E-Health and Machine Learning

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Talk overview

- Our Group
- Machine Learning
- PROCLAIM
- Médula

Knowledge Engineering and Machine Learning

- Our aim is to:
  - Study the theory, implementation and application of computational techniques to problems in environmental problems, medicine and e-commerce
- Our emphasis is on:
  - Machine learning representations, algorithms autonomous agents and applications
- Our favourite techniques are:
  - Case Base Learning, Clustering
  - Bayes nets, Action Languages
- The (major) research tools we have produced are:
  - SHARE-*it*, HARMON-ia, PROCLAIM

What is learning?

- "Learning denotes changes in a system that ... enable a system to do the same task more efficiently the next time."

  Herbert Simon

- "Learning is constructing or modifying representations of what is being experienced."

  Ryszard Michalski

- "Learning is making useful changes in our minds."

  Marvin Minsky

Why learn?

- Understand and improve efficiency of human learning
  - Use to improve methods for teaching and tutoring people (e.g., better computer-aided instruction)
- Discover new things or structure that were previously unknown to humans
  - Examples: data mining, scientific discovery
- Fill in skeletal or incomplete specifications about a domain
  - Large, complex AI systems cannot be completely derived by hand and require dynamic updating to incorporate new information.
  - Learning new characteristics expands the domain or expertise and lessens the *brittleness* of the system
- Build software agents that can adapt to their users or to other software agents

Alan Turing

Norbert Wiener

John von Neumann

Edward Teller

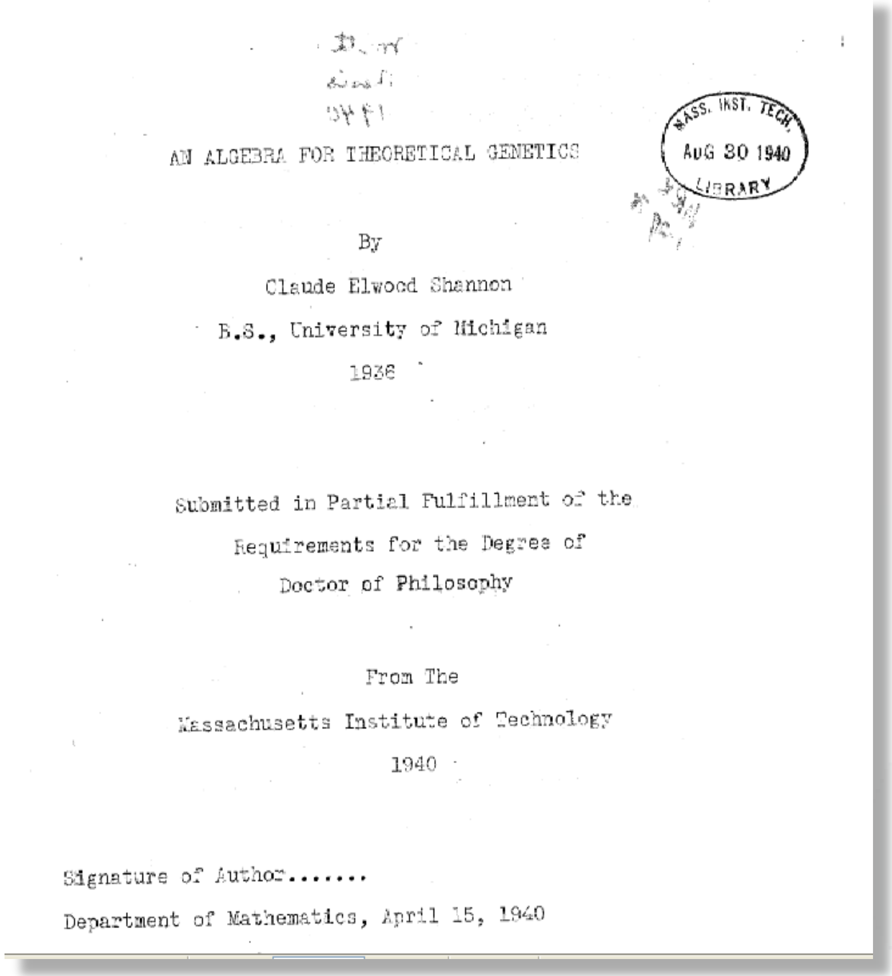
Francis Crick

Richard Feynman

Claude Shannon

Quite unknown story: many scientific giants applied information-based approaches to study medical/biological issues.

Claude E. Shannon's PhD Thesis



AN ALGEBRA FOR THEORETICAL GENETICS

By

Claude Elwood Shannon

B.S., University of Michigan

1936

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

From The

Massachusetts Institute of Technology

1940

Signature of Author.......

Department of Mathematics, April 15, 1940

"An algebra for theoretical genetics".

PhD Thesis, MIT, 1940 (published in 1993)

Definitions

- **Health Informatics**: The acquisition, storage, processing and communication of information to ensure that:
  - It is supplied to the right place at the right time,
  - It is in a form comprehensible to the users,
  - It is adequate to support their activities and the organisations they work
  - The quality and dependability of information is appropriate to its uses

- **E-Health**: the part of Health Informatics that addresses distributed, mobile, pervasive, ambient systems

Cross-Cutting Aspects

- **Patient Records**: difficult problems in developing robust distributed systems that meet organisational needs and confidentiality while enabling effective use of information – key underpinning to health tourism/wellness.
- **Resource monitoring and management**: problem of dynamism in the metrics with reliability of data – engineering problem to provide an agile IT response.
- **User information/learning**: fundamental problems with the volume of available data, assuring quality, developing and promoting effective learning – key to cost reductions.
- **Governance, quality, audit**: capturing policy, coping with change and distributed regulation – key to public confidence.
- **Sensing and Monitoring**

Literature-Based Evidence

- Randomized trials, systematic reviews, guidelines
- Constitutes only small fraction of research literature
- Study design and reporting problems abundant
- Electronic resources mostly not machine-interpretable:
  - The Cochrane Library, Best Evidence, Clinical Evidence, etc.
- Emerging machine-interpretable knowledge bases:
  - The Trial Bank, genomic information databases, etc.
- Need advanced free-text understanding techniques

Practice-Based Evidence

- Local databases and data warehouses from:
  - registries and repositories, health information systems, electronic medical records, laboratory systems, etc.
- Complements and supplements general, literature-based evidence
- Required for risk and outcome analysis and practice guideline development
  - Improve process and intervention designs

Research-Based Evidence

- Experimental data and results generated through specific design and analysis
- Can be *sliced* and *diced* into various formats and categories for further processing
- Complements and supplements practice-based evidence
- Required for risk and outcome analysis and practice guideline development
    - Improve process and intervention designs

Human-Directed Evidence

- Policy makers or clinicians' objectives
- Patients' preferences and concerns through
  - direct interactions
  - feedback from health-related resources, e.g., websites, surveys, etc.
- Increase health care quality through
  - Facilitating communication
  - Fostering shared decision making
  - Personalized care plan
  - Improving clinical outcomes

Executive Information Systems

- Target users
  - Health policy makers, quality assurance managers, hospital administrators, medical directors, department chiefs, etc.
- Functions
  - Integrate information from different sources
  - Keep track of internal and external changes
  - Identify and monitor resource utilization
  - Support risk analysis and risk management
- Objectives
  - Achieve strategic vision and mission
  - Gain high level perspective on
    - key performance indicators
    - trends in organization

Monitoring and Control Systems

- Target users
  - Clinicians, pharmacists, administrators
- Functions
  - Selectively monitor clinical data continuously
  - Test data against predefined criteria to send alerts
- Objectives
  - Detect and prevent adverse events
    - Alarming laboratory results
    - Drug contraindications
    - Critical care monitoring

Risk or Outcome Prediction Systems

- Target users
  - Clinicians, surgery or treatment planning teams, health policy makers, quality assurance managers, hospital administrators
- Functions
  - Perform classification and prediction of outcome or risk with respected to specific outcome measures, e.g., length of stay, death, complications, based on data collected in a population
  - Derive outcome predictors, staging scores or risk stratification indices
  - Support risk analysis and risk management at the bedside and in policy planning
- Objectives
  - Facilitate decision making in routine and complex situations
  - Serve as educational and communication tools

Clinical Diagnostic & Treatment Systems

- Target users:
  - Clinicians, patients, students
- Functions:
  - Recommend diagnosis and treatment planning
  - Detect adverse or specific events
  - Critique care management plans
- Objectives:
  - Facilitate decision making in routine and complex situations
  - Provide reference and confirmation information
  - Support scenario analyses for better insights
  - Serve as educational and communication tools

Protocol-Based Decision Systems

- Target Users
  - Clinicians, patients, administrators
- Functions
  - Create, maintain, and access to disease management and best practice guidelines from different information sources
  - Transform often-ignored guidelines to dynamic programs for
    - real-time patient-specific management advice
    - automated recommendations, reminders, alerts, and adjustment of device settings
  - Support outcomes analysis and outcomes management
- Objectives
-
  - Promote systematic record keeping
  - Support rational decision making
  - Improve clinician acceptance
  - Improve quality and reduce cost of care

Rule-Based Techniques

- Knowledge structured as a set of rules
- If {A1,A2,A3} then {B1,B2} else {C1}
- Forward reasoning or data-driven reasoning
  - If patient's serum potassium level is below 3.0 then assert hypokalemia
  - If hypokalemia, then send report to hospital staff
- Backward reasoning or goal-driven reasoning
  - If fever and runny nose then flu
  - If temperature is higher then 36.9C, then fever
  - Assert runny nose

Model-Based Techniques

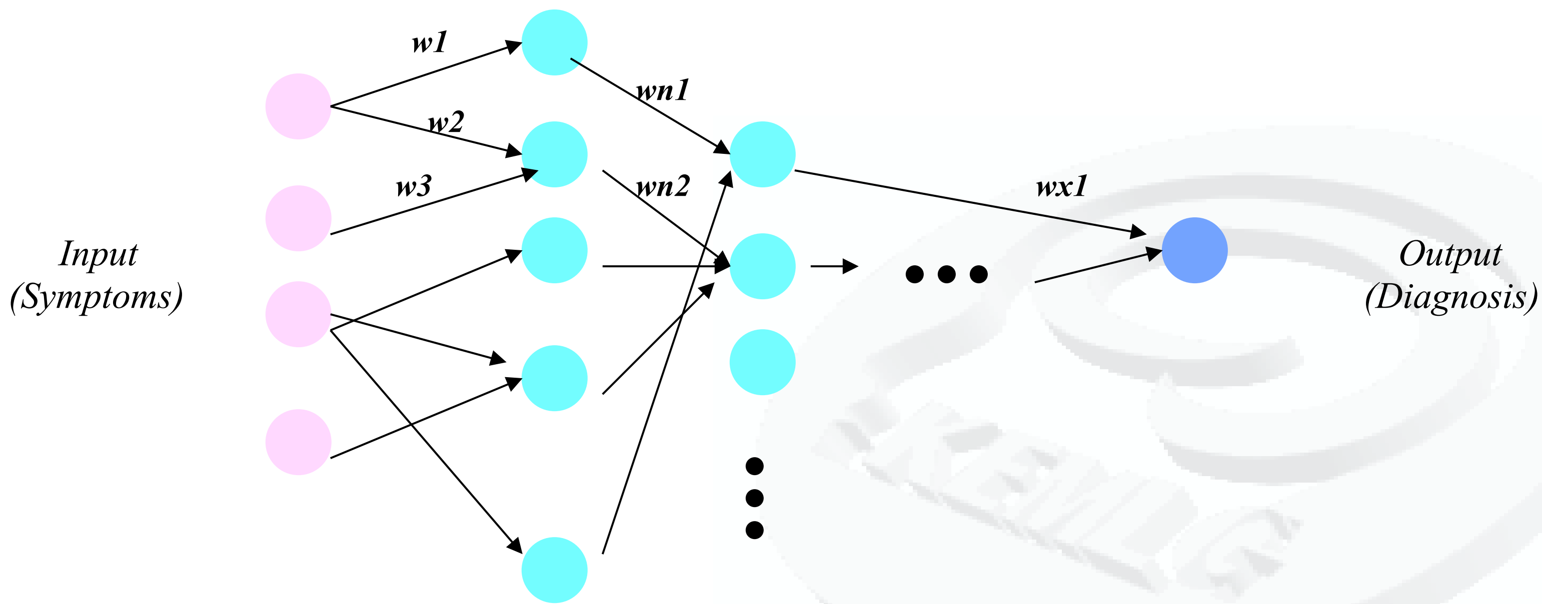
- Semantic networks or frames as knowledge representations for diseases and processes
- A set of concepts with a set of attributes
  - Concept: disease
  - Name: pneumonia
  - ICD code: 481
  - Body part affected: lung
  - Standard treatment: antibiotic
- Inheritance and other inferences to derive conclusions from the concept hierarchies

Case-Based Techniques

- Diagnosis or prediction based on similarity to previous cases and classifications
  - Previous cases of patients with common cold
    - C1, C2, C3
    - Each with slightly different symptoms and recommended treatments
  - New case D1
    - With some symptoms common to C1 and C2
    - With some new symptoms unseen before
  - Can D1 be classified as common cold?
    - If so, can the previous treatments be used?
    - If not, what to do with D1?

Neural Network Techniques

- Pattern recognition and analysis of underlying disease dynamics
  - look for patterns in training sets of data
  - learn the patterns
  - develop the ability to classify new patterns



Business Intelligence Systems

- Major functionalities
  - Reporting
  - Online analytic analysis (OLAP)
  - Dashboards
  - Data integration
  - Data mining

- Technology categories
  - Enterprise BI systems (EBIS)
  - Query and reporting tools
  - Advanced BI tools – OLAP/statistical and data-mining tools
  - BI platforms

Probabilistic Network Systems

- Bayesian networks:
  - Annotated directed acyclic graphs
  - Model partial causality structures with incomplete or probabilistic information
  - Depict and facilitate communication on human-oriented qualitative structures
- Problem characteristics:
  - Diagnosis or classification
  - Causal interpretation or prediction
  - Multiple input multiple output

No Free Lunch Theorem

There is a lack of inherent superiority of any classifier

If we make no prior assumption about the nature of the classification task, is any classification method superior overall?

Is any algorithm overall superior to random guessing?

The answer is **NO** to both questions..

No Free Lunch Theorem

Learning algorithm 1 is better than learning algorithm 2. Is ultimately a statement about the relevant target function

Experience with a broad range of techniques is the best insurance for solving arbitrary new classification problems

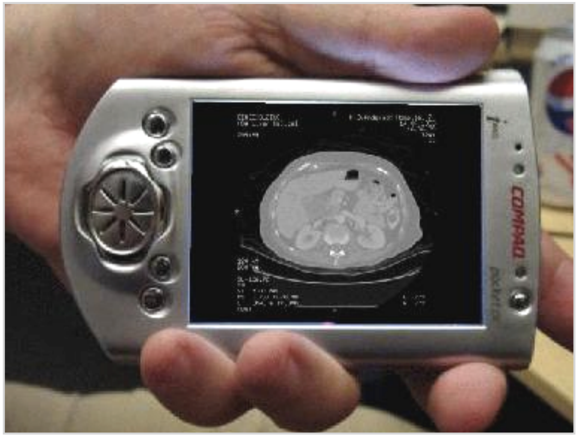
Ugly Duckling Theorem

No-Free Lunch addresses learning or classification.

In the absence of assumptions there is no *best* feature representation.

e-Health

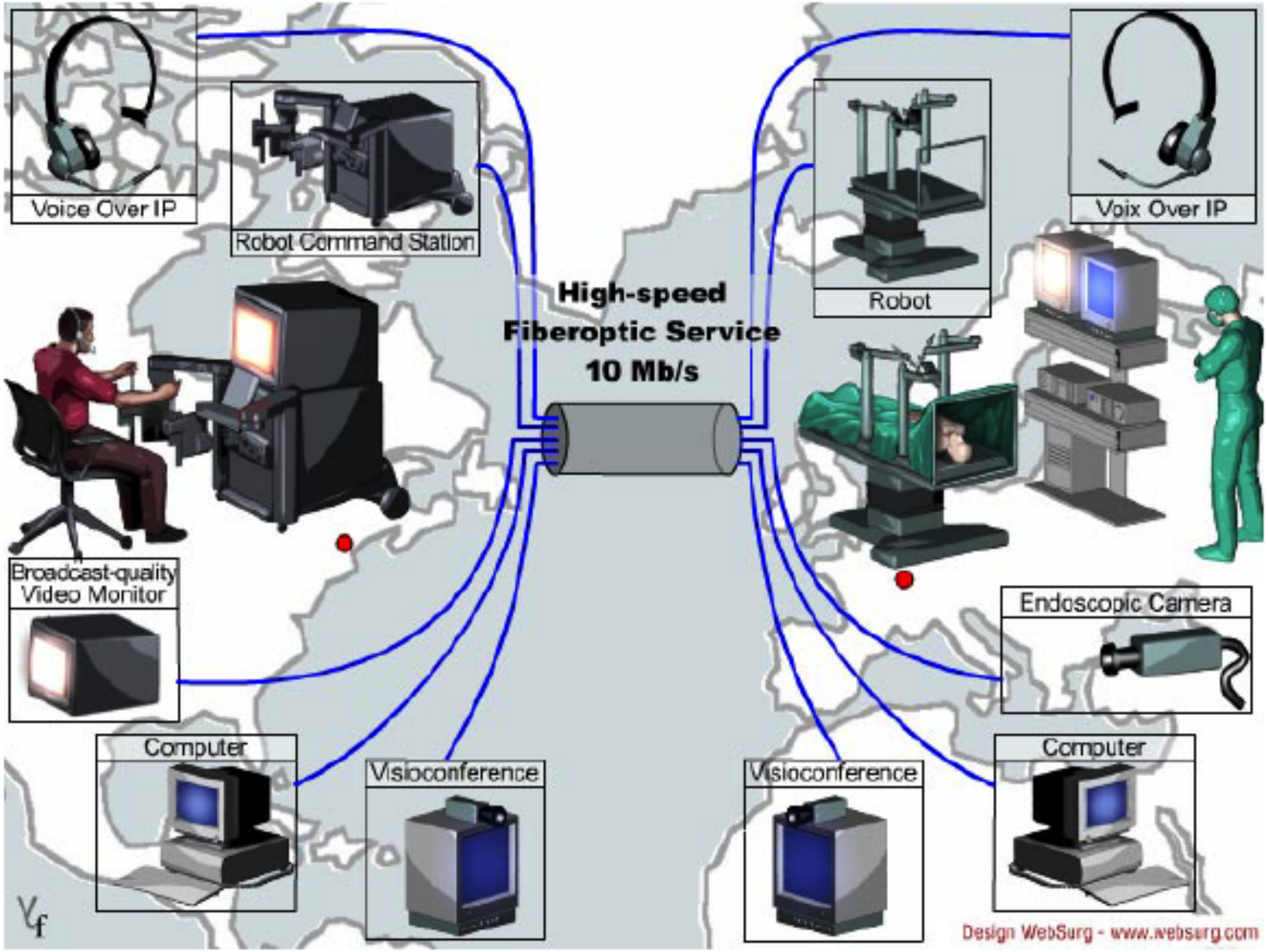
- ***Cut costs***
- ***Quality of Diagnosis & Treatment***
- ***Serve patients better***



IST Project
MTM in Tele-medicine

Lindbergh Operation

A real tele-operation !



Lindbergh Operation

Number of possible combinations Between 25.000 genes $= 10^{72403}$!!

There wouldn't be enough material
In the whole universe for nature to
Have tried out all the possible interactions
Even over the long period of billions of years
Of the evolutionary process

Real Time protein simulation :
A computing challenge
(In nature, a protein "folds" in 20 milliseconds)

e-Health: It is still early days!

- ***Major ICT advances still to come enabling:***
  - *From Genomics to Proteomics (Physiome)*
  - *Virtual Organs (simulation)*
  - *Non Invasive imaging (Beyond C.scan, MRI, PET)*
- ***Integration of emerging ICTs into Health Care***
  - *Empowering the individual*
  - *Preventive*
  - *"Next" generation monitoring (independence)*
- ***New e-Health markets emerging (e.g. elderly)***
- ***Plenty of privacy / security / cost / liability issues!***
- ***EU Policy and Programmes***

ProCLAIM

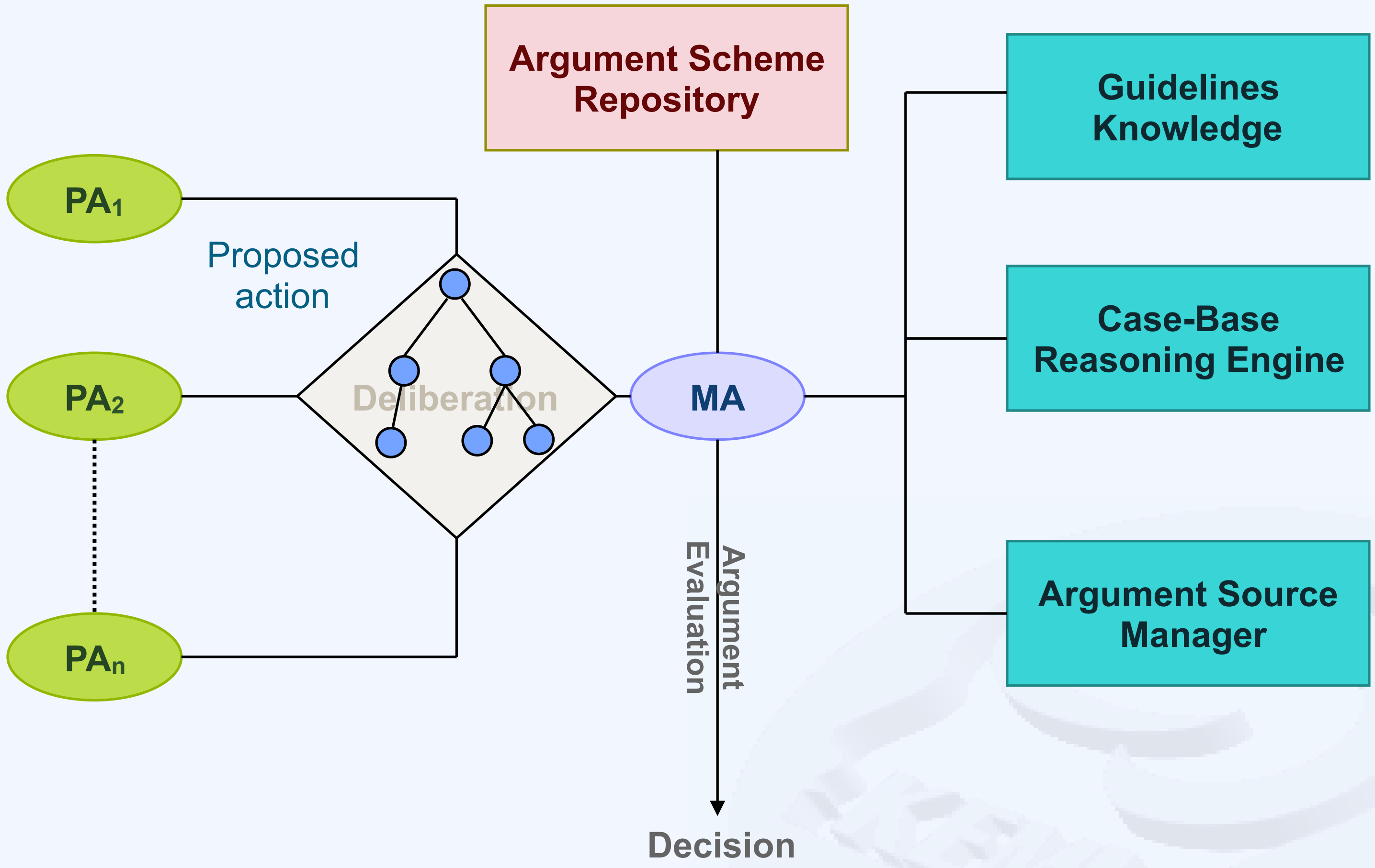
- *ProCLAIM*: An Argument-Based Framework for deliberating over the appropriateness of a proposed course of action
- Human Organ Transplantation, a Working Scenario
- Deliberating over Action Proposals using Argument Schemes and Critical Questions
  - A protocol-based exchange of arguments
  - *Towards constructing a Repository of Argument Schemes*
- Conclusions

Introducing the *ProCLAIM* model

- Argument-based Framework
- Collaborative Decision Making
  - Provide an environment for agents to argue over the appropriateness of a proposed action.

    whether it is justified to undertake a proposed action
- Safety-Critical domains
  - Guidelines Knowledge
  - *Wrong* Decisions/Actions may be catastrophic
  - Actions may be appropriate despite violating Guidelines

The *ProCLAIM* Architecture



PA Proponent Agent

MA Mediator Agent

Human Organ Transplantation

- **Human Organ Transplantation** is the only effective therapy for many life-threatening diseases.
- Commonplace medical event.
- Disparity between the demand for and the supply of organs for transplantation.
- Great percentage of human organs are discarded as being considered non-viable.

15 % livers 20% kidneys 60% hearts 85% lungs 95% pancreas

Human Organ Transplantation :: An example

Donor's data:…smoking history…. no COPD….

Is the Lung Viable?

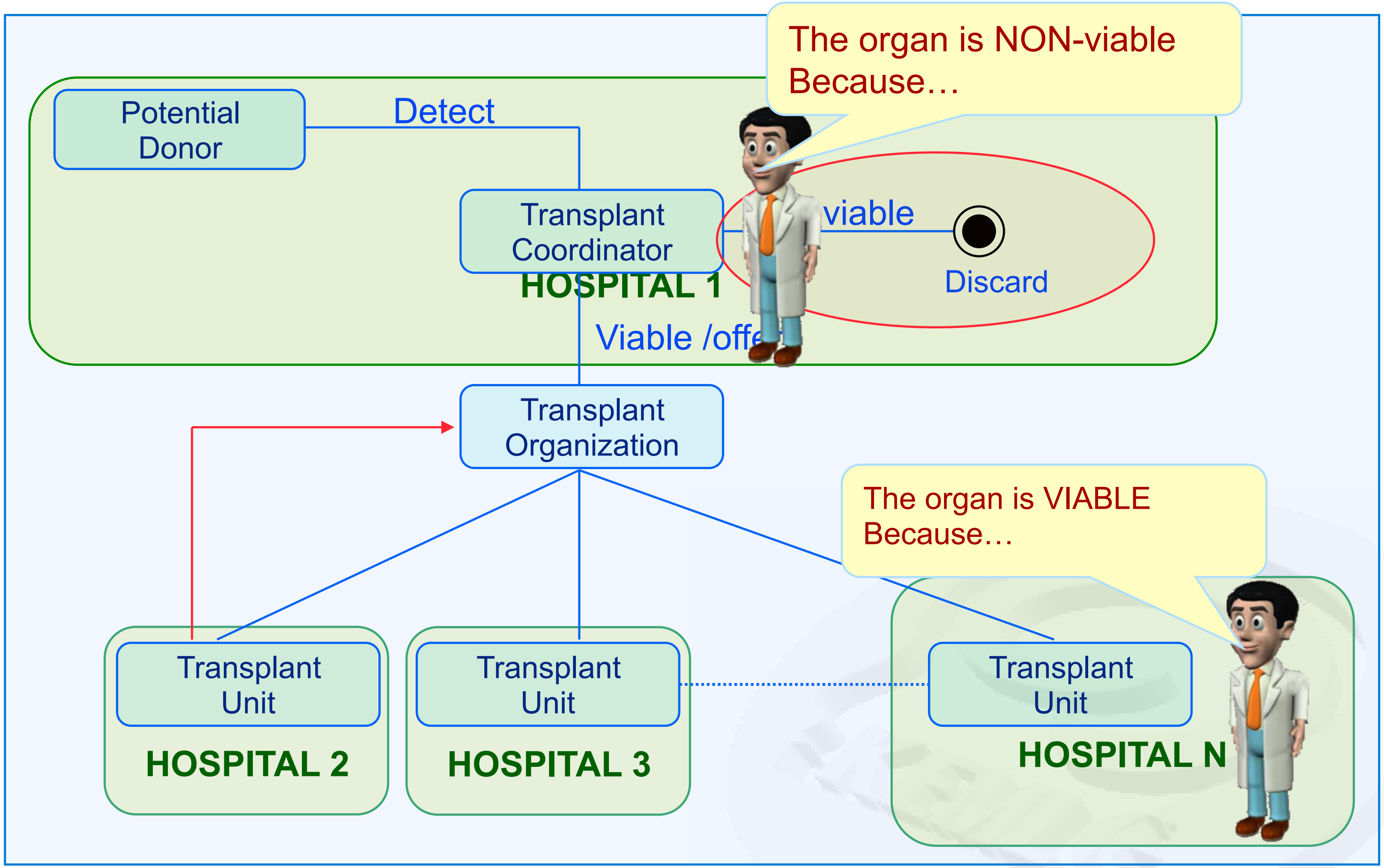
The Lung is non-viable because the donor has a smoking history.

Smoking history is not a contraindication, since the donor did not have any COPD

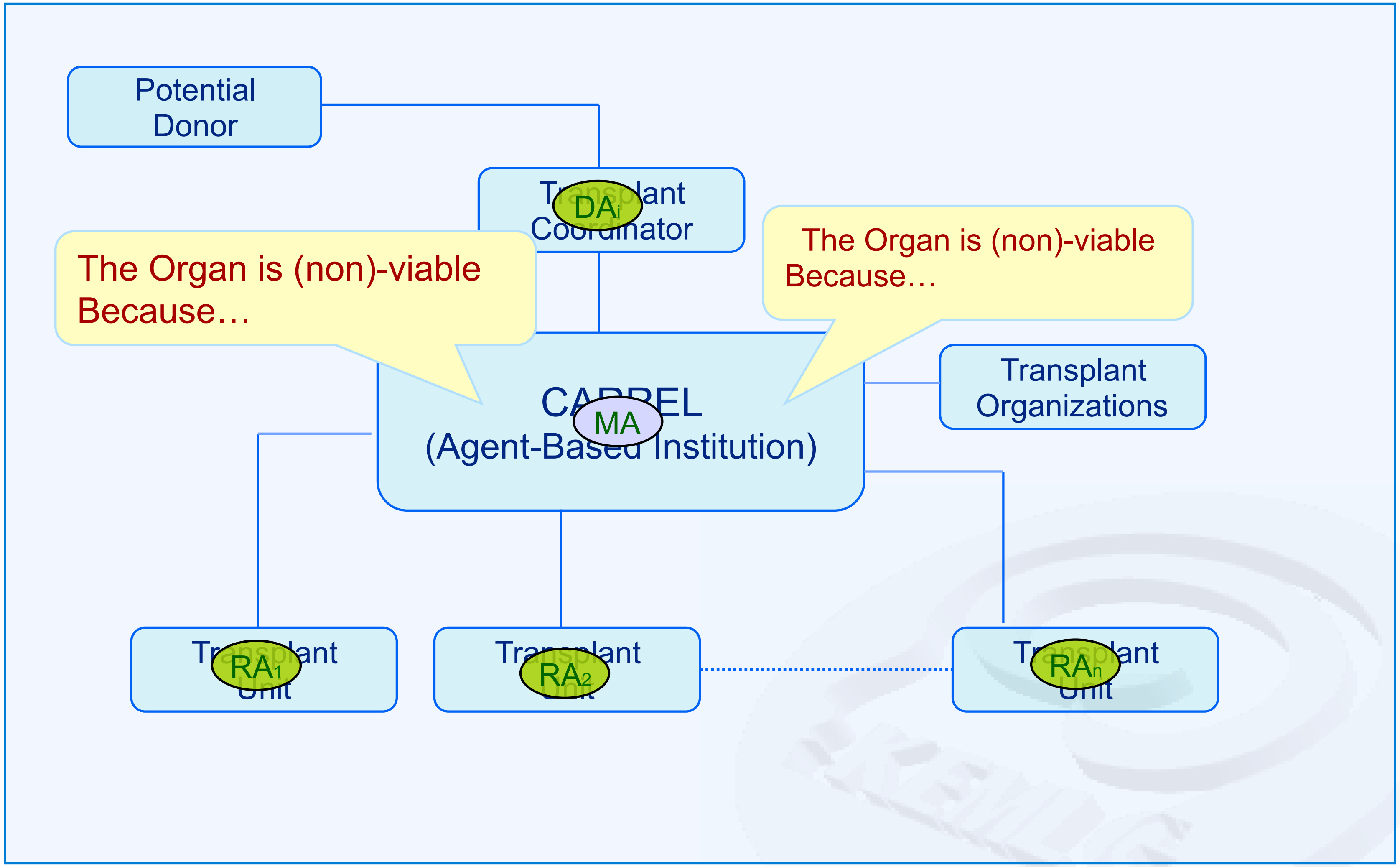
Any kind of smoking history could be acceptable unless there is a COPD.

General guidelines suggest discarding lungs of donors with a smoking history of more than 20-30 pack-year.

Human Organ Selection Process



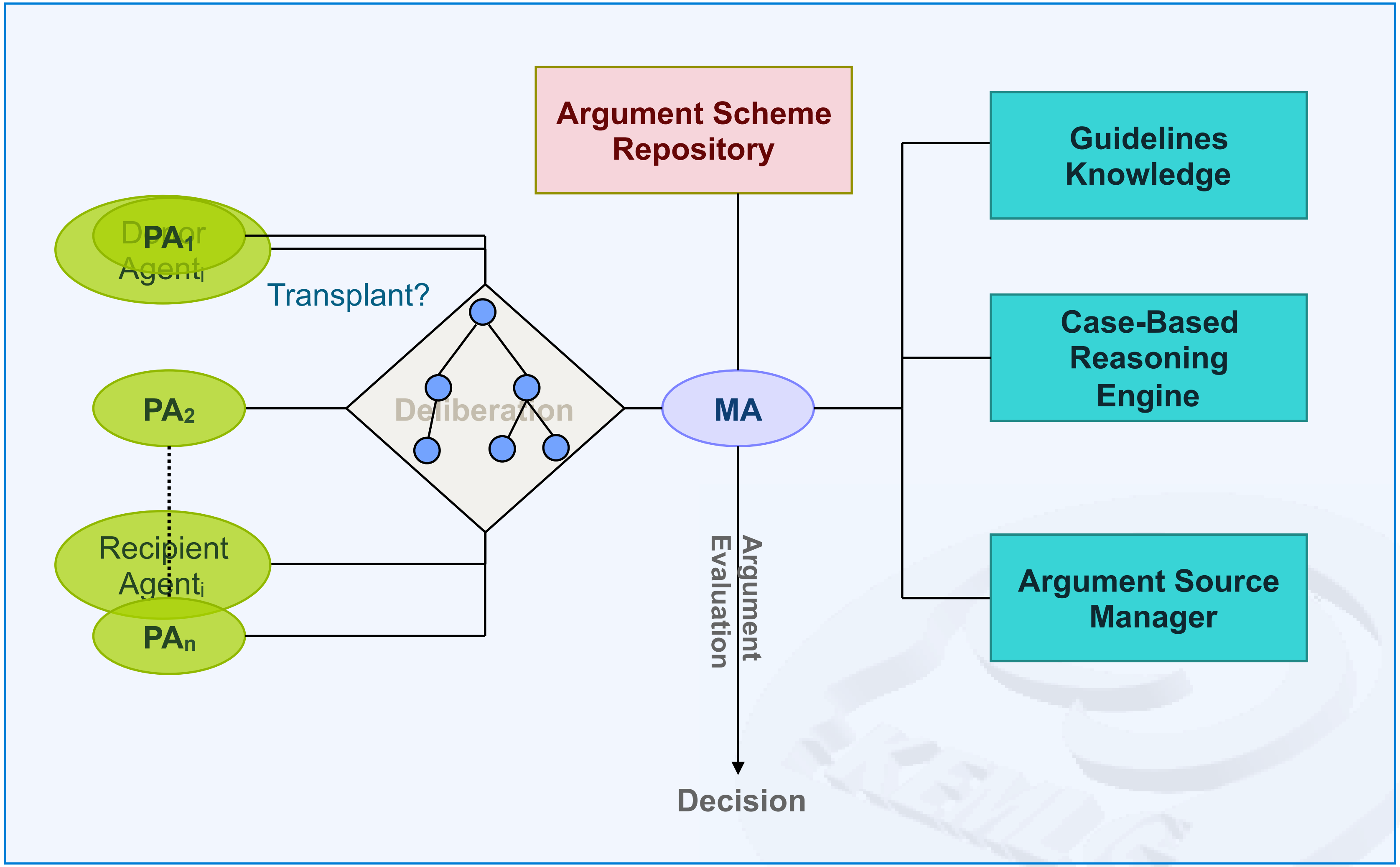
Organ Selection Process managed by CARREL



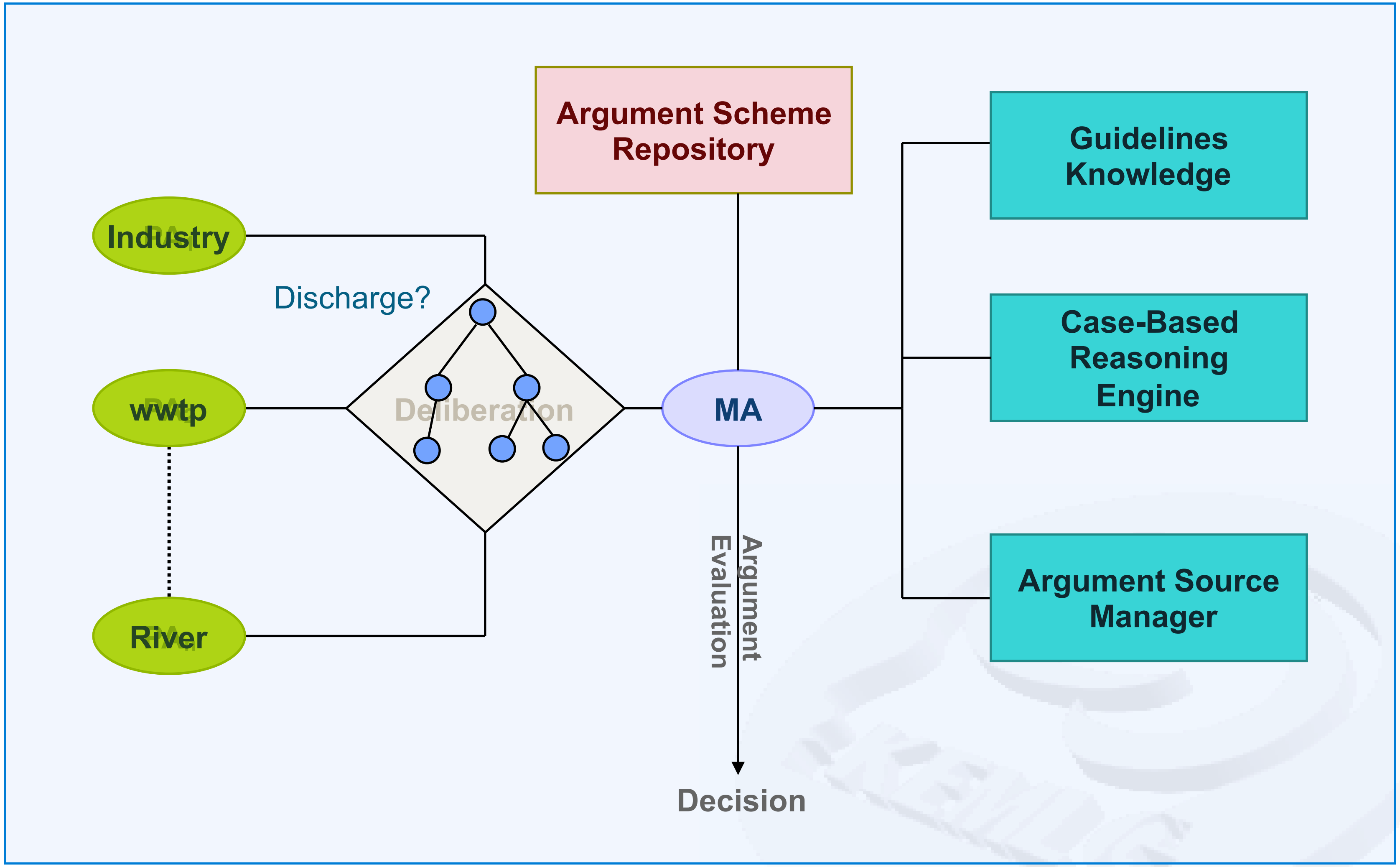
DA Donor Agent

RA Recipient Agent

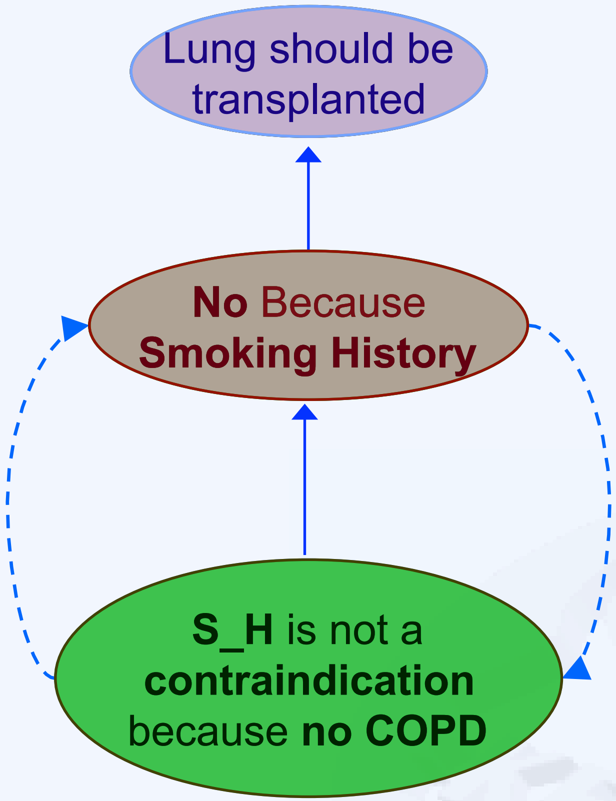
Architecture of the Transplant Scenario



Should a Industrial Waste be Discharged?



Should the Lung be Transplanted?



Dung, 1995

Argument Schemes and Critical Questions as a Protocol

VS: **Viability Scheme**:

Donor ***D*** of organ ***O*** is available
And no contraindications are known for
donating ***O*** to Recipient ***R***
Therefore Organ ***O*** is viable

VS_CQ1: Does donor ***D*** has a contraindication ***C*** for transplanting organ ***O*** into recipient ***R***?

NVS_CQ2: Is ***C*** a contraindication?

NVS: **Non-Viability Scheme:**

Donor ***D*** of organ ***O*** had condition ***C***
And ***C*** is a contraindication for donating ***O***
Therefore ***O*** is non-viable

NDAS : **No Disease Associated Scheme:**

If donor ***D*** did not have the disease ***E***
that is a manifestation of ***C***
Then ***C*** is not a contraindication for donating ***O***

GFS : **Graft Failure Scheme:**

When transplanting organ ***O*** from donor ***D*** with condition
C to a recipient ***R***, ***R*** may end up having a *Graft Failure*
Therefore, ***C*** is a contraindication for transplanting ***O*** into ***R***

Argument Schemes and Critical Questions as a Protocol

VS: **Viability Scheme**:
Donor ***D*** of organ ***O*** is available
And <u>no contraindications</u> are known for
donating ***O*** to Recipient ***R***
Therefore Organ ***O*** is viable

NVS: **Non-Viability Scheme:**
Donor ***D*** of organ ***O*** had condition ***C***
And ***C*** is a <u>contraindication</u> for donating ***O***
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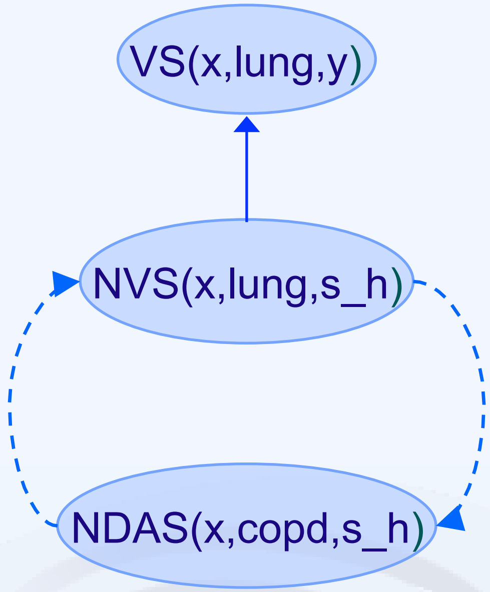
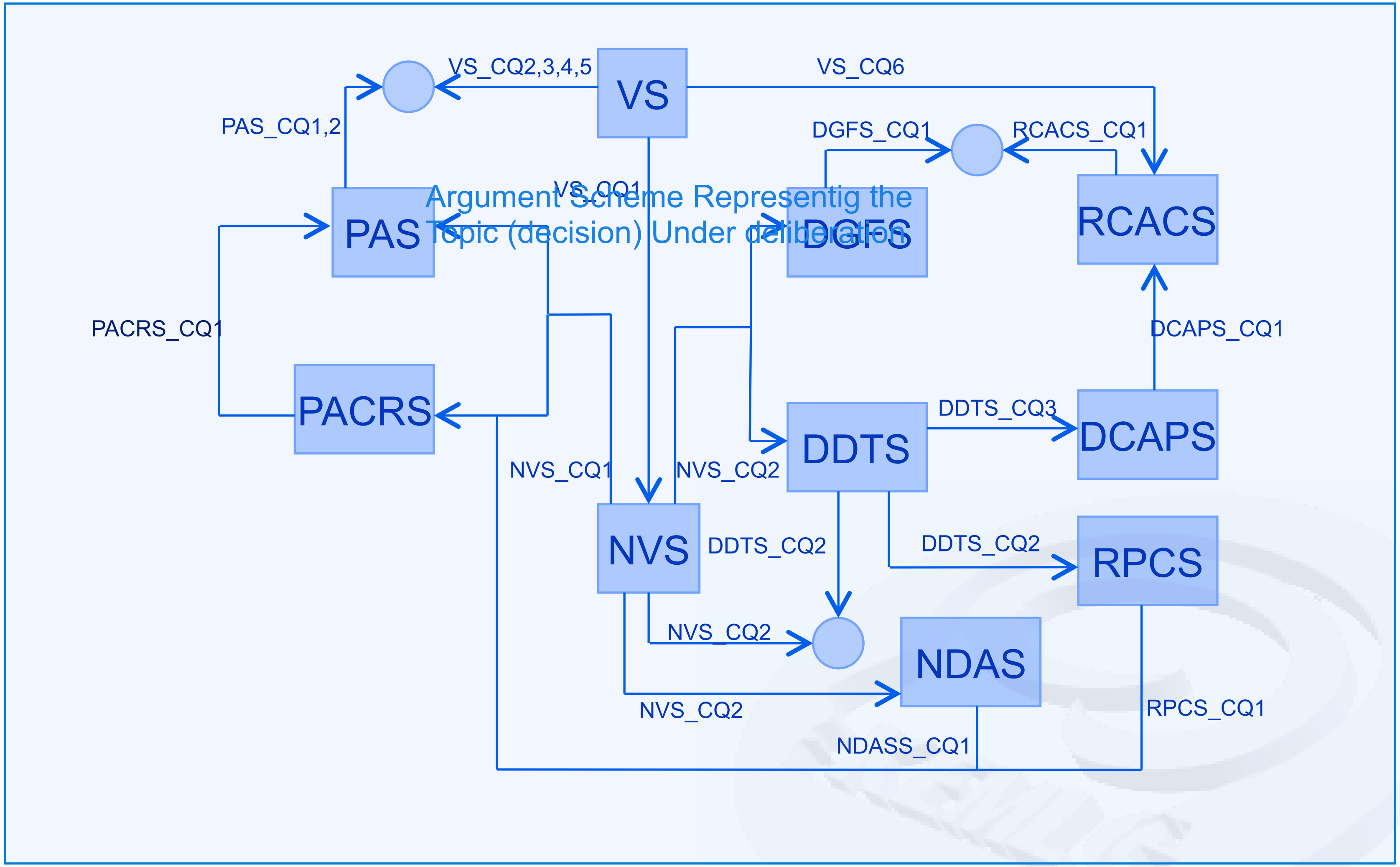
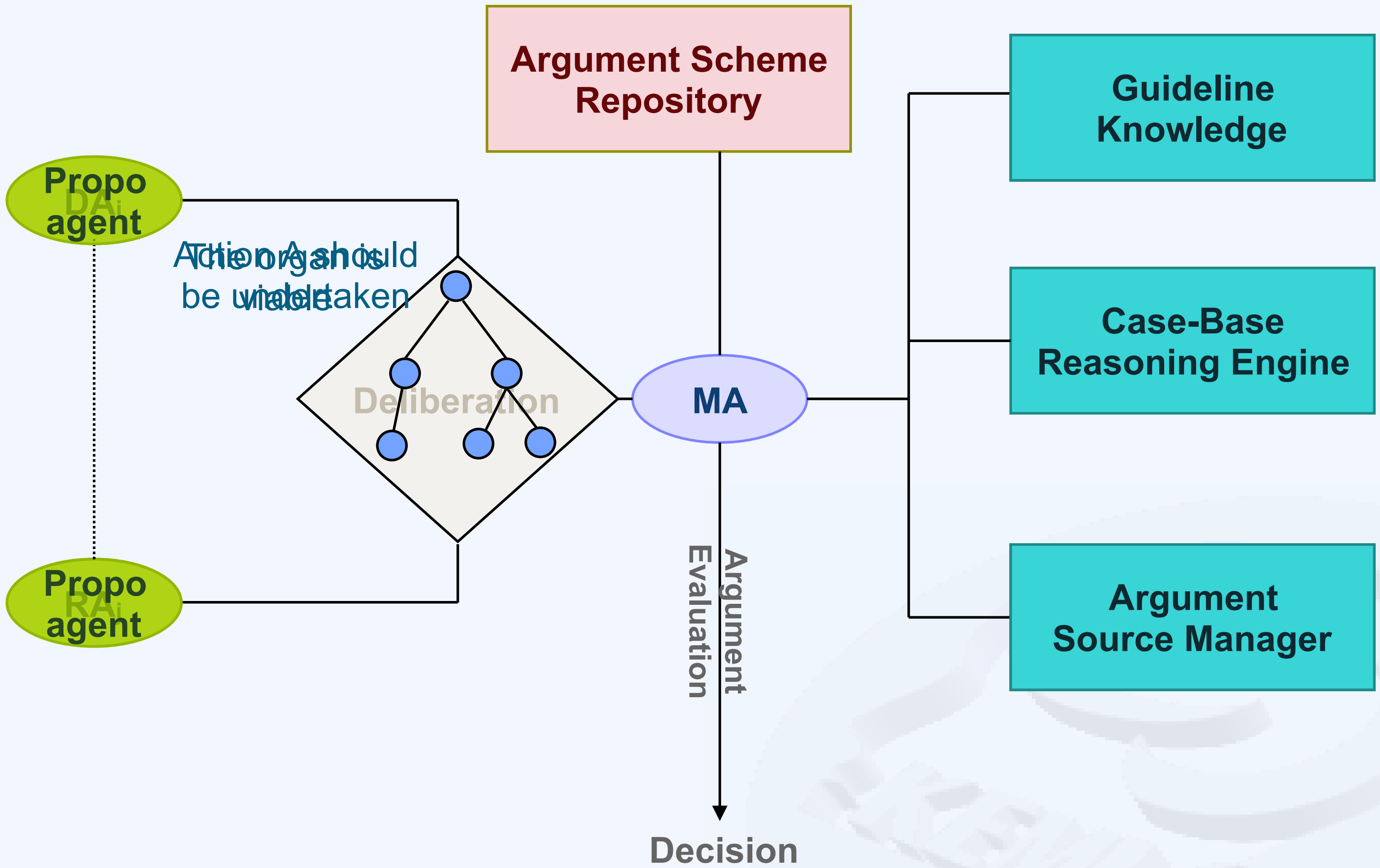


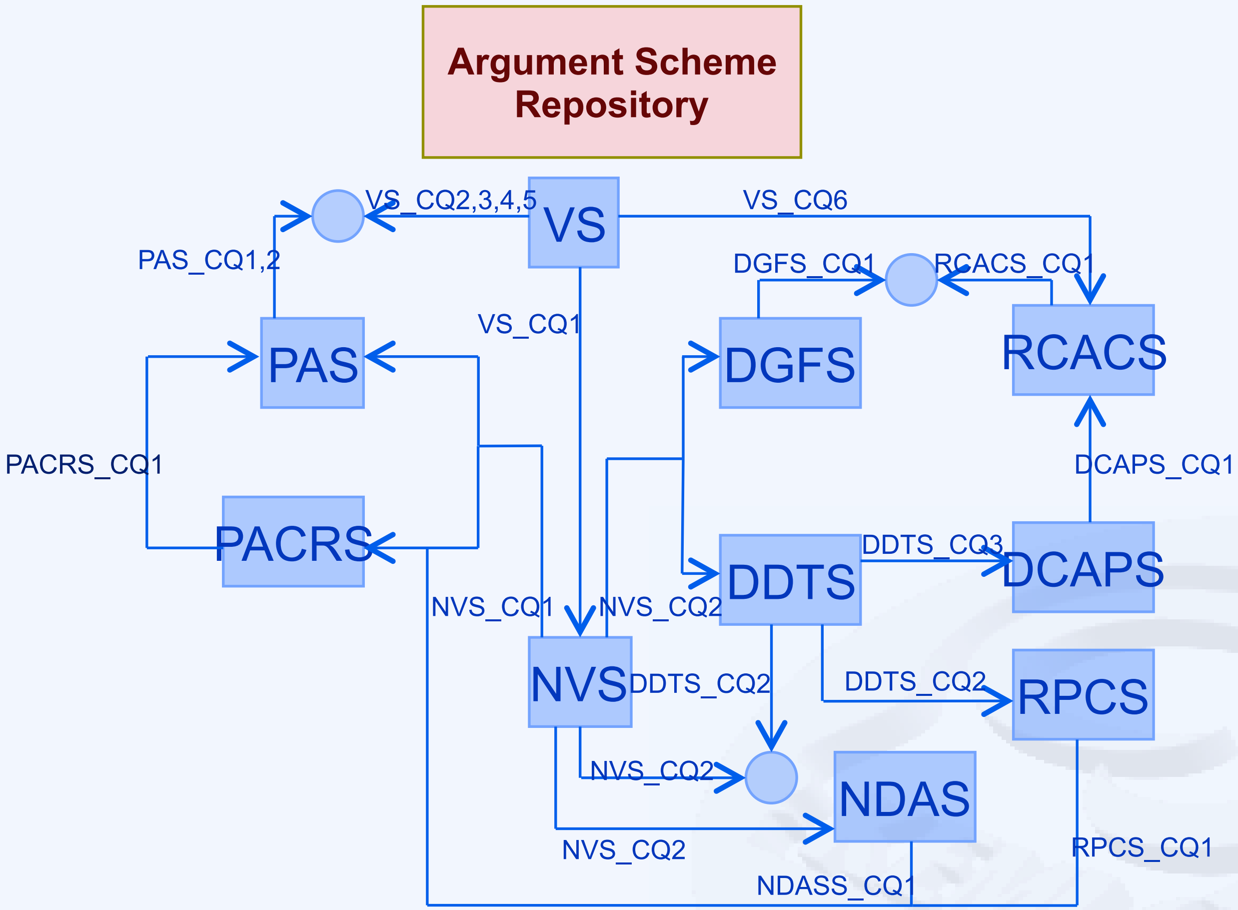
Argument Schemes and Critical Questions as a Protocol



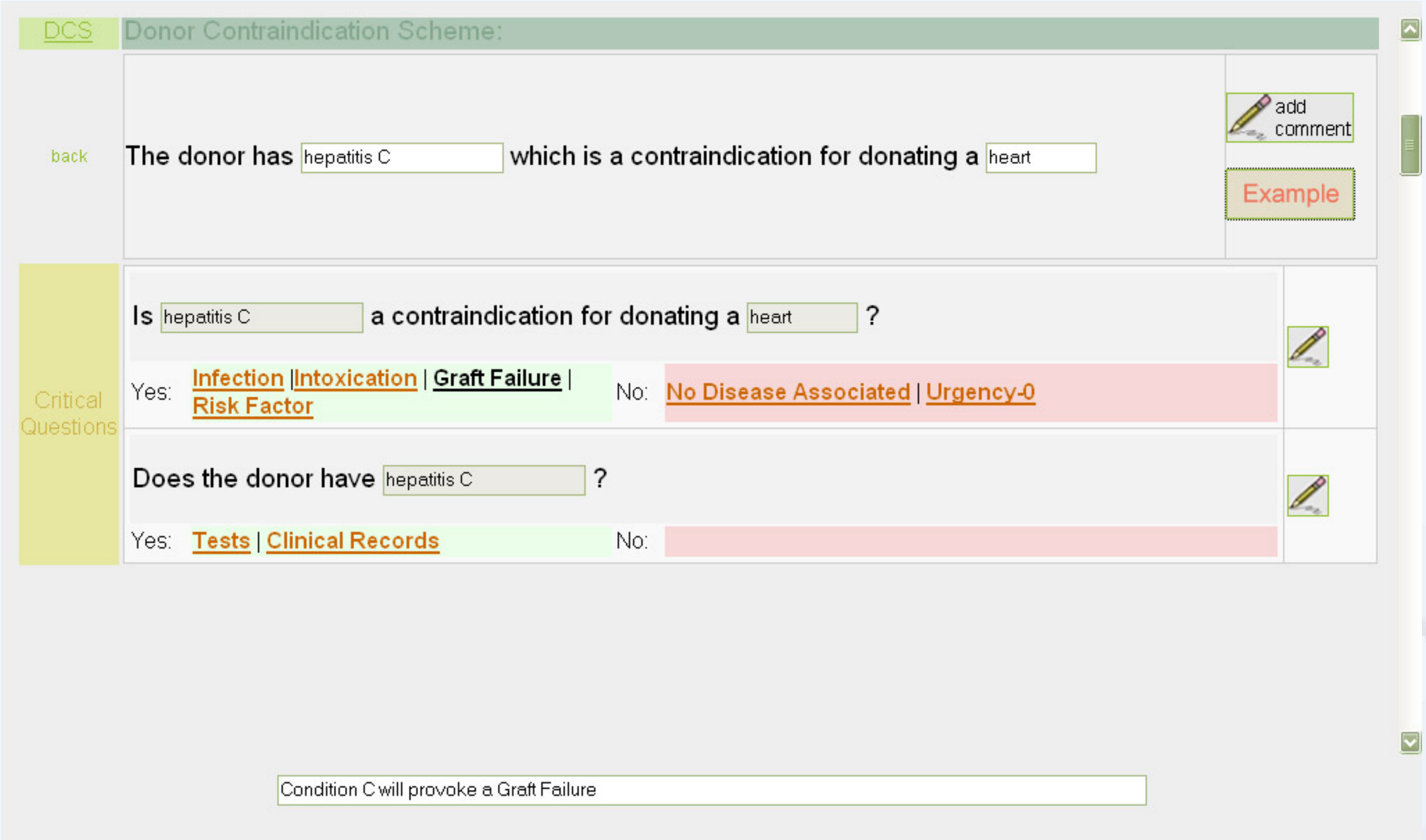
Architecture of the *ProCLAIM* model



Argument Scheme Repository "Problem"

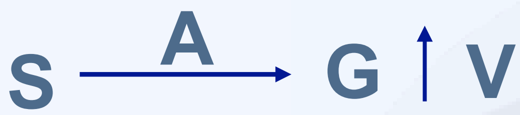


Argument Scheme Repository "Problem"



Argument Schemes and Critical Questions

- Walton & Kreb
- Atkinson *et al.*



Argument Schemes and Critical Questions

- 16 Critical Questions:
  - Blah blah
  - Blah blah blah
- Atkinson *et al.*

Argument Scheme Over Action Proposal

In the current circumstances **R**
we should perform action **A**
to achieve new circumstances **S**
which will realise some goal **G**
~~which will promote some value **V**~~

V = safety

$$R \xrightarrow{A} G \uparrow V$$

Atkinson *et al*, 2005

Argument Scheme Over Action Proposal

Undesirable Goals:

```
-severe_infection
-cancer
-acute_rejection
...
```

Argument Scheme Over Action Proposal

<Context, Fact, Prop_Action, Effect, Neg_Goal>

Context is a set of facts that are not under dispute.

Fact is a set of facts that, given the context ***Context*** and the proposed action (set of actions) ***Prop_Action*** result in a set of states ***Effect*** that realizes some undesirable goal ***Neg_Goal***.

Argument Scheme Over Action Proposal

Abstract Argument Schema:

<Context, Fact, Prop_Action, Effect, Neg_Goal>

Argument Pro:

<Context, Fact, Prop_Action, Effect, `nil` ***>***

Argument Con:

<Context, Fact, Prop_Action, Effect, `seve_infect` ***>***

Protocol-based exchange of arguments

AS1: < min_context, {} , prop_action, {}, nil >

context = {donor(D,O), potential_recip(R,O)}.

prop_action = {transplant(O,R)}.

Protocol-based exchange of arguments

AS1: < min_context, {} , prop_action, {}, nil >

↓

AS2: < min_context, fact , prop_action, effect, neg_goal >

context = {donor(D,O), potential_recip(R,O)}.

prop_action = {transplant(O,R)}.

fact = {donor_prop(D,P1)} (P1= Hepatitis C)

effect = {recipient_prop(R,P2)} (P2= Hepatitis C)

neg_goal = severe_infection.

Protocol-based exchange of arguments

AS1: < min_context, {} , prop_action, {}, nil >

AS2: < min_context, fact , prop_action, effect, neg_goal >

AS3: < min_context **u** fact, fact2, prop_action, {}, nil >

context = {donor(D,O), potential_recip(R,O), donor_prop(D,P1)}.

prop_action = {transplant(O,R)}.

fact2 = {donor_prop(D,P3)}

P1 = Smoking H

P3 = No COPD

Protocol-based exchange of arguments

AS1: < min_context, {} , prop_action, {}, nil >

AS2: < min_context, fact , prop_action, effect, neg_goal >

AS3

AS4: < min_context **u** fact, {}, prop_action **u** action2, {}, nil >

context = {donor(D,O), potential_recip(R,O), donor_prop(D,P1)}.

prop_action = {transplant(O,R), **treatment(R,T)**}.

P1 = Streptoccocus Viridans Endocarditis (Effect = sv infection)
T = Penicillin

Protocol-based exchange of arguments

AS1: < min_context, {} , prop_action, {}, nil >

AS2: < min_context, fact , prop_action, effect, neg_goal >

AS3

AS4

AS5: < min_context **u** fact**,** fact2, prop_action, effect, **nil** >

context = {donor(D,O), potential_recip(R,O), donor_prop(D,P1)}.

fact2 = { potential_recipient_prop(R,P2) }   (P1= Hepatitis C)

prop_action = {transplant(O,R)}.

Effect = { recipient_prop(R,P2) }   (P2= Hepatitis C)

Protocol-based exchange of arguments

AS1: < min_context, {} , prop_action, {}, nil >

AS2: < min_context, fact , prop_action, effect, neg_goal >

AS3

AS4 **AS5** **AS6:** < min_context, fact2, prop_action, **nil** >

Where **fact2** more specific that **fact**

context = {donor(D,O), potential_recip(R,O)}.

fact2 = {donor_prop(D,P2) } (P2 more specific than P1)

prop_action = {transplant(O,R)}.

P1 = Cancer P2 = non systemic cancer

Protocol-based exchange of arguments

AS1: < min_context, {} , prop_action, {}, nil >

AS2: < context, **new_fact**, prop_action, effect, neg_goal >

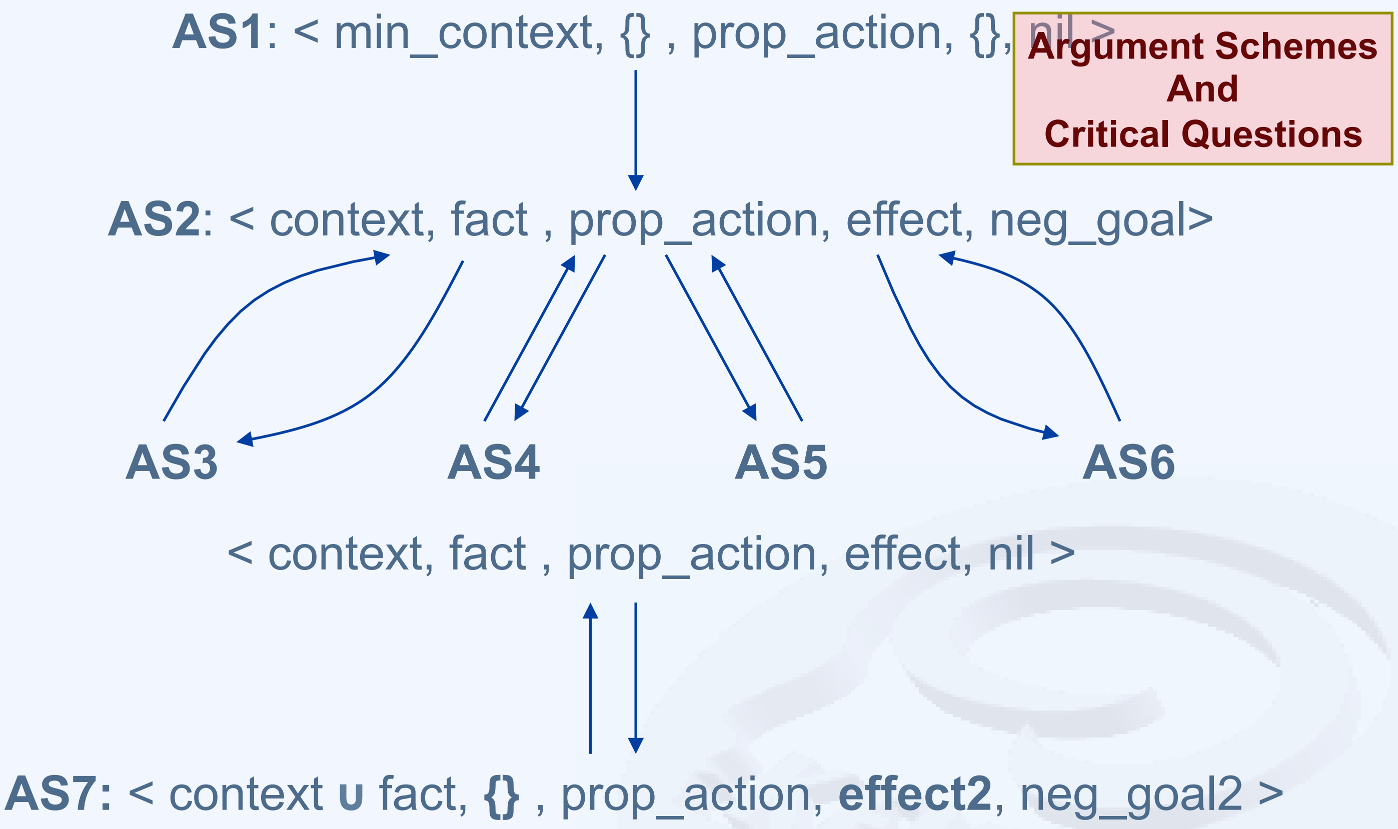
AS3 **AS4** **AS5** **AS6**

< context, fact , prop_action, effect, **nil** >

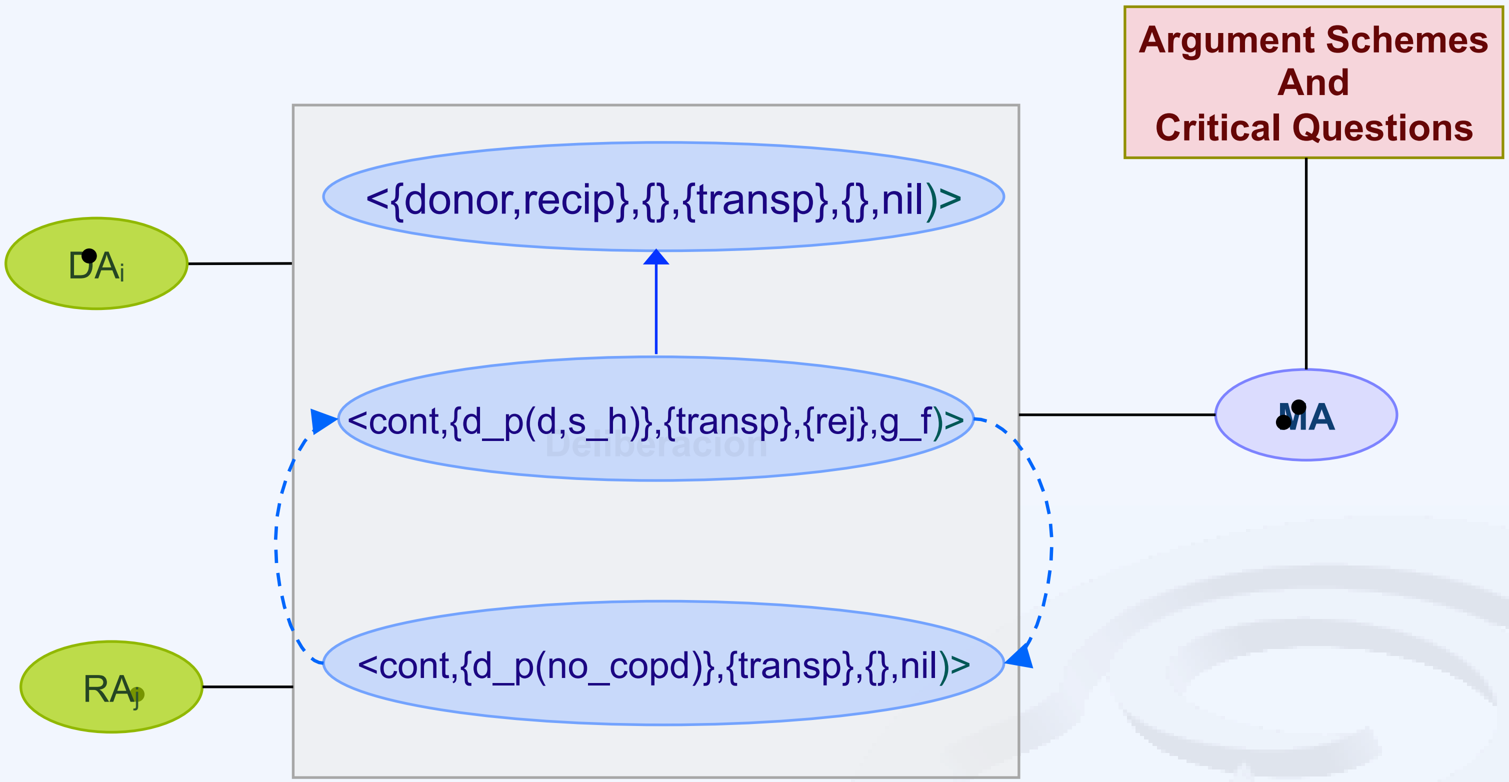
AS7: < context **u** fact, **{}** , prop_action, **effect2**, neg_goal2 >

effect2 different from **effect**

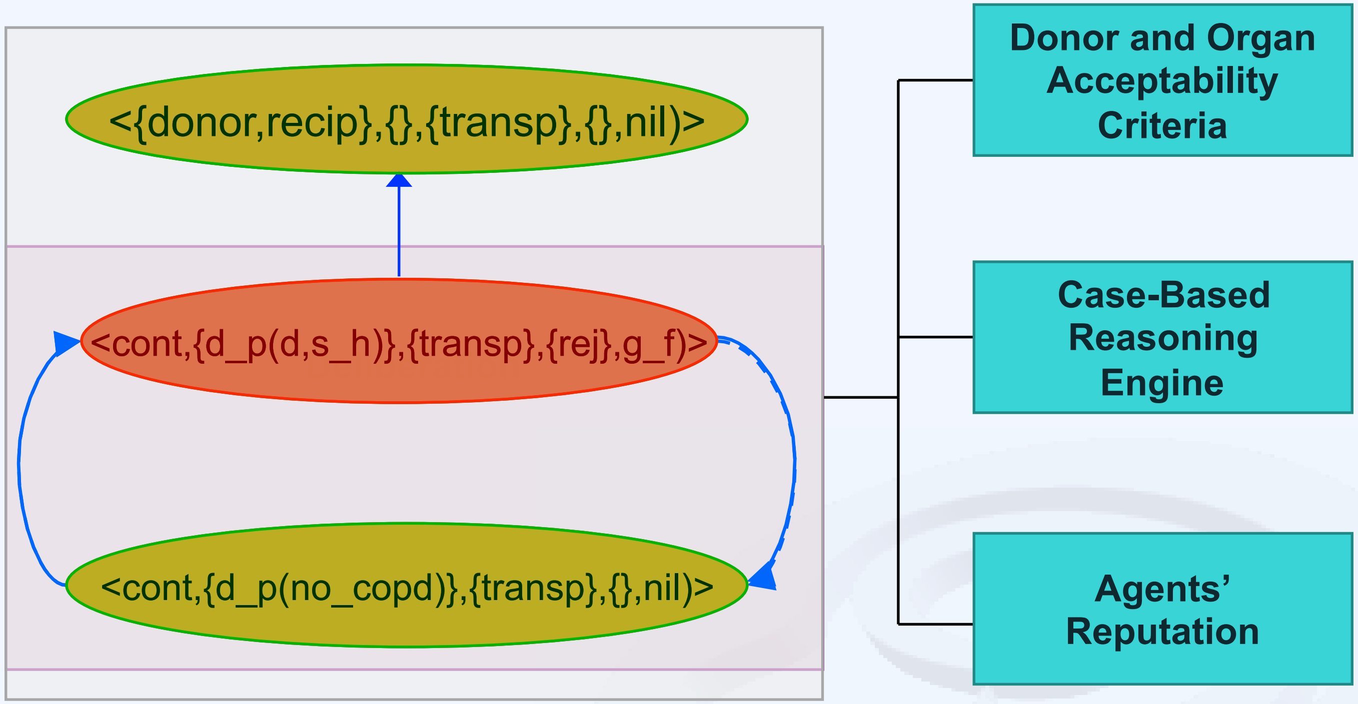
Argument Scheme Repository



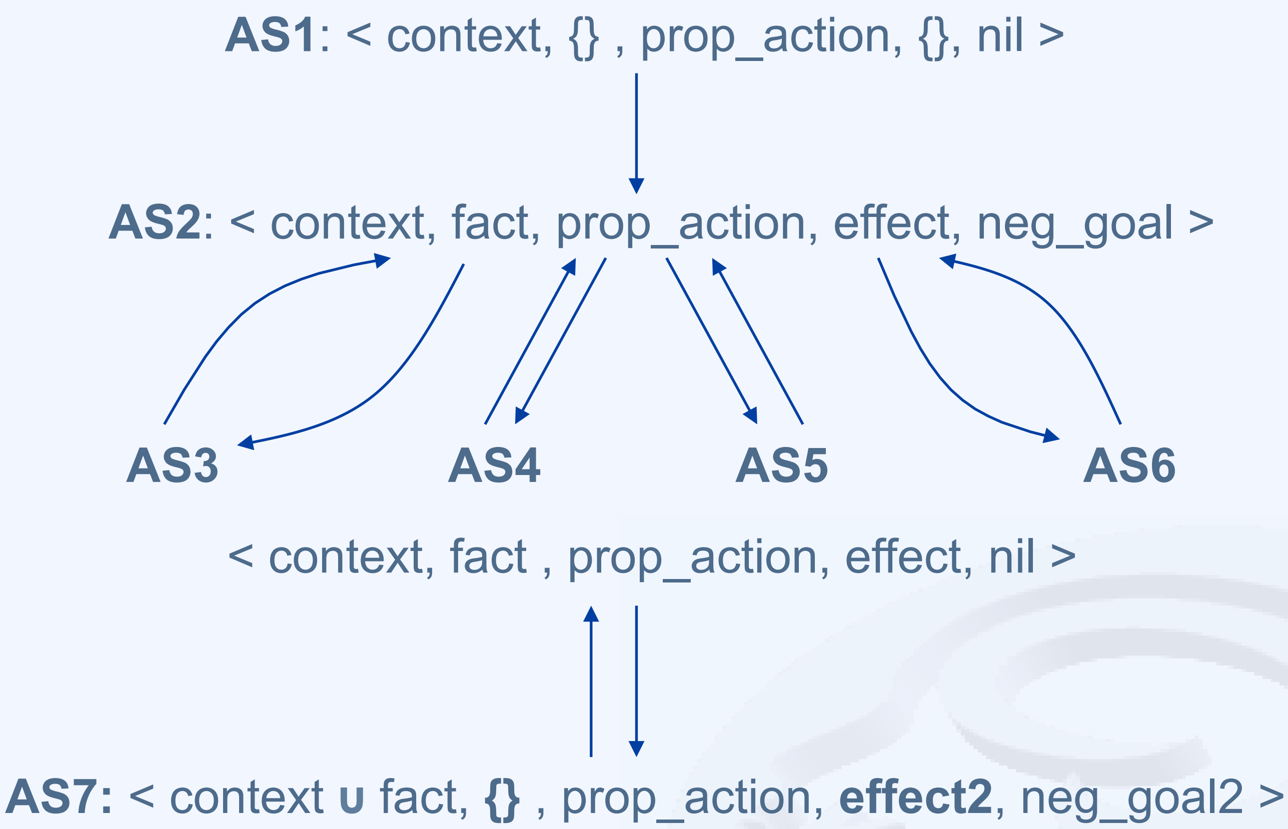
Argumentation Example



Argument Evaluation



Building the Arument Scheme Repository



Building the Arument Scheme Repository

AS1: < {donor(D,O),pot_recip(R,O)}, {} , {transp(O,R)}, {}, nil >

AS2: < context, fact, prop_action, effect, neg_goal >

AS3 **AS4** **AS5** **AS6**

< context, fact , prop_action, effect, nil >

AS7: < context **u** fact, **{}** , prop_action, **effect2**, neg_goal2 >

Building the Arument Scheme Repository

AS1: < {donor(D,O),pot_recip(R,O)}, {} , {transp(O,R)}, {}, nil >

AS2: < context, {d_p(D,P1)} , prop_action, {recip_prop(P2)}, sever_infect>

AS3 **AS4** **AS5** **AS6**

< context, fact , prop_action, effect, nil >

AS7: < context **u** fact, **{}** , prop_action, **effect2**, neg_goal2 >

Building the Arument Scheme Repository

AS1: < {donor(D,O),pot_recip(R,O)}, {} , {transp(O,R)}, {}, nil >

AS2: < context, {d_p(D,P1)} , prop_action, {**reject(R,O)**}, **graft_failure**>

AS3 **AS4** **AS5** **AS6**

< context, fact , prop_action, effect, nil >

AS7: < context **u** fact, **{}** , prop_action, **effect2**, neg_goal2 >

Building the Arument Scheme Repository

Facts

donor(D,O)

pot_recip(R,O)

d_prop(D,P)

r_prop(R,P)

....

Actions

transplant(O,R)

treat(R,T)

move(H1,R,H2)

....

Effects

recip_prop(R,P)

reject(R,O)

....

Neg_Goals

severe_infect

graft_failure

cancer

intoxication

....

Building the Arument Scheme Repository

AS1: < context, {} , prop_action,{}, nil >

Actions

transplant(O,R)

treat(R,T)

move(H1,R,H2)

....

Building the Arument Scheme Repository

AS1: < context, {} , {transplant(O,R)},{}, nil >

Facts

```
donor(D,O)
pot_recip(R,O)
d_prop(D,P)
r_prop(R,P)
..........................................
```

Building the Arument Scheme Repository

AS1: < {d(D,O),pot_re(R,O)}, {} , {transplant(O,R)},{}, nil >

↑

AS2: < {d(D,O),pot_re(R,O)}, fact , {transplant(O,R)}, effect, neg_goal >

Neg_Goals

```
severe_infect
graft_failure
cancer
intoxication
```

…………………………………………

Building the Arument Scheme Repository

AS1: < {d(D,O),pot_re(R,O)}, {} , {transplant(O,R)},{}, nil >

AS2: < {d(D,O),pot_re(R,O)}, fact , {transplant(O,R)}, effect, sev_inf >

Effects

recip_prop(R,P)

reject(R,O)

....

Building the Arument Scheme Repository

AS1: < {d(D,O),pot_re(R,O)}, {} , {transplant(O,R)},{}, nil >

↑

AS2: < {d(D,O),pot_re(R,O)}, fact , {transplant(O,R)}, {r_p(R,P2)}, sev_inf >

Facts

```
donor(D,O)
pot_recip(R,O)
d_prop(D,P)
r_prop(R,P)
.........................................
```

Building the Arument Scheme Repository

AS1: < {d(D,O),pot_re(R,O)}, {} , {transplant(O,R)},{}, nil >

AS2: < {d(D,O),pot_re(R,O)}, {d_p(D,P1)} , {transplant(O,R)}, {r_p(R,P2)}, sev_inf >

AS2: < {d(D,O),pot_re(R,O)}, fact , {transplant(O,R)}, effect, neg_goal >

Neg_Goals
severe_infect
graft_failure
cancer
intoxication
....

Building the Arument Scheme Repository

AS1: < {d(D,O),pot_re(R,O)}, {} , {transplant(O,R)},{}, nil >

AS2: < {d(D,O),pot_re(R,O)}, {d_p(D,P1)} , {transplant(O,R)}, {r_p(R,P2)}, sev_inf >

AS3 **AS4** **AS5** **AS6**

Facts

- donor(D,O)
- pot_recip(R,O)
- d_prop(D,P)
- r_prop(R,P)
- ………………………………

Actions

- transplant(O,R)
- treat(R,T)
- move(H1,R,H2)
- ………………………………

Effects

- recip_prop(R,P)
- reject(R,O)
- ………………………………

Neg_Goals

- severe_infect
- graft_failure
- cancer
- intoxication
- ………………………………

Conclusions

- Our Aim is to provide a setting where agents can deliberate over the appropriateness of proposed actions in complex and sensible domains (e.g. transplantation, environmental)
- Argumentation is a convenient technique to address this problem
- Additional components must be defined for the practical realization of these deliberations
- The specificity of the defined schemes allows for agents (also autonomous) deliberation in real world scenarios.
- An Jade-based Application implements the Transplant scenario. (The Large Scale Demonstrator of the EU project ASPIC: argumentation.org)