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
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”.

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 \textit{sliced} and \textit{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 respect 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 36.9°C, 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
A real tele-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

Argument Scheme Repository

PA₁
Proposed action

PA₂

PAₙ

MA
Decision

Guidelines Knowledge

Case-Base Reasoning Engine

Argument Source Manager

Deliberation

Argument Evaluation

Proponent Agent

Mediator Agent

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Proposed action
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

Potential Donor  Detect

Transplant Coordinator  Viable / Non-viable

Transplant Organization

Transplant Unit  HOSPITAL 2

Transplant Unit  HOSPITAL 3

Transplant Unit  HOSPITAL N

The organ is VIABLE Because…

The organ is NON-viable Because…

Detectable

Discard
The Organ is (non)-viable Because…

Organ Selection Process managed by CARREL

Potential Donor

Transplant Coordinator

The Organ is (non)-viable Because…

CARREL
(Agent-Based Institution)

Transplant Organizations

DA
Donor Agent

RA
Recipient Agent

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Architecture of the Transplant Scenario

- **Argument Scheme Repository**
- **Guidelines Knowledge**
- **Case-Based Reasoning Engine**
- **Argument Source Manager**

**Decision**

- **Transplant?**
- **Deliberation**
- **MA**
- **Argument Evaluation**

**Agents**
- Donor Agent
- Recipient Agent
- PA_i
- PA_2
- PA_n
Should a Industrial Waste be Discharged?
Should the Lung be Transplanted?

Lung should be transplanted

No Because Smoking History

S_H is not a contraindication because no COPD

Dung, 1995
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

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 $R$
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

NVS: Non-Viability Scheme:
Donor $D$ of organ $O$ had condition $C$
And $C$ is a contraindication for donating $O$
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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

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Architecture of the *ProCLAIM* model

- **Argument Scheme Repository**
- **Guideline Knowledge**
- **Case-Base Reasoning Engine**
- **Argument Source Manager**

Proposition 1: The organ is viable

Decision: Action A should be undertaken

Proposition 2: Action A should be undertaken
Argument Scheme Repository “Problem”
The donor has **hepatitis C** which is a contraindication for donating a **heart**.

Is **hepatitis C** a contraindication for donating a **heart**?

Yes: Infection | Intoxication | Graft Failure | Risk Factor

No: No Disease Associated | Urgency-0

Does the donor have **hepatitis C**?

Yes: Tests | Clinical Records

No:
Argument Schemes and Critical Questions

- Walton & Kreb
- Atkinson et al.

S → A → G → V
16 Critical Questions:
- Blah blah
- Blah blah blah

Atkinson et al.
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 $V$.

$V = \text{safety}$

Atkinson et al, 2005
Argument Scheme Over Action Proposal

Undesirable Goals:

- severe_infection
- cancer
- acute_rejection
...

donor  transp  recipient

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<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:

\[
<\text{Context}, \text{Fact}, \text{Prop\_Action}, \text{Effect}, \text{Neg\_Goal}>
\]

Argument Pro:

\[
<\text{Context}, \text{Fact}, \text{Prop\_Action}, \text{Effect}, \text{nil}>
\]

Argument Con:

\[
<\text{Context}, \text{Fact}, \text{Prop\_Action}, \text{Effect}, \text{seve\_infect}>
\]
Protocol-based exchange of arguments

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

\[
\text{context} = \{\text{donor}(D,O), \text{potential}\_\text{recip}(R,O)\}.
\]

\[
\text{prop\_action} = \{\text{transplant}(O,R)\}.
\]
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)}.  P1 = Smoking H

fact2 = {donor_prop(D,P3)}  P3 = No COPD
Protocol-based exchange of arguments

\[ \text{AS1}: \langle \text{min\_context}, \{\}, \text{prop\_action}, \{\}, \text{nil} \rangle \]

\[ \text{AS2}: \langle \text{min\_context}, \text{fact}, \text{prop\_action}, \text{effect}, \text{neg\_goal} \rangle \]

\[ \text{AS3} \]

\[ \text{AS4}: \langle \text{min\_context \_u\_fact}, \{\}, \text{prop\_action \_u\_action2}, \{\}, \text{nil} \rangle \]

context = \{donor(D,O), potential\_recip(R,O), donor\_prop(D,P1)\}.

prop\_action = \{transplant(O,R), treatment(R,T)\}.

P1 = Streptococcus 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 than 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

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Protocol-based exchange of arguments

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

AS2: < min_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

AS1: < min_context, {}, prop_action, {}, 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 >
Argumentation Example

Argument Schemes And Critical Questions

\[
<\{\text{donor, recip}\}, \emptyset, \{\text{transp}\}, \emptyset, \text{nil}\rangle
\]

\[
<\text{cont}, \{\text{d}_p(\text{d, s}_h)\}, \{\text{transp}\}, \{\text{rej}\}, \text{g}_f\rangle
\]

\[
<\text{cont}, \{\text{d}_p(\text{no copd})\}, \{\text{transp}\}, \emptyset, \text{nil}\rangle
\]
Argument Evaluation

<{donor, recip}, {}, {transp}, {}, nil>

<cont, {d_p(d, s_h)}, {transp}, {rej}, g_f>

<cont, {d_p(no_copd)}, {transp}, {}, nil>

Donor and Organ Acceptability Criteria

Case-Based Reasoning Engine

Agents’ Reputation
Building the Argument Scheme Repository

AS1: < context, {}, prop_action, {}, 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 Argument 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 Argument 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**

**AS7:** < context u fact, \{\}, prop_action, effect2, neg_goal2 >
Building the Argument 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 Argument 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

---

R → A → S

G⁻

nil
Building the Argument Scheme Repository

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

**Actions**

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

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

Facts

<table>
<thead>
<tr>
<th>donor(D,O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pot_recip(R,O)</td>
</tr>
<tr>
<td>d_prop(D,P)</td>
</tr>
<tr>
<td>r_prop(R,P)</td>
</tr>
</tbody>
</table>

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Building the Argument Scheme Repository

**AS1:** \(<\{d(D,O), pot\_re(R,O)\},\{transplant(O,R)\},\{\},\{\},\text{nil}\>\)

**AS2:** \(<\{d(D,O), pot\_re(R,O)\},\text{fact},\{transplant(O,R)\},\text{effect},\text{neg\_goal}\>\)

**Neg\_Goals**

- severe\_infect
- graft\_failure
- cancer
- intoxication

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Building the Argument Scheme Repository

**AS1**: \(<\{d(D,O), pot\_re(R,O)\}, \{\}, \{transplant(O,R)\}, \{\}, \text{nil} >

**AS2**: \(<\{d(D,O), pot\_re(R,O)\}, \text{fact}, \{transplant(O,R)\}, \text{effect, sev\_inf} >

Effects

- \(\text{recip\_prop}(R, P)\)
- \(\text{reject}(R, O)\)
Building the Argument 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 Argument Scheme Repository

**AS1**: \(< \{d(D,O), pot\_re(R,O)\}, \{\}\, , \{transplant(O,R)\}, \{\}\, , \text{nil}\)>

**AS2**: \(< \{d(D,O), pot\_re(R,O)\}, \{d\_p(D,P1)\} , \{transplant(O,R)\}, \{r\_p(R,P2)\}, \text{sev\_inf}\)>

**AS2**: \(< \{d(D,O), pot\_re(R,O)\}, \text{fact} , \{transplant(O,R)\}, \text{effect}, \text{neg\_goal}\)>

**Neg_Goals**

- severe_infect
- graft_failure
- cancer
- intoxication
Building the Argument Scheme Repository

**AS1**: \(<\{d(D,O),pot\_re(R,O)\}, \emptyset, \{transplant(O,R)\}, \emptyset, \text{nil}\>\)

**AS2**: \(<\{d(D,O),pot\_re(R,O)\}, \{d\_p(D,P1)\}, \{transplant(O,R)\}, \{r\_p(R,P2)\}, \text{sev\_inf}\>\)

---

**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

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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)