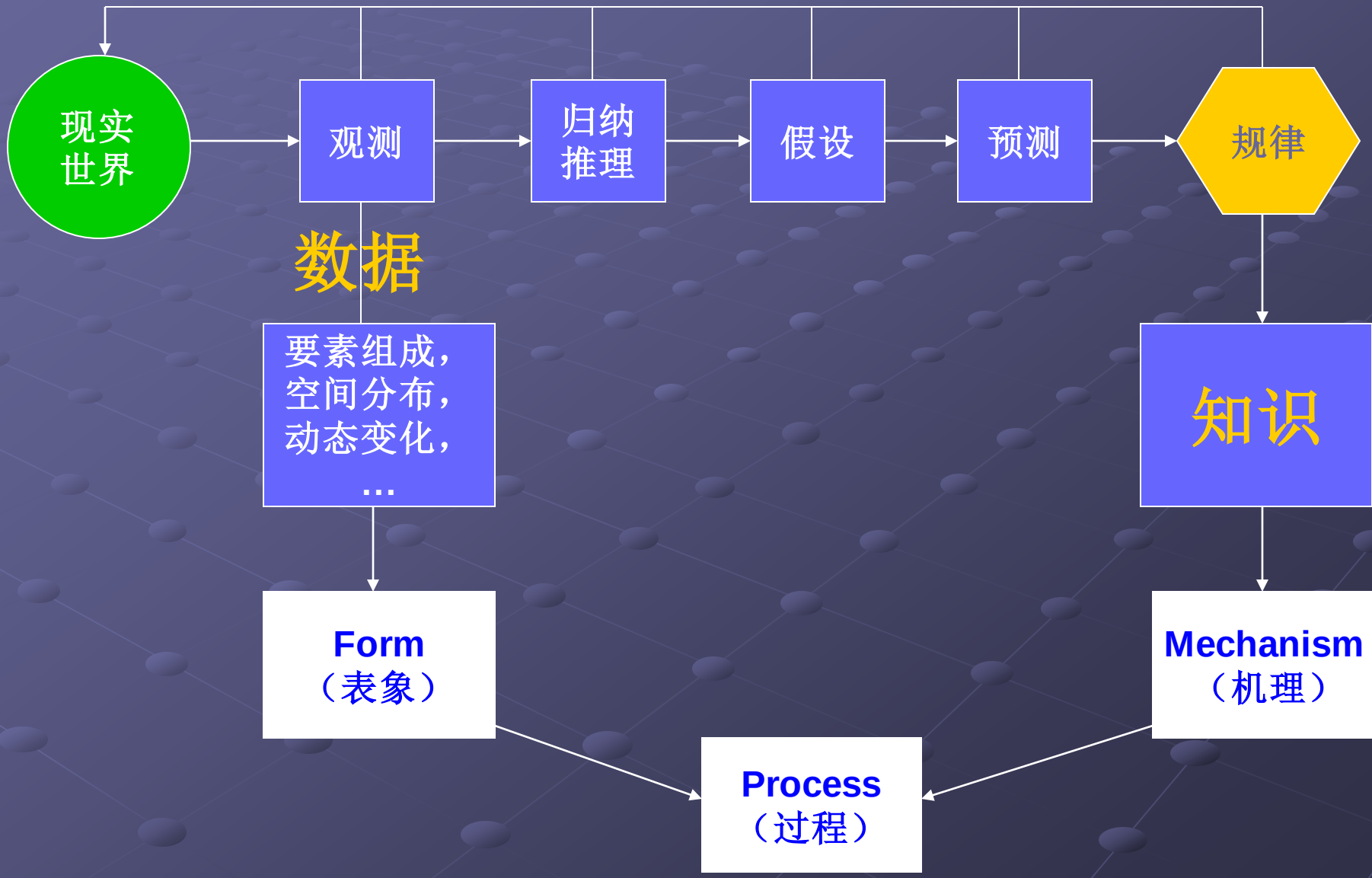
什么是过程？

过程 ＝ 表象 ＋ 机理

（Process = Form + Mechanism）

— (Yu, 2005)

认识世界的方法


现实世界
观测
归纳推理
假设
预测
规律
数据
要素组成，空间分布，动态变化，…
知识
Form（表象）
Mechanism（机理）
Process（过程）

数据，信息，与知识

AUTHORS	DATA	INFORMATION	KNOWLEDGE
Zeleny (1987)	knowing-nothing	knowing-what	knowing-how and knowing-why
Machlup (1983)	raw, reification of information	fragmented, ephemeral, and empirical flow	structured, enduring, and consistent stock
Woodward (1992)	raw quantitative or qualitative facts for creating information	data ordered and contextualized in ways that gives them meaning	the cumulative understanding of information
Wiig (1993)	-	facts organized to describe a situation of condition	truths and beliefs, perspectives, and concepts, judgments and exceptions methodologies and know-how
Nonaka and Takeuchi (1995)	-	a flow of meaningful messages	commitments and beliefs created from these messages
Spek and Spijkervet (1997)	not yet interpreted symbols	data with meaning	the ability to assign meaning
Davenport (1997)	simple observations	data with relevance and purpose	valuable information from the human mind
Davenport and Prusak 1998	a set of discrete facts	a message meant to change the receiver's perception	experience, values, insights and contextual information
Quigley and Debons (1999)	does not answer questions to a particular problem	answers the questions what, where, when, or who	answers the questions why or how
Choo, Detlor, et. al (2000)	Facts	data vested with meaning	justified true beliefs
Bellinger, Castro, et al. (2000)	is raw; simply exists and has no significance beyond its existence	data that has been given meaning by way of relational connection	is the appropriate collection of information, such that its intent is to be useful
Schreiber, Akkermans, et al. (2000)	uninterpreted signals	meaning attached to data	(1) attach purpose and competence to information (2) potential to generate actions
Longley, Goodchild, et al. (2001)	raw data, context- free	data being given some interpretation, serving some purposes	value of information being added by interpretation based on contexts, experiences, and purpose
Setzer (2001)	a sequence of quantified or quantifiable symbols	informal abstraction representing something of significance to a particular person	as a personal, inner abstraction of something that has been experienced by someone
Lo, Yeung, et al. (2002)	a collection of facts in numerical values, characters, symbols, or signals	processed data that are meaningful, valuable and useful to users	the concepts of data and information

Data	raw and uninterpreted facts（未经解释的信号）
Information	interpreted from data （解释） with meaning attached（含义） what/where/when/who fragmentary and less organized（零散）
Knowledge	cumulative understanding of information （累积的信息） well organized （组织性） how/why linked to judgment and actions（能够进行判断和指导行为）

知识 与 过程

Throughout most of the history of the discipline (i.e., geography), geographic knowledge has been declarative — i.e., it has focused on collecting and representing the physical and human facts of existence. In the latter part of this century there has been a change from inventory dominated activity to the creation of knowledge generated by emphasizing cognitive demands, such as understanding 'why' and 'how' in addition to 'what' and 'where'. This has required a change from an emphasis on form to an emphasis on process."

— R. Golledge (2002)

Data	raw and uninterpreted facts
Information	with meaning attached interpreted from data what/where/when/who fragmentary and less organized
Knowledge	cumulative understanding of information well organized how/why linked to judgment and actions

需要表达什么知识？

(A)

How people understand the world

Conceptualization

(B)

How people play roles in the world

Laws
Policies
plans
Religions
Morals
Beliefs
Goals

目前GIS缺乏：

- 知识表达
- 人与社会
- 人与环境相互作用
- 尺度的关联性

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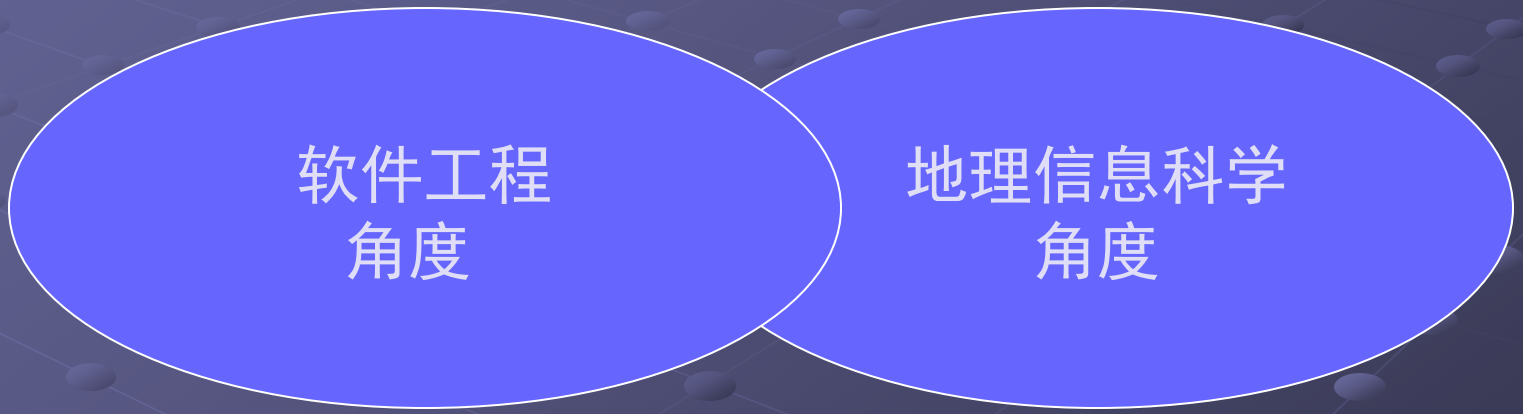
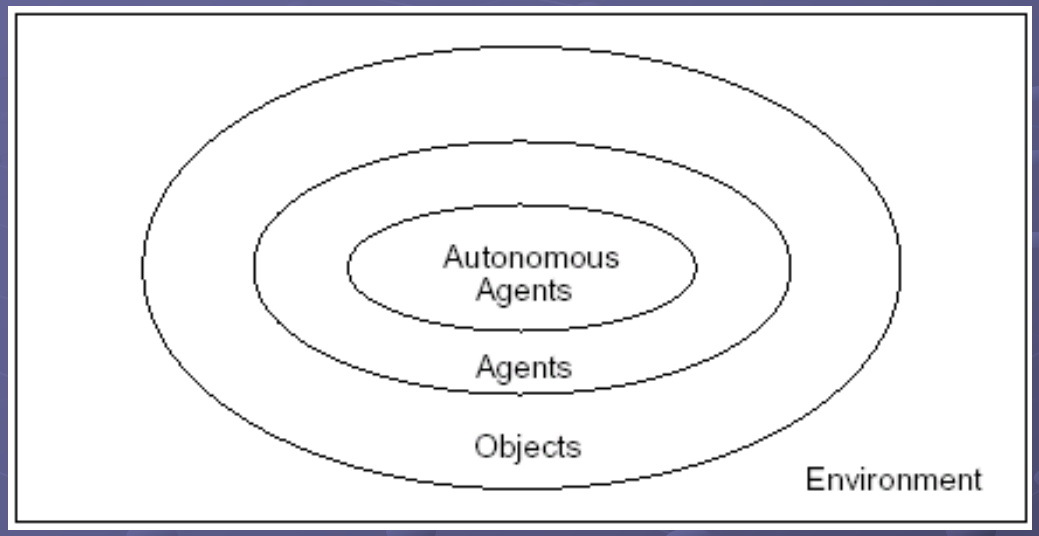
Toward a new geographic representation framework

- GeoAgent
  - GeoAgent as a basic representation component for goal-driven, social behaviors
  - Future GIS: Field，Object，GeoAgent， time
- Data centered representation -> knowledge-oriented representation

How do we view the world



软件工程角度



(Luck and d'Inverno 2001)

实体（Entity）: a collection of attributes

环境（Environment）: a collection of entities

对象（Object）: an entity with a set of actions

智能体（Agent）: an object with goals

独立自主的智能体（Autonomous agent）: a self-motivated agent that pursues its own agenda

智能体：分布式，独立，协作

- 什么是智能体?
  - Shoham (1993): have mental states, such as knowledge, belief, intention, and obligation
  - Franklin and Graesser (1997): are systems situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of their own agenda and so as to effect what it senses in the future
  - Jennings et al. (1998): are characterized with situatedness, autonomy, flexibility, and social ability

Object vs. Agent

- 对象（Object）与智能体 (Agent) (Zambonelli, et al. 2003)
  - 智能体
    - 独立自主（Autonomous）
    - 有目标（Goal-driven）
    - 社会性（Social）
  - 对象:
    - 非独立自主（Non-autonomous）
    - 无目标（No goals）
    - 行为被外力驱动（Passive activities only driven by external forces）

GIScience 角度

- 对象（Object） vs. 场（Field）
  - Couclelis 1992：类似物理学原子和场
  - Cova et al. （2002)： 离散 vs. 连续现象
    - 场：温度，气压等
    - 对象（或要素）：河流，道路建筑等
- 但是，缺乏表达地球体中那些有智能，有目的，独立自主，相互协作（冲突）的行为

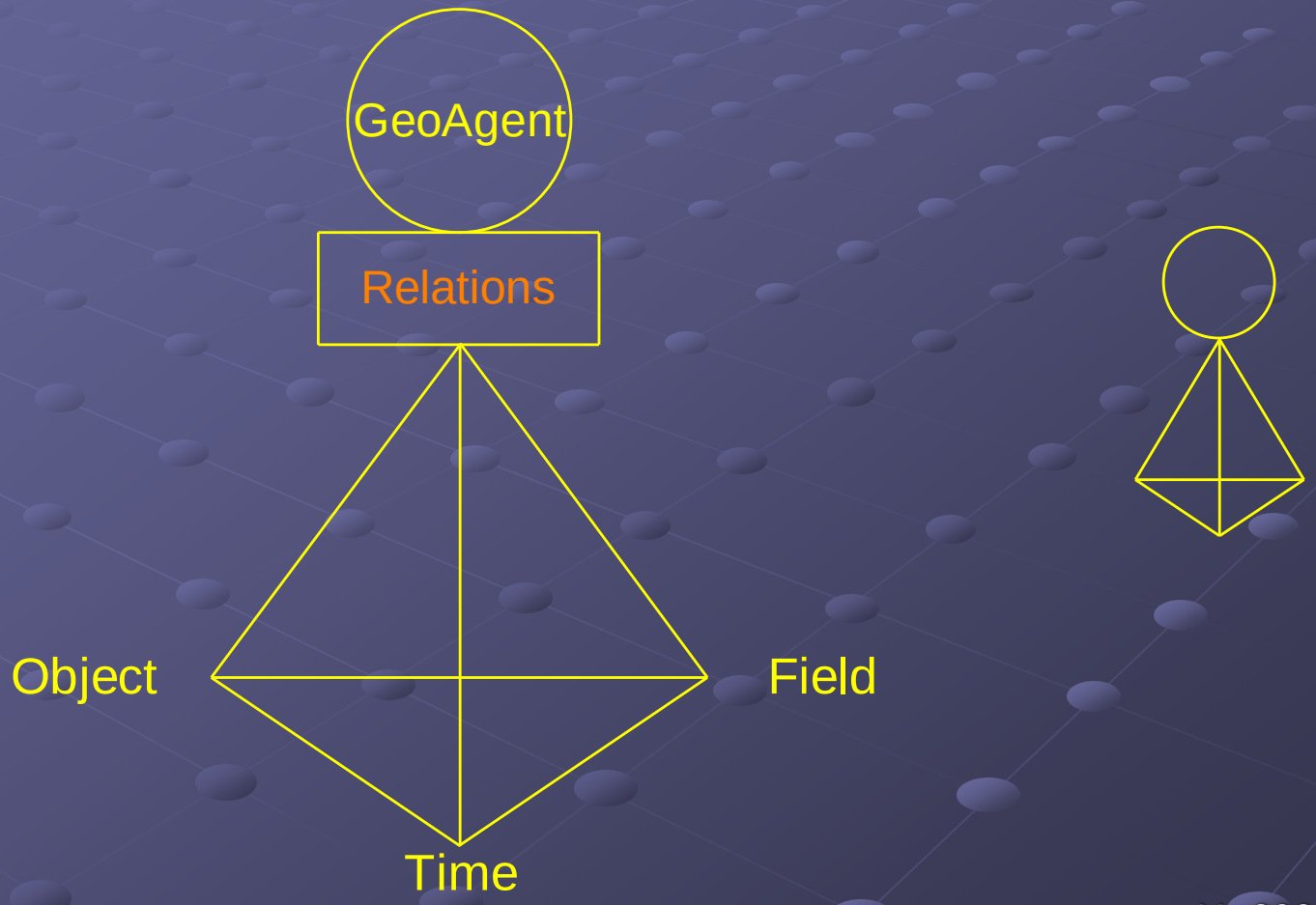
地理智能体

地理智能体(GeoAgents)

- 在GIScience中超越对象/场概念，用以表达地球体中智能行为的基本单元
- 四大特点（Yu, Peuquet 2009）
  - It is a representation component (i.e. designating something in the geographic world);
  - It has goals;
  - It interacts with a geographic environment; and
  - It is used in a geographic application context.

一个表达地理过程的基本框架: FOTAR

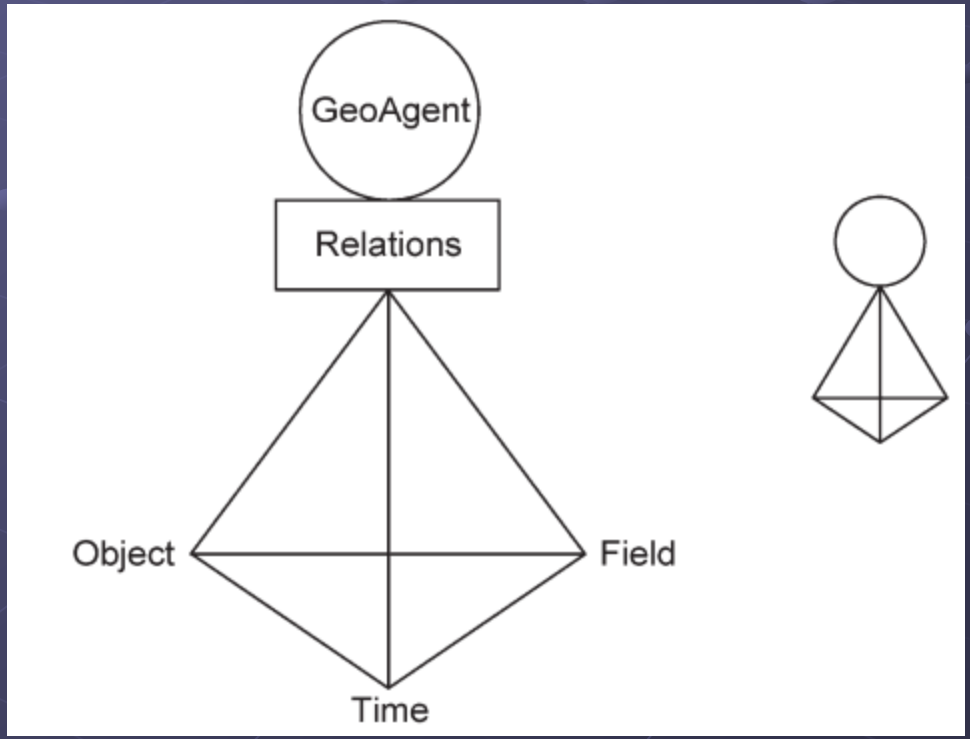
(Field, Object, Time, GeoAgents, Relations):



Yu 2006, in submission

The FOTAR framework

- FOTAR (Field, Object, Time, GeoAgents, Relations)
- Field: natural & social
  - continuous space
  - With driving forces
- Objects:
  - Discrete features
  - Passive reactions
- GeoAgents
  - Special objects
  - With motivation and social characteristics
- Time: dynamic



(A)

How people understand the world

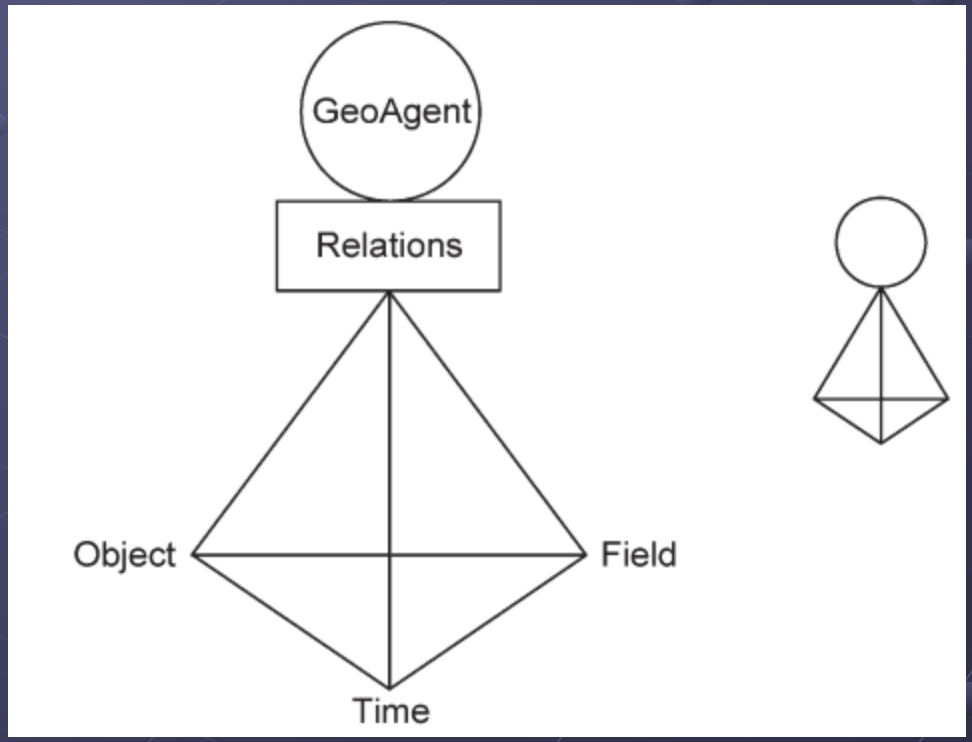
Conceptualization

(B)

How people play roles in the world

Laws
Policies
plans
Religions
Morals
Beliefs
Goals

需要知识表达



表达知识的技术

- 数学模型:
  - 利于表达数量关系
  - 利于模拟动态变化
  - 利于进行预测预报
- 图:
  - 利于表达相关关系
- 专家系统:
  - 利于表达行为规则(“如果...就...”)
  - 利于自动推理
- 人工智能体
  - 分布式的知识表达
  - 协作行为

表达知识的技术

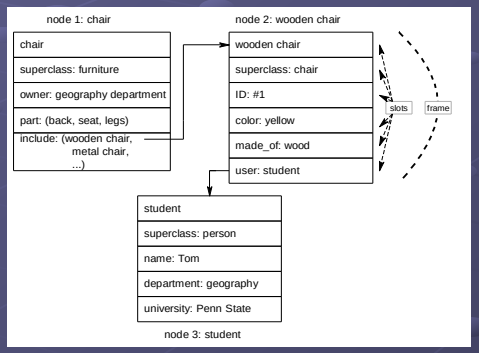
- 数学模型

$$Y = f(x1, x2, \ldots xn)$$

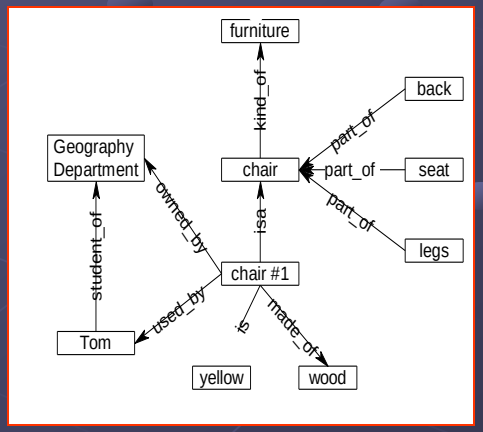
  - 善于
    - 定量关系
    - 模拟
    - 预测
  - 不善于
    - 定性的法规，规则

表达知识的技术

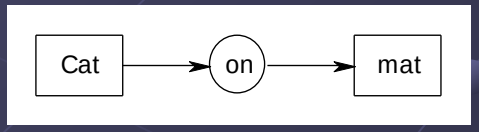
- 图（善于表达关系，不善于表达行为）
  - Frames (Minsky 1975)



  - Semantic networks (Collins and Quillian, 1969)
  - Concept maps (Novak and Gowin 1984)

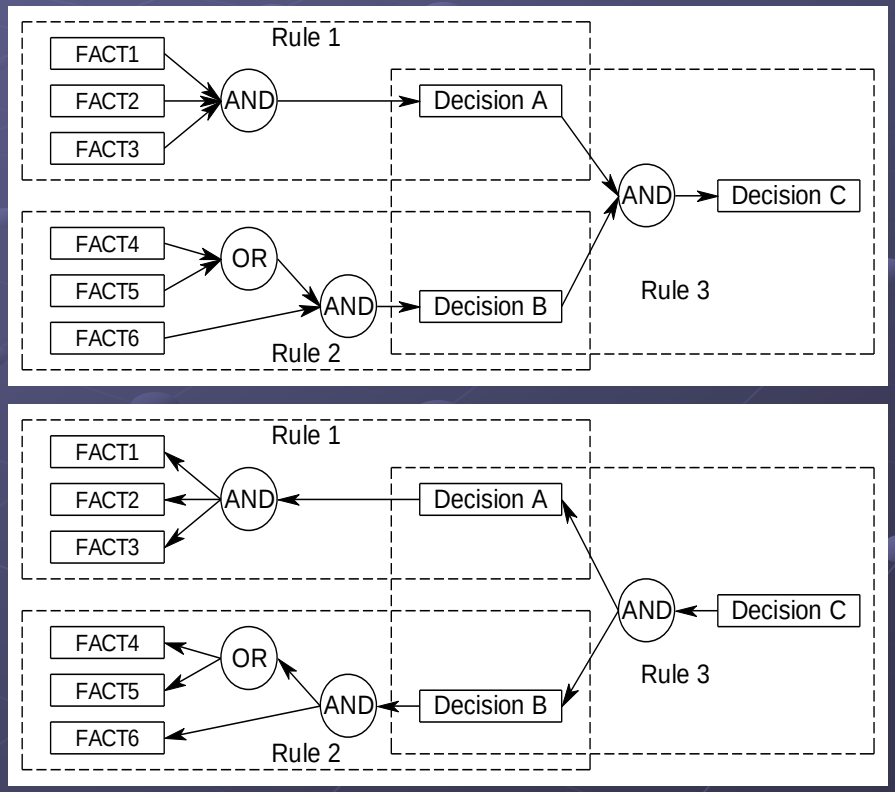


  - Conceptual graphs (Sowa 1984)



表达知识的技术

- 专家系统
  - 知识行为
  - 自动推理
  - IF...THEN 规则
  - 传统上是集中式而非分布式的知识表达



- 地理过程具有整体性，区域差异性，及尺度相关性
- 没有任何单一技术可以全面表达地理过程的复杂性

“To solve really hard problems, we’ll have to use several different representations.”

—M. Minsky (1991, p38)

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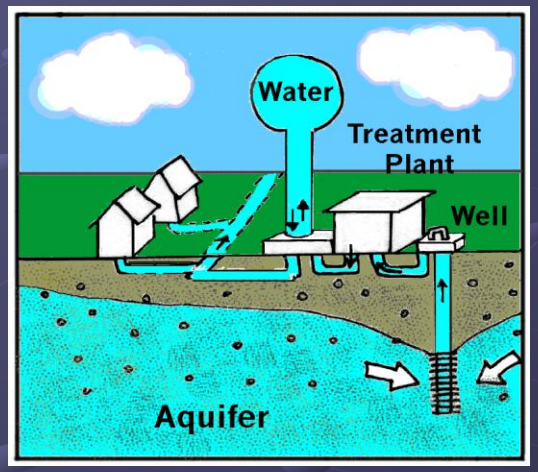
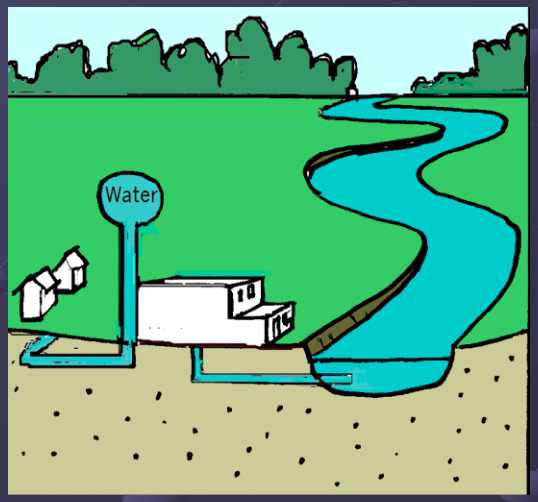
美国社区水资源管理背景知识

- 社区水系统
  (community water systems (CWSs)):
  - 全美共有54000 CWSs
  - 水源:地下水或地表水
  - 提供约2.68亿人口的日常用水
  - 受州及联邦环保局领导
  - 是水资源管理的最基层单位





MODFLOW

水资源管理中的复杂的人与环境作用过程

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)+W=S_s\frac{\partial h}{\partial t}$$

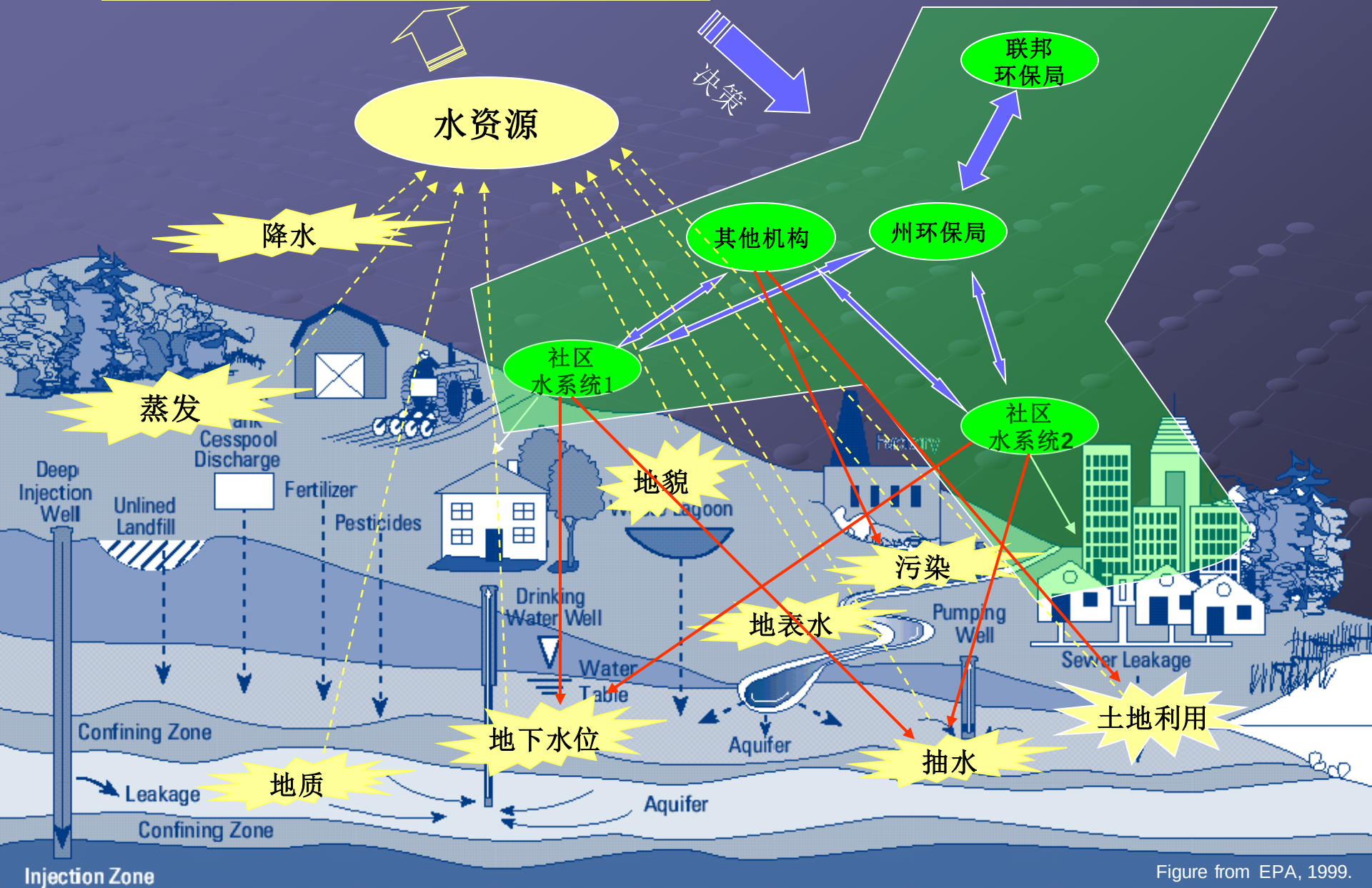
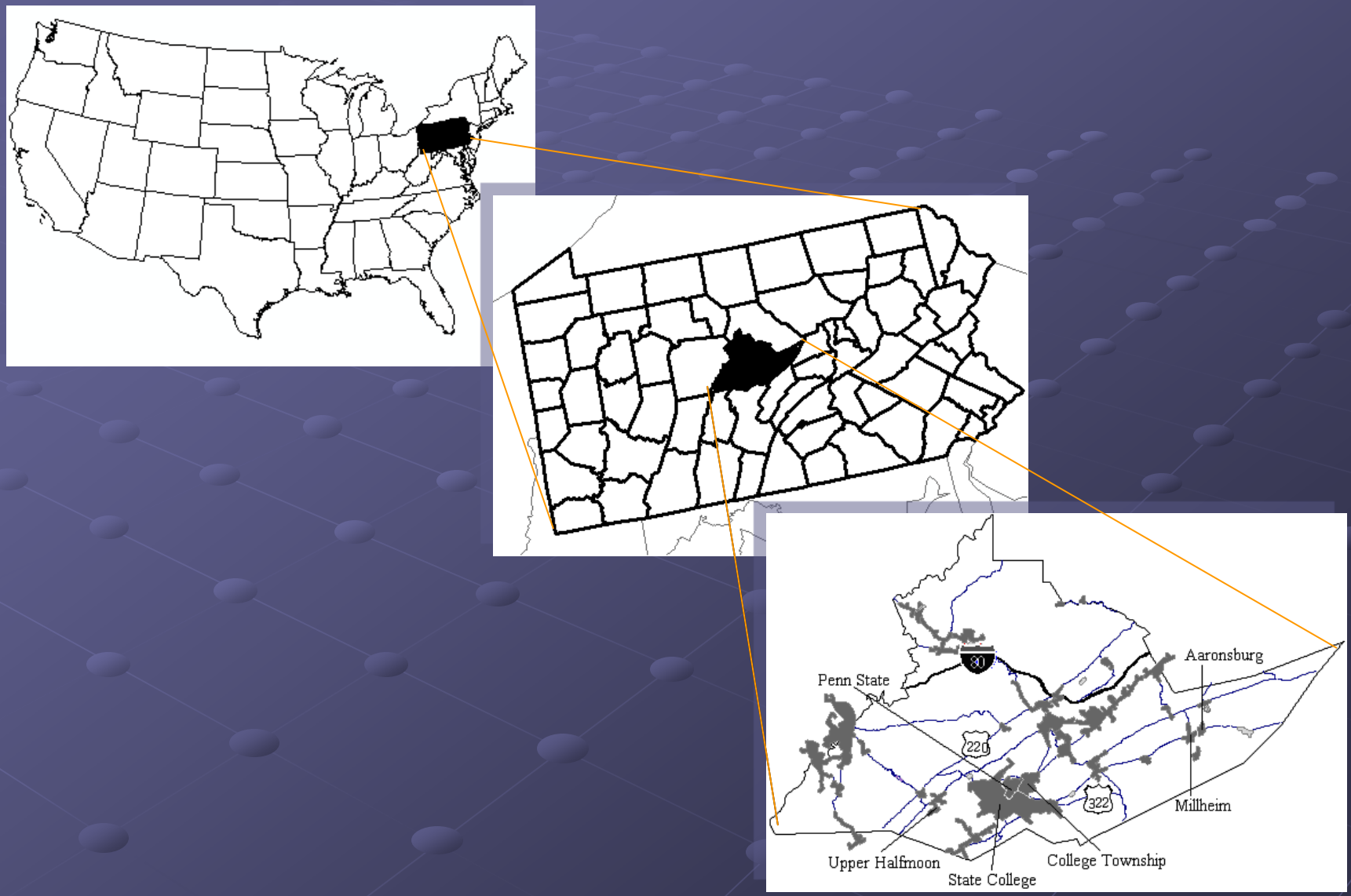


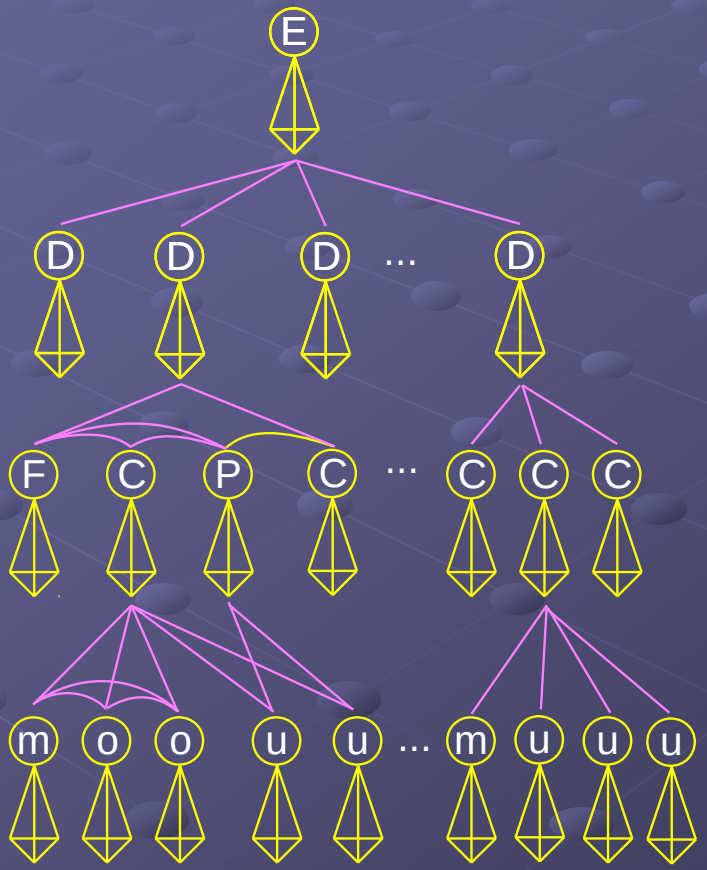
Figure from EPA, 1999.

研究区域: 美国宾夕法利亚州(宾州)中部



用FOTAR构建多尺度人与环境的相互作用过程

- 以水资源管理为例



E: Environmental Protection Agency
(联邦环保局及全美尺度的数据环境)

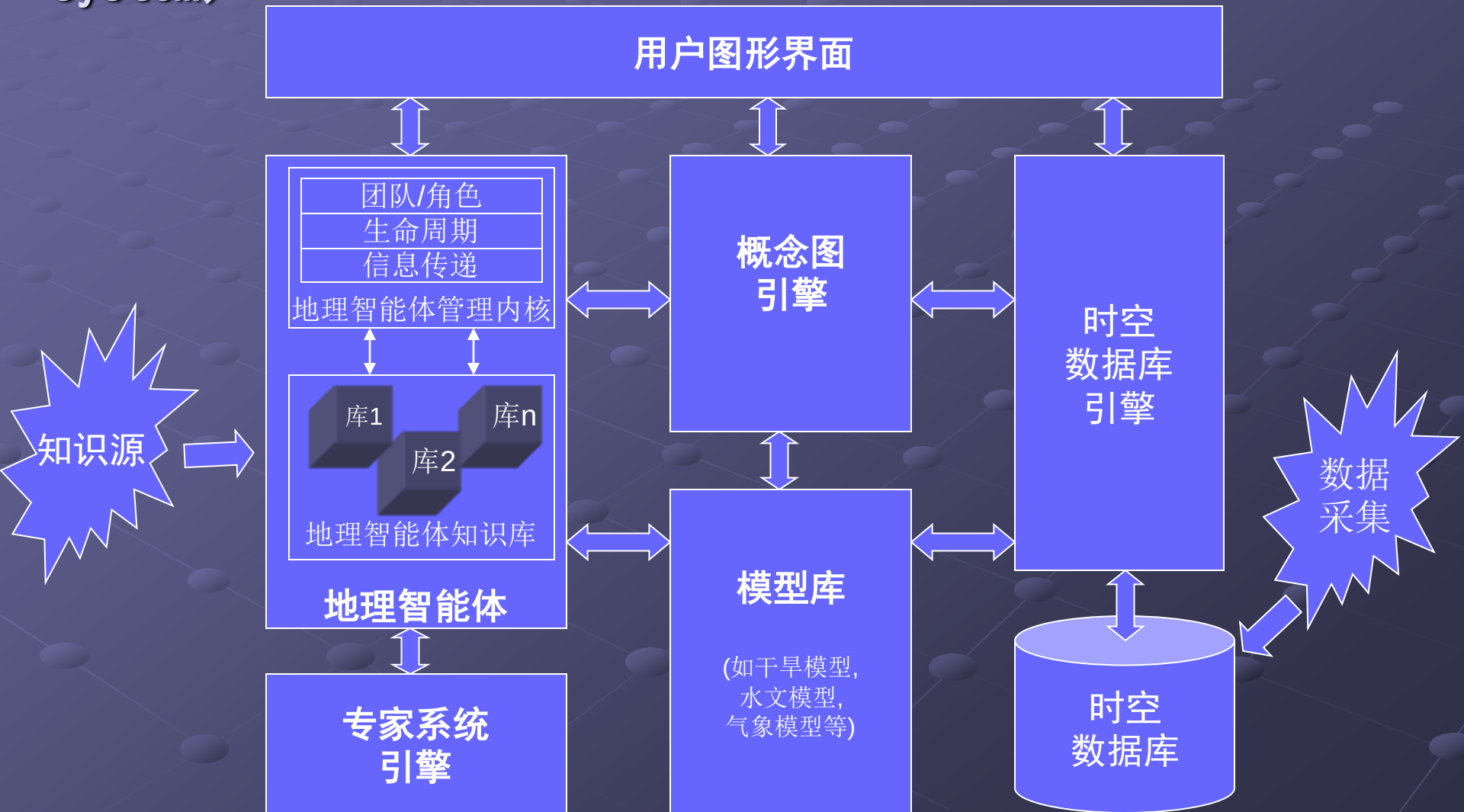
D: Department of Environment Protection
(州环保局及全州尺度的数据环境)

C: Community water system(社区水系统)
F: Fire department (社区防火部门)
P: Power company(电力公司）

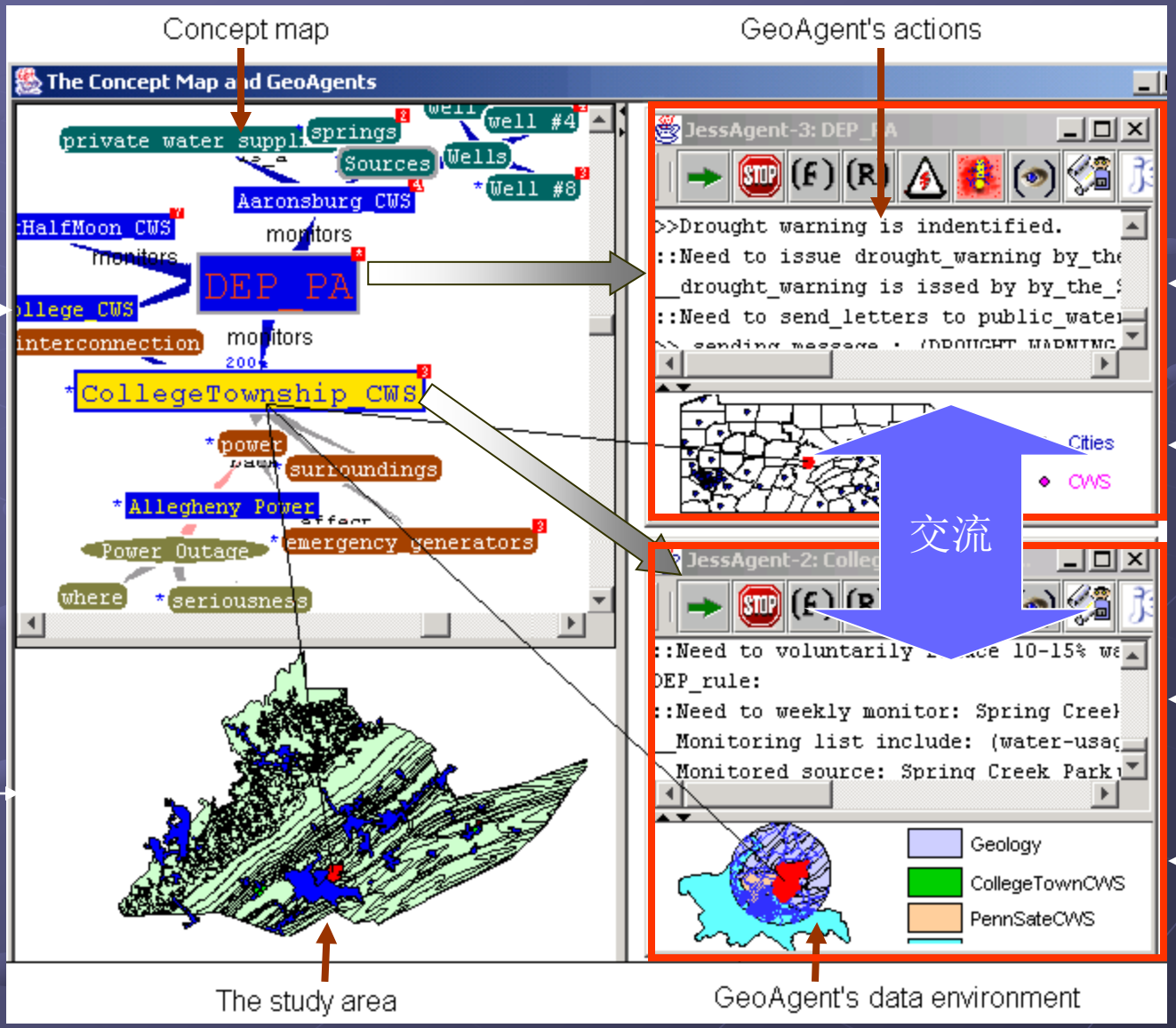
M: water manager（水系统经理）
O: water operator (水系统操作员)
U: water users （用水户）

原型系统

- 基于地理智能体的知识系统（GeoAgent-based Knowledge System）



<<基于地理智能体的知识系统>>的部分图形界面



概念图

研究区域

地理智能体1

知识库的输出

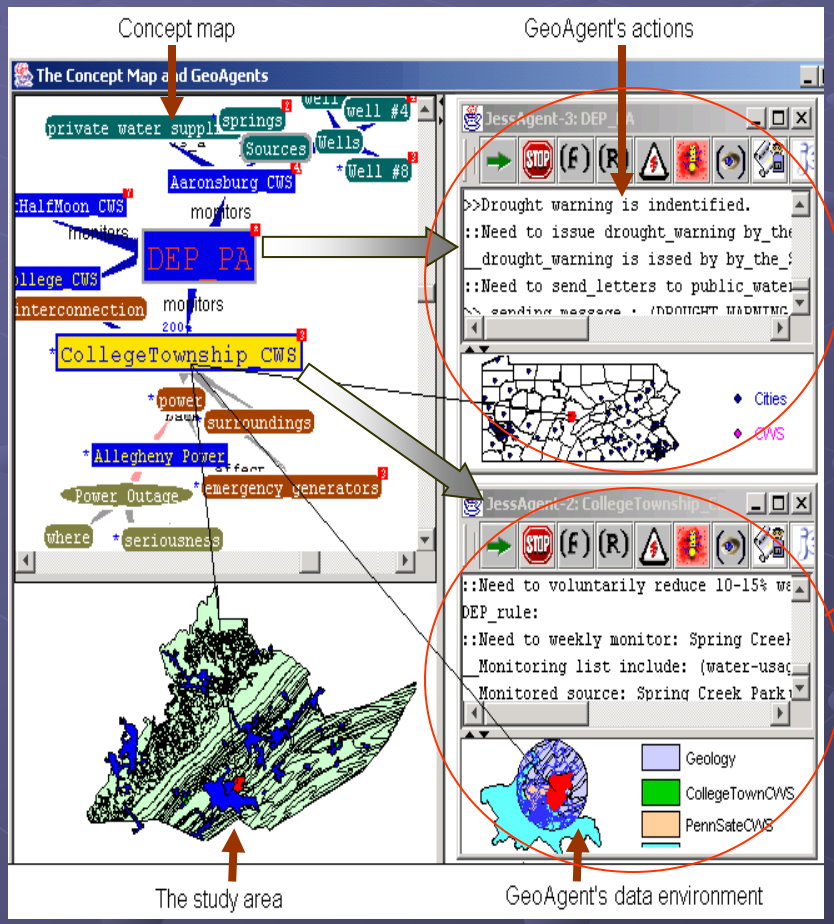
空间数据库显示

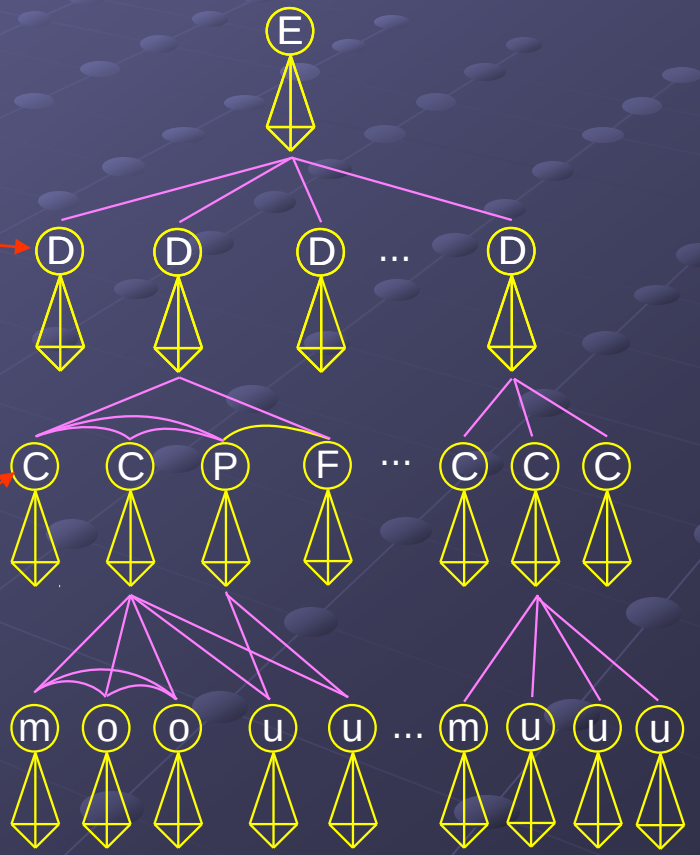
地理智能体2

知识库的输出

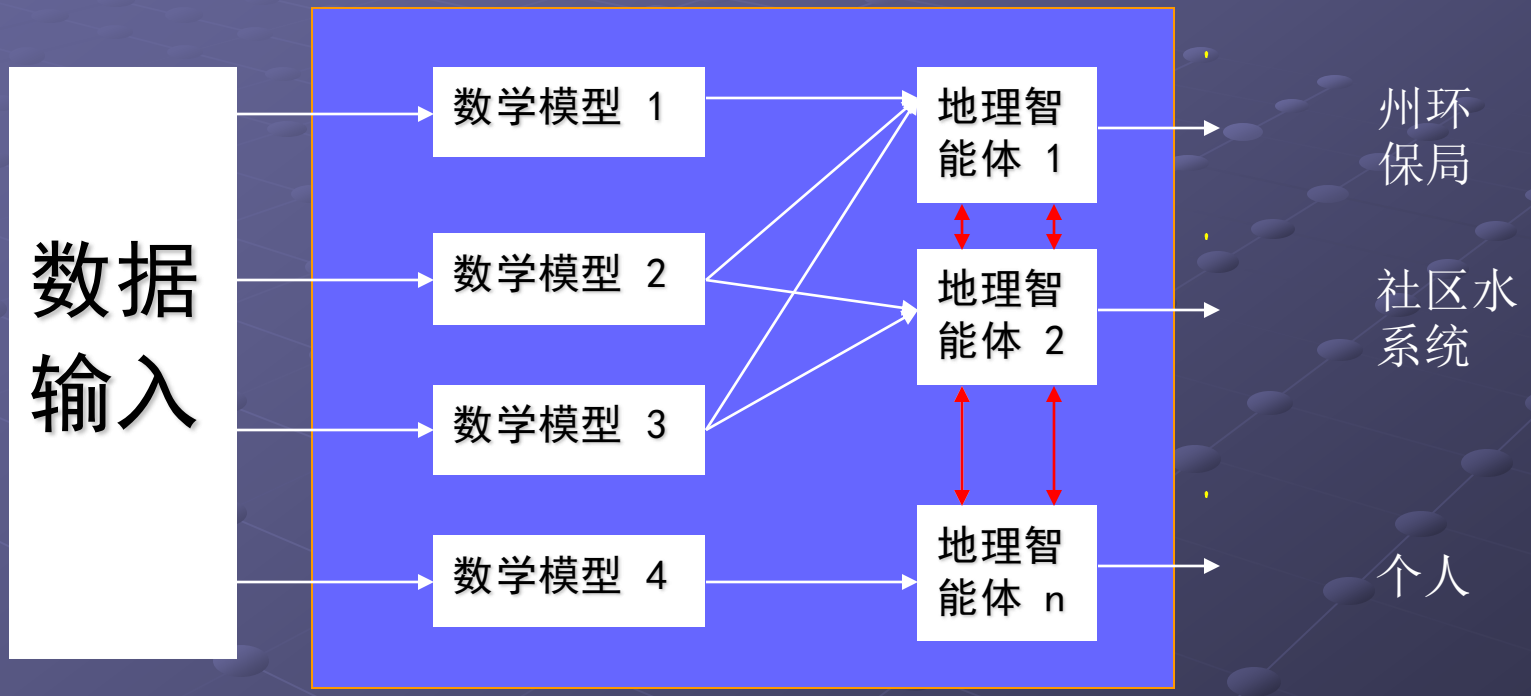
空间数据库显示

构建多尺度的人与环境的相互作用过程



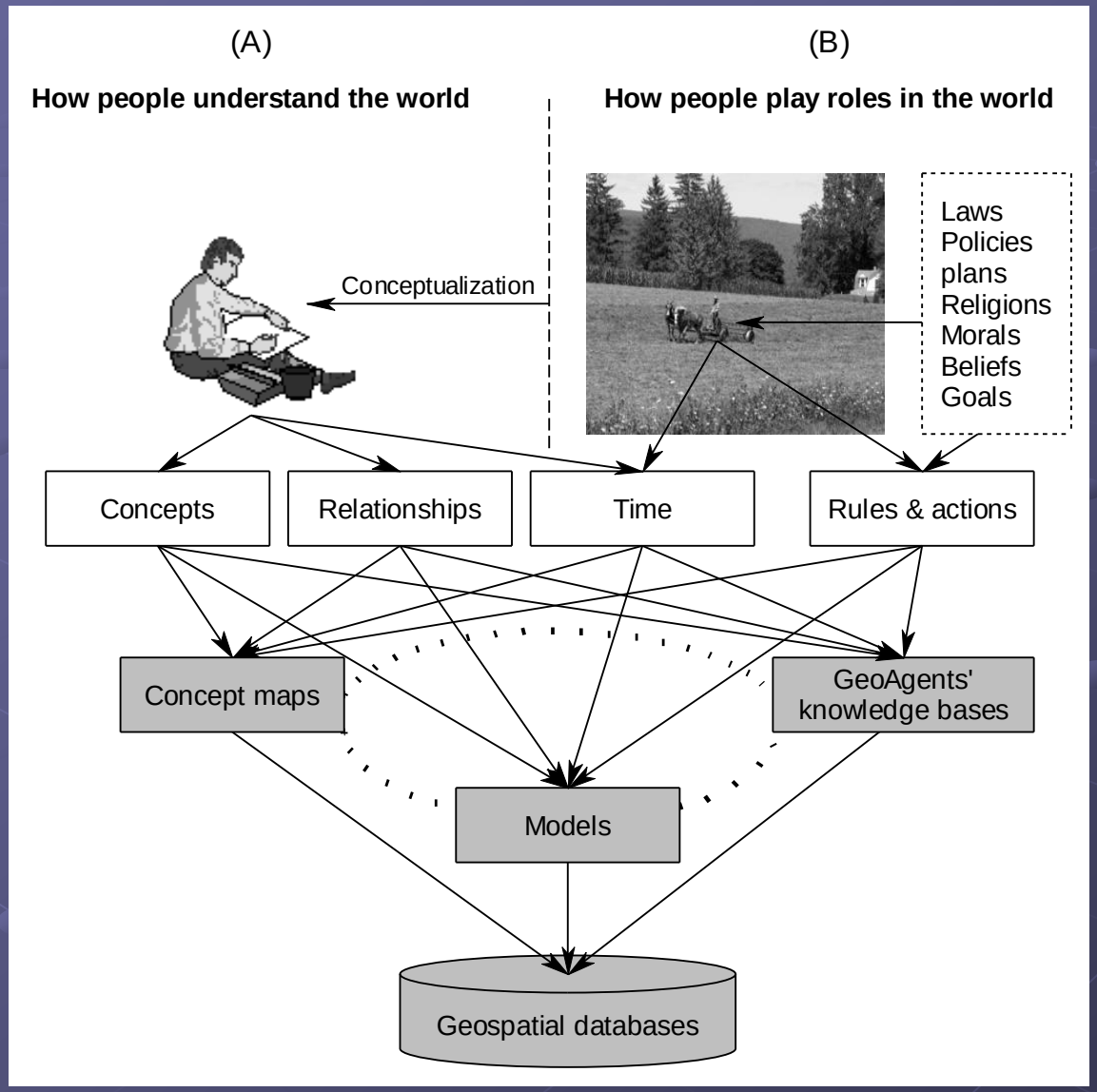


监测模拟与协作响应一体化



实时监测　　模拟预报　　决策推理　　协作反应

面向知识的方法



- 知识源
  - 文本
  - 采访

文本知识

例：一个水系统的部分应急计划

Name of the CWS: College Township CWS
Emergency: Power outage
Corrective actions:

Station A and Station B are considerably dependent upon electric power. The operator should visually inspect the stations for smoke, fire, or alarms causing or resulting from power failure. The operator should determine whether the entire station or only portions of the station are without power. The operator should determine if the station itself or the surrounding area is without power. The operator should contact the local power company or an electrical contractor. If the power failure is the result of the local power company, the operator should call the power company and inform the power company that a part or the whole public water system has been effected, and find out how long the power outage is expected to last. If the power outage is short term (less than two hours), the existing storage facilities should be able to supply the water system. If the power outage is expected to last more than two hours, the following procedures should be followed:

1. Emergency generator: obtain, connect, and use emergency generator to operate the Station A. If Emergency generator is not an option then,
2. Emergency interconnection: operate to the extent possible.
3. Restrictive Water use: contact the local fire departments, local radio station, and newspaper.
4. If the system pressure drops below 20 PSI (Pounds per Square Inch), additional boil water order restriction must be issued and notification to the public.
5. Water hauling.

文本分析

Name of the CWS: College Township CWS
Emergency: Power outage
Corrective actions:

[Sentence group 1: checking the causes of the power outage]

The station is considerably dependent upon electric power. The operator should visually **inspect** the station for *smoke, fire, or alarms* causing or resulting from power failure. The operator should **determine** whether the entire station or only portions of the station are without power. The operator should **determine** if the stations or the surrounding areas are without power.

[Sentence group 2: determining how long it will last]

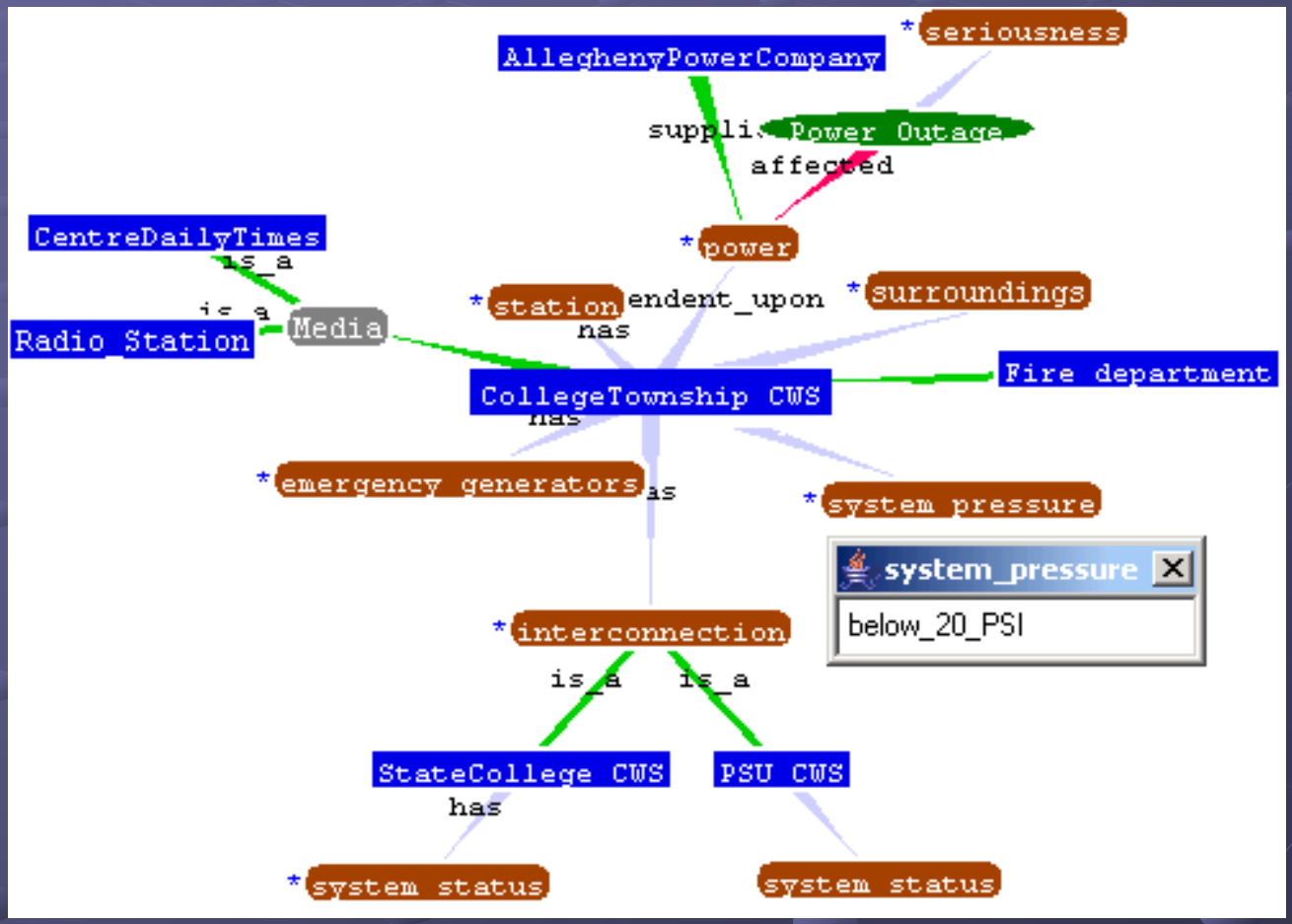
The operator should **contact** the local Power Company or an electrical contractor. If the power failure is the result of the local power company, the operator should **call** the power company and **inform** the power company that a part or the whole public water system has been affected, and **find out** how long the power outage is expected to last.

[Sentence group 3: taking actions to recover water supply]

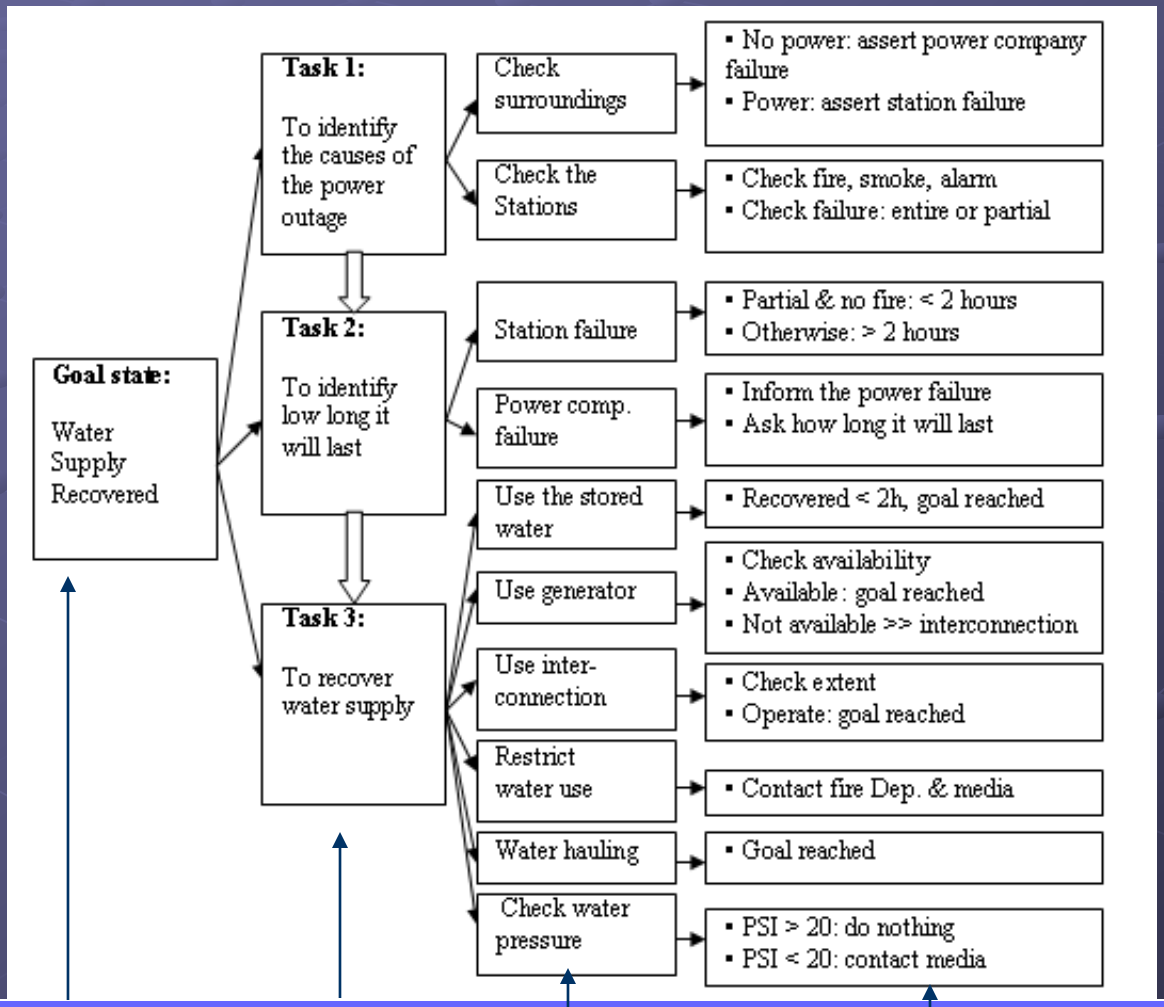
If the *power outage* is short term (*less than two hours*), the existing storage facilities should be able to supply the water system. If the *power outage* is expected to last *more than two hours*, the following procedures should be followed:

1. Emergency generator: **obtain, connect,** and **use** emergency generator to operate the Station A. If Emergency generator is not an option then,
2. Emergency interconnection: **operate** to the extent possible
3. Restrictive water use: **contact** the local fire departments, local radio station, and newspaper.
4. If the system pressure drops *below 20 PSI* (pounds per square inch), additional boil water order restriction must be issued and **notification** to the public.
5. **Water hauling**

- 用概念图提取关键要素
- 建立要素间的相互关系



- 根据文本规划地理智能体的行为规则：



为地理智能体的行为规则编程(专家系统):

(1) the goal and high-level tasks of the power outage plan:

IF (Power == power_outage)
StateUpdating: (1) power_outage = true
(2) goal = water_supply_recovered
(3) goal_status = not_achieved
Tasks: (1) identify causes
(2) identify lasting time
(3) to recover water supply
(4) determine boil water order

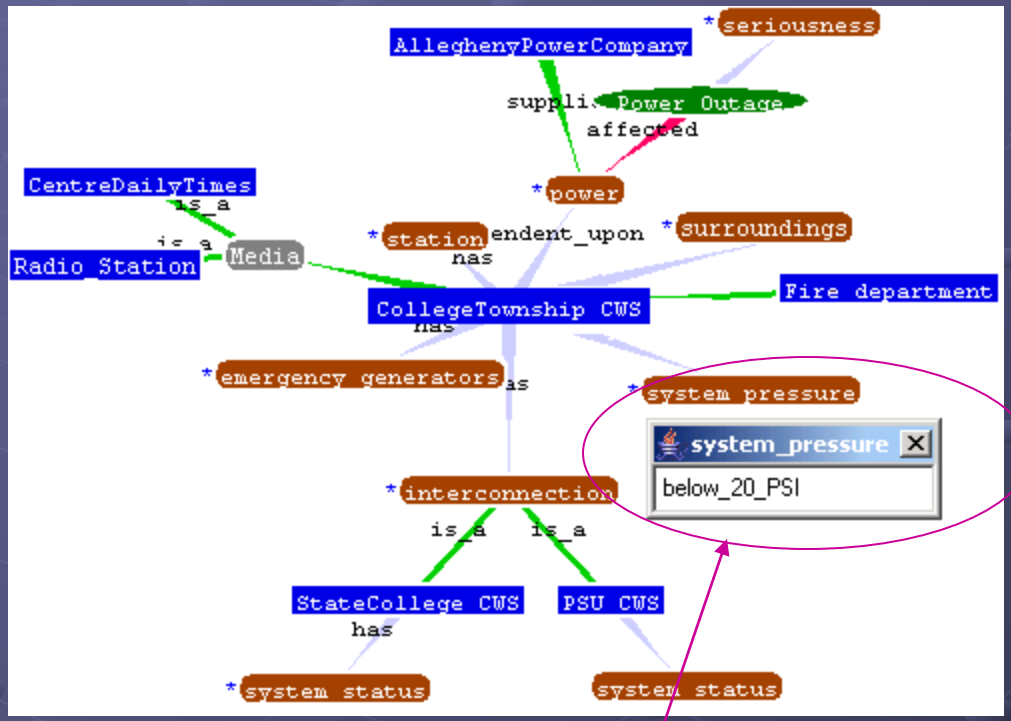
(2) the task of recovering water supply:

IF (task == recover_water_supply && goal_status == not_achieved)
Tasks: (1) use the stored water
(2) check generator
(3) check interconnection
(4) restrict water use
(5) check system pressure
(6) water hauling
(7) withdraw the current task

(3) the actions of using generator (i.e., from the other part of the emergency plan):

IF (task == check_generator &&
emergency_generator == available &&
goal_status == not_achieved)
Actions:(1) check the generator's fuel and oil level
(2) connect generator leads to external terminal box
(3) put Off-Auto switches for High Service pumps to the Off position
(4) use key interlock to open the main circuit breaker
(5) use key interlock to close the standby generator breaker
(6) start generator when the breaker is closed
(7) goal reached: water_supply_recovered
(8) withdraw the current task
(9) withdraw the current goal
StateUpdating: (1) goal_status = achieved

- 建立概念图与地理智能体行为规则的联系：

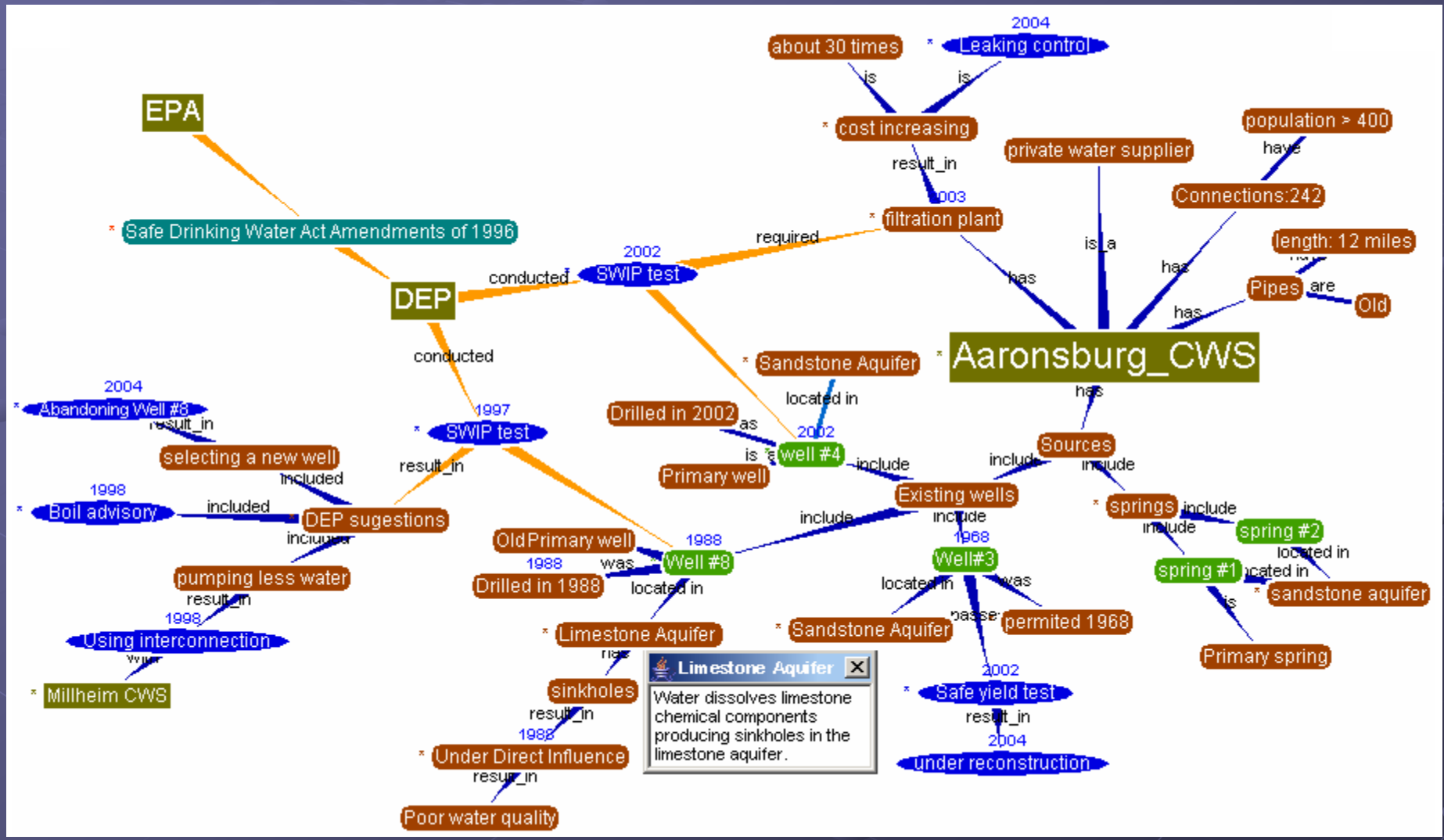



```
(defrule check_system_pressure
      IF (task = = check_system_pressure && system_pressure = = below_20_PSI)
 Actions:
      (1) query the names of the newspaper and radio station
      (2) sendACLMessag to the newspaper and radio station =>
          action: broadcast; content: boil_water_needed_for_CollegeTownship_water_users
      (3) withdraw the current task
)
```

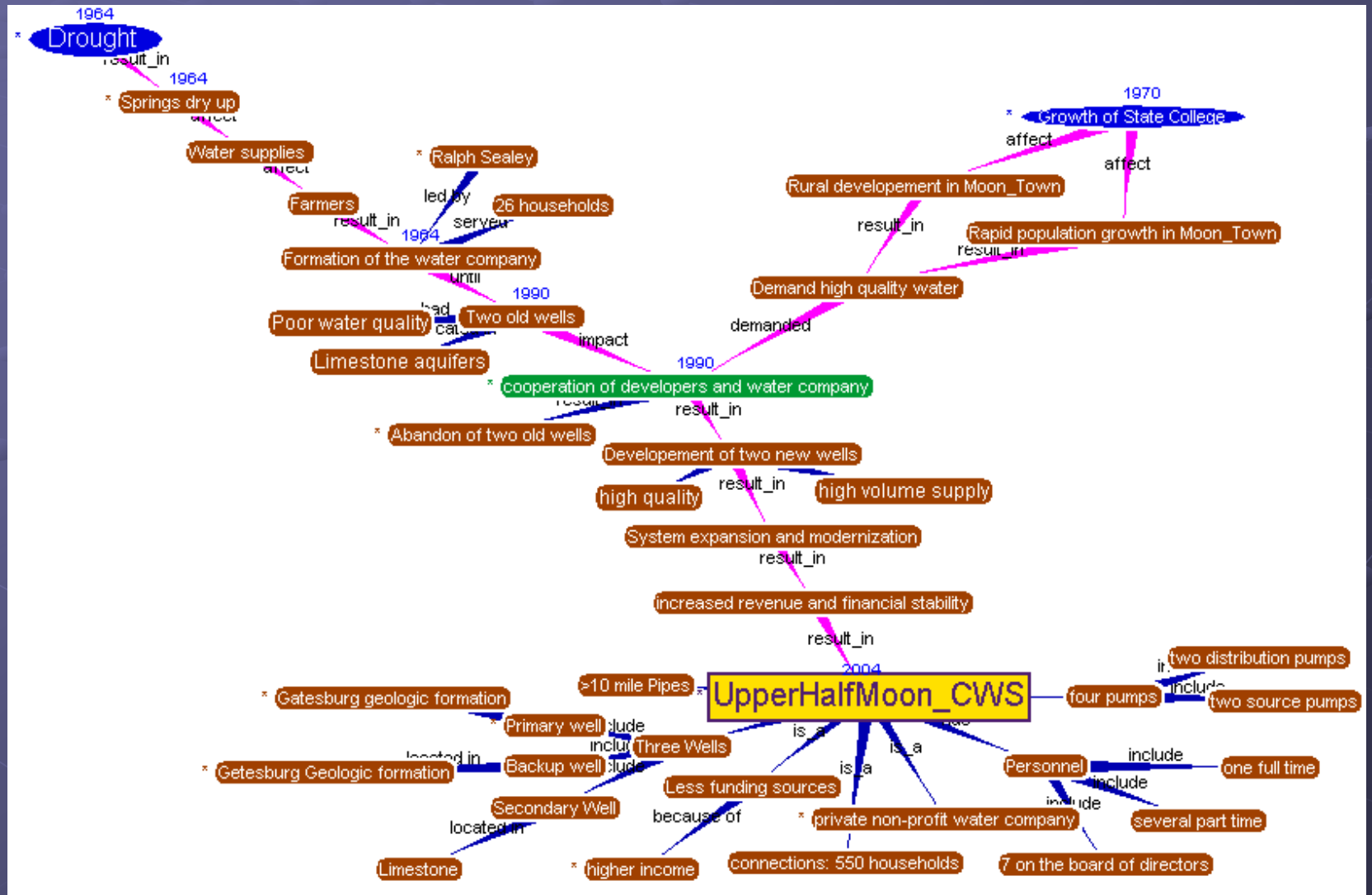
提取专家对水资源管理过程的理解

- 采访专家

部分采访结果

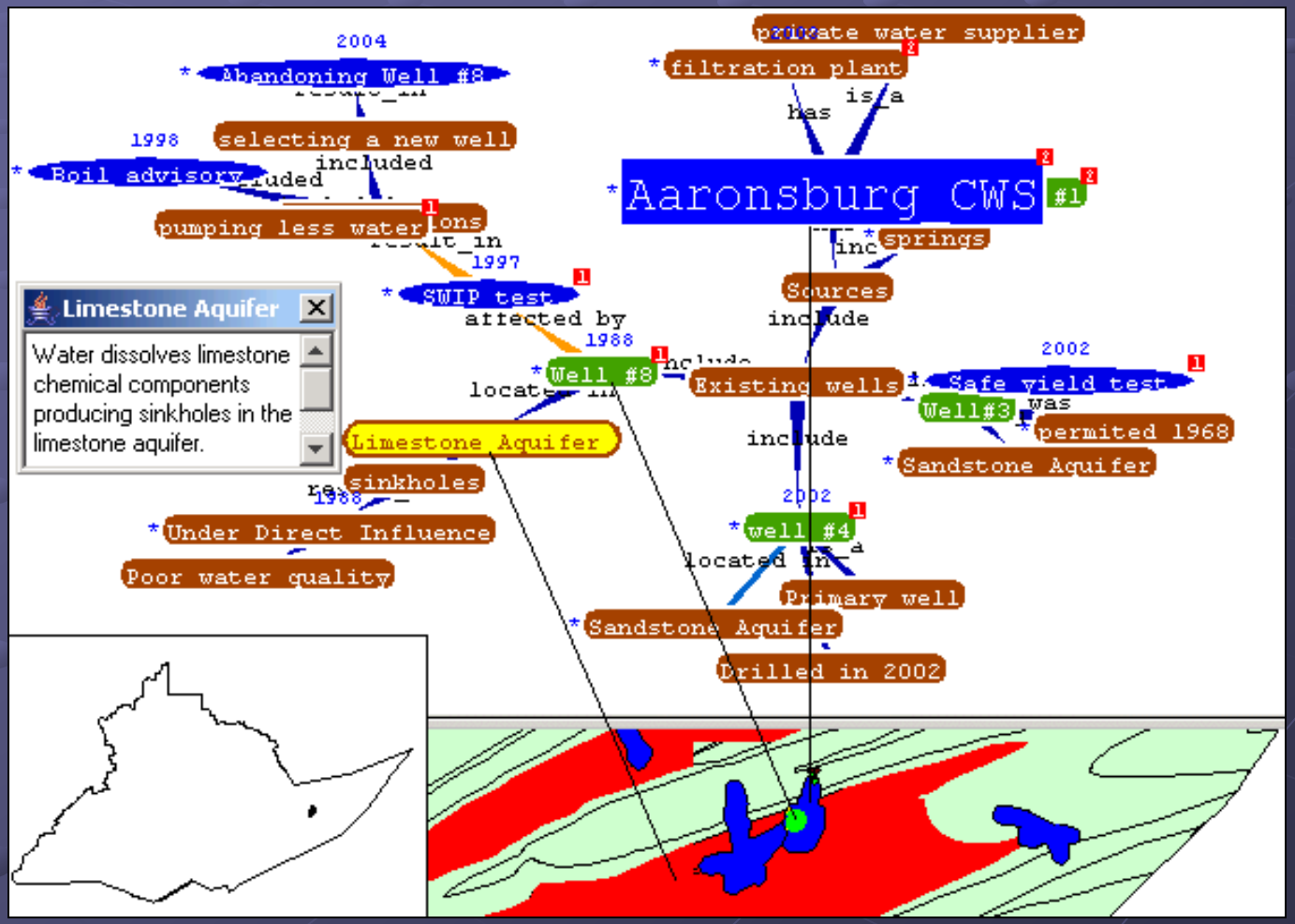

EPA
Safe Drinking Water Act Amendments of 1996
DEP
conducted
conducted
2002
SWIP test
required
1997
SWIP test
result_in
2004
Abandoning Well #8
result_in
selecting a new well
included
1998
Boil advisory
included
DEP sugestions
pumping less water
result_in
1998
Using interconnection
Millheim CWS
about 30 times
is
2004
Leaking control
is
cost increasing
result_in
2003
filtration plant
private water supplier
population > 400
have
Connections:242
length: 12 miles
Pipes
are
Old
has
is_a
has
has
Aaronsburg_CWS
has
Sandstone Aquifer
located in
Drilled in 2002
as
is
Primary well
2002
well #4
include
Sources
include
include
Existing wells
include
include
springs
include
include
spring #2
located in
spring #1
located in
sandstone aquifer
Primary spring
Old Primary well
1988
Well #8
1988
was
Drilled in 1988
located in
Limestone Aquifer
sinkholes
result_in
1988
Under Direct Influence
result_in
Poor water quality
1968
Well#3
located in
was
passed
Sandstone Aquifer
permited 1968
2002
Safe yield test
result_in
2004
under reconstruction
Limestone Aquifer
Water dissolves limestone chemical components producing sinkholes in the limestone aquifer.

部分采访结果


1964
Drought
result_in
1964
Springs dry up
affect
Water supplies
affect
Farmers
result_in
Ralph Sealey
led by
26 households
served
1964
Formation of the water company
until
1990
Poor water quality
had
cat
Two old wells
impact
Limestone aquifers
1970
Growth of State College
affect
affect
Rural developement in Moon_Town
result_in
Rapid population growth in Moon_Town
result_in
Demand high quality water
demanded
1990
cooperation of developers and water company
result_in
Abandon of two old wells
Developement of two new wells
result_in
high quality
high volume supply
System expansion and modernization
result_in
increased revenue and financial stability
result_in
2004
UpperHalfMoon_CWS
>10 mile Pipes
Gatesburg geologic formation
Primary well
Three Wells
Getesburg Geologic formation
Backup well
Secondary Well
located in
Limestone
is_a
Less funding sources
because of
higher income
is_a
private non-profit water company
connections: 550 households
is_a
Personnel
include
one full time
include
several part time
7 on the board of directors
four pumps
two distribution pumps
two source pumps

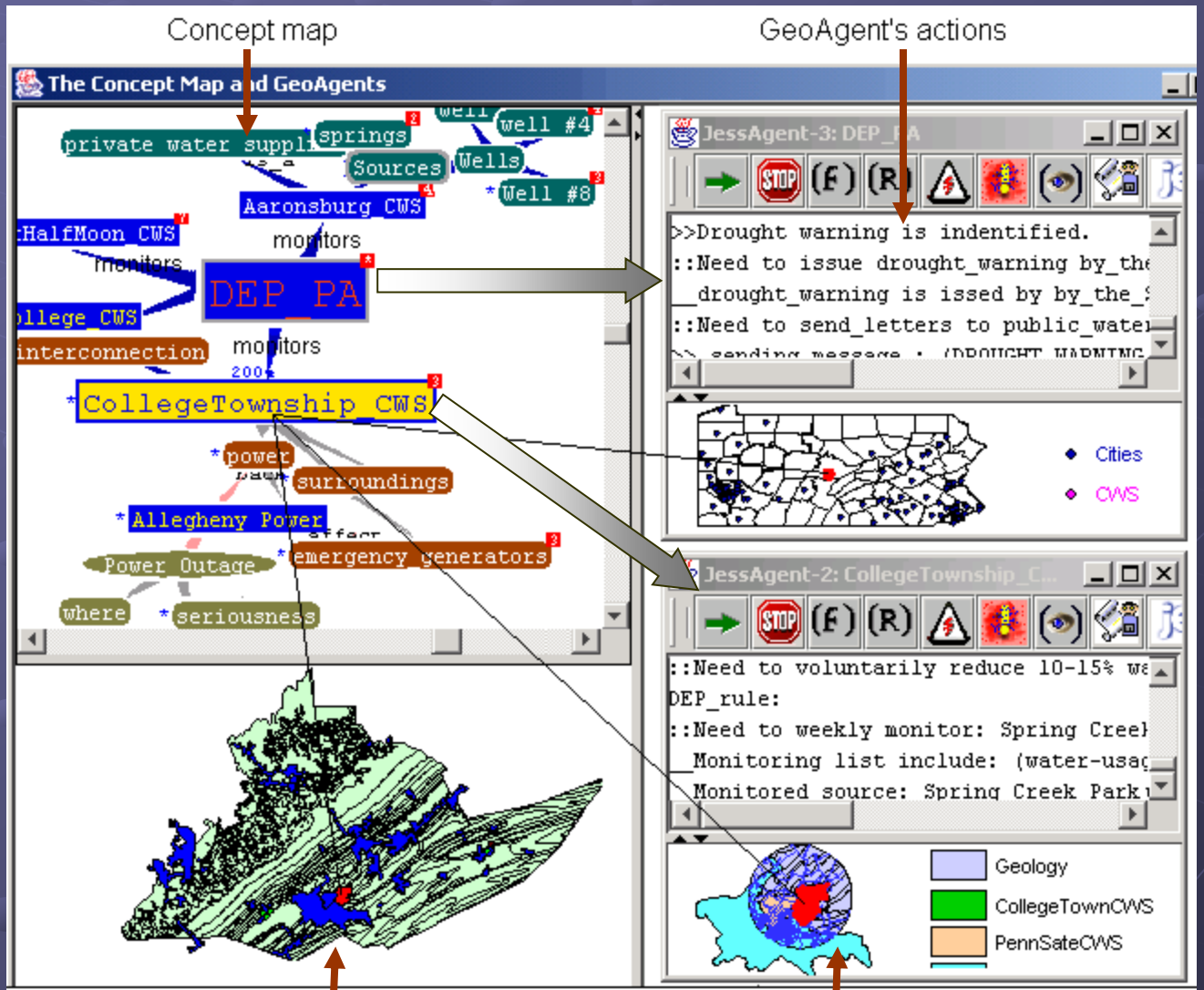
知识与数据的结合(1)

- 概念图与空间数据结合(数据主要从一些官方网站下载)



知识与数据的结合(2)

- 概念图、地理智能体、与空间数据结合



灾害（干旱）管理实例

- 表达灾害管理过程
  - 自然过程
  - 社会过程
- 多层次协同应急的决策支持

宾州干旱管理体系

社会结构

州级

- 干旱应急计划
- 减少用水法规
- 禁止非必要用水
- 干旱期节水指
- …

社区水系统

- 干旱应急计划

应急体系

干旱等级

- 干旱警示 Drought watch
- 干旱预警 Drought warning
- 干旱紧急状态 Drought emergency

监测模拟

干旱指标

- 降水:
- 河流流量:
- 地下水水位:
- 帕玛干旱指数:
- 水库存水:

- 干旱指标判断标准：
  - 降水：
  - 河流流量：
  - 地下水水位：
  - 帕玛干旱指数：
  - 水库存水：

Duration of Deficit Accumulation (months)	Watch (Deficit as Percent of Normal Precipitation)	Warning (Deficit as Percent of Normal Precipitation)	Emergency (Deficit as Percent of Normal Precipitation)
3	25	35	45
4	20	30	
5	20	30	40
6	20	30	40
7	18.5	28.5	38.5
8	17.5	27.5	37.5
9	16.5	26.5	36.5
10	15	25	35
11	15	25	35
12	15	25	35

Indices	Watch	Warning	Emergency
Stream flows (exceedance)	75%~89%	90%~95%	>95%
Groundwater levels (exceedance)	75%~89%	90%~95%	>95%
PHDI	-2.00~-2.99	-3.00~-3.99	≤-4.0

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Watch	30-22	37-26	48-33	65-49	83-66	89-72	81-67	67-52	50-38	36-24	26-18	27-19
Warning	22-13	26-17	33-23	49-38	66-58	72-67	67-60	52-43	38-28	24-15	18-8	19-9
Emergency	13-0	17-0	23-0	38-0	58-0	67-0	60-0	43-0	28-0	15-0	8-0	9-0

演示：

验证

- 采访学生（7名）
- 采访专家（4名）

结果

Questions	Expected answers	Number of students who addressed the answers	
Do you understand the concept maps?	Yes	7	100%
	No	0	0%
Can you explain **why** the Aaronsburg CWS was trying to abandon its previous primary water source, Well #8?	Limestone aquifer, sinkhole, poor water quality	7	100%
	EPA SDWAA 1996	5	71%
	DEP SWIP test 1997	5	71%
	New Well # 4 (2003)	1	14%
Can you imagine what problem the Aaronsburg CWS system now is facing?	Financial problem	5	71%
	Don't know	2	29%
Can you explain **how** Upper Halfmoon CWS has developed into a modern CWS over the past 40 years?	Drought 1964: formation of the CWS	4	57%
	Tiny CWS, poor water quality before 1990	7	100%
	Growth of State College since 1970s	5	71%
	Incorporation of the CWS and the developers in 1990	6	86%
	New sources since 1990	6	86%
	Population growth, more income, modernization, since 1990	7	100%
Can you describe **how** the Millheim CWS responded to the snow storm in 1995?	Snow knocked down the tree, cut off the power line: power outage	7	100%
	Power outage: lowered the water pressure, alarmed the operator	7	100%
	Operator: using generators	7	100%
Can you explain **why** the smaller Philips Creek, instead of the larger Elk Creek, is used as the primary water source for the Millheim CWS?	Philips: protected by forest, less pollution	7	100%
	Elk: exposed to farmland, natural and agricultural pollution	7	100%
With the spatial map, do you think you can understand the concept map better?	Yes	6	86%
	Not really	1	14%

被采访学生评论

- "I guess the (geospatial) map will show me the 'what', the 'what' of the (water) systems, but not necessarily how things work; or the 'how' and 'why'; (such as) where things are; why they are; and how things operate within a (water) system. The (geospatial) map will show me kind of 'what' and 'where', but not 'how' and 'why', really. "
- "The (geospatial) map shows relationships based on space, but not necessarily based on causes and effects. On the concept map, the linkages show, you know, 'this is required by that', 'this is equal to this', 'this includes this', or 'has this', or 'is based on that'. And those terms add knowledge to the concept map. But you don't get it in (geospatial) maps."
- "The GIS software would not have much information on it. It is not very meaningful if you only know where the location is. It is better to have both information (i.e. the knowledge layer) and location."
- "You can see the story, the history, very quickly… So you can see the history, why these things happened. For example, I can see here, because of the vulnerability to drought (i.e. the drought of 1999 on the Millheim concept map), they switched the source (from Philips Creek) to Elk Creek. "
- "I think it (i.e. the concept map) is better than having a narrative paragraph, and then looking at the (geospatial) map. It allows seeing the two things (i.e. the concept map and the geospatial map). It's very nice… (I) could get a lot of knowledge very quickly."

被采访专家评论

- is able to represent the complex process of human-environment interactions
- can be useful for policy makers to test their operational rules
- is a very useful tool for training new employees
- can be valuable in supporting quick decision-making in emergency situations

提要

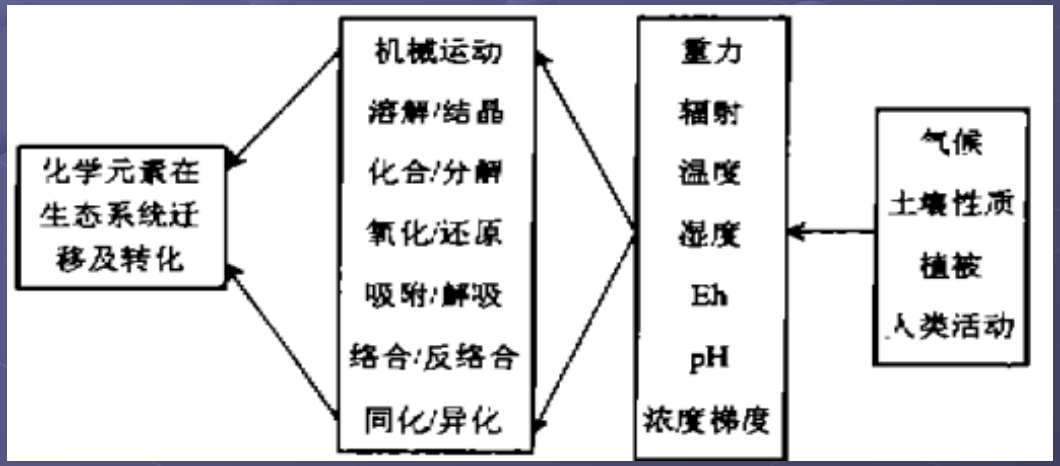
- 近代地理学发展概述
- GIS发展
- 基于地理智能体的新表达框架
- 应用实例
- 未来发展探讨

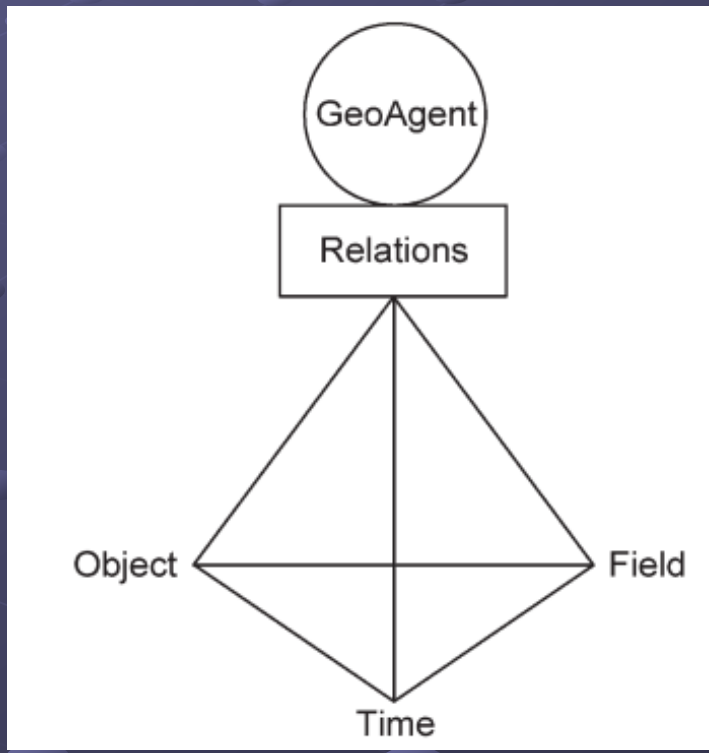
未来畅想

- A universal geographic model?

李长生：量、群、流、场
Universal natural rules

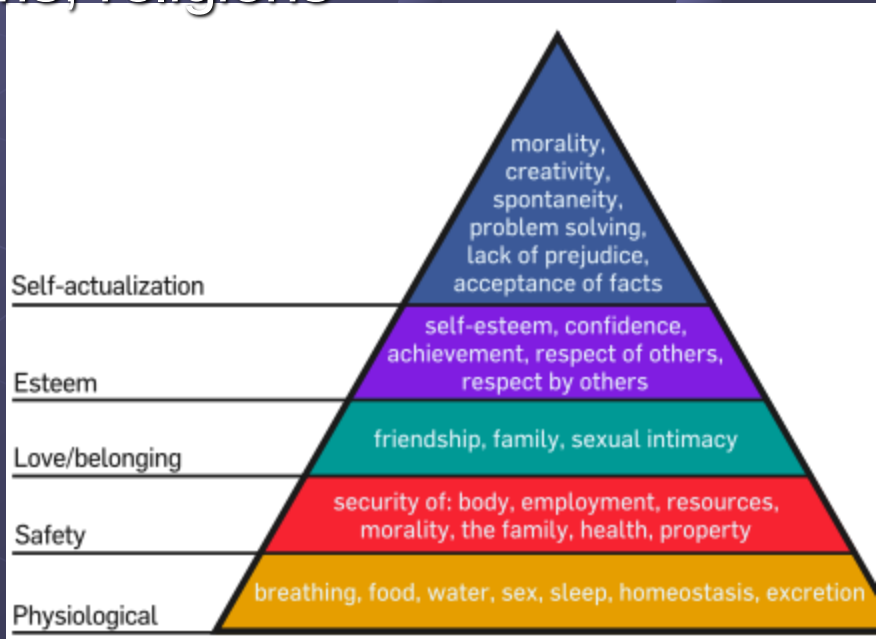
结果　　行为　　场力　　要素





未来畅想

- Universal social behavioral rules?
  人之初，性本善；性相近，习相远
  - Individual motivations: Maslow's hierarchy of needs
    需求金字塔
  - Economic drivers：Cost/benefit
    *天下熙熙*皆为利来，天下攘攘皆为利往
  - Social fields：laws, customs, religions
    法律、习俗、教义：
  - Distance
    距离法则



未来畅想

- 应用
  - 法规习俗知识库：查询，推理
  - 法规检验
  - 推理与决策
  - 应急响应
  - 地球系统过程模拟与预测

谢谢!