ROBABILISTIC ONTOLOGIES AND PRAGMATICS FOR COMPLEX SYSTEMS INTEGRATION

Paulo Cesar G da Costa
Bernard Zeigler
Michael Hieb
Kathryn B. Laskey

Center of Excellence in C4I

"…The commander is compelled during the whole
paign to reach decisions on the basis of situations
cannot be predicted … The problem is to grasp, in
numerable special cases, the actual situation which
vered by the mist of uncertainty, to appraise the fa
rectly and to guess the unknown elements, to reac
ecision quickly and then to carry it out forcefully an
relentlessly."

Helmuth von Moltke, 1800-18

Paret, P.; Craig; A.G.; Gilbert, F. (1986) Makers of Modern Strategy: From M
the Nuclear Age. London, UK: Oxford University Press (Page 289)

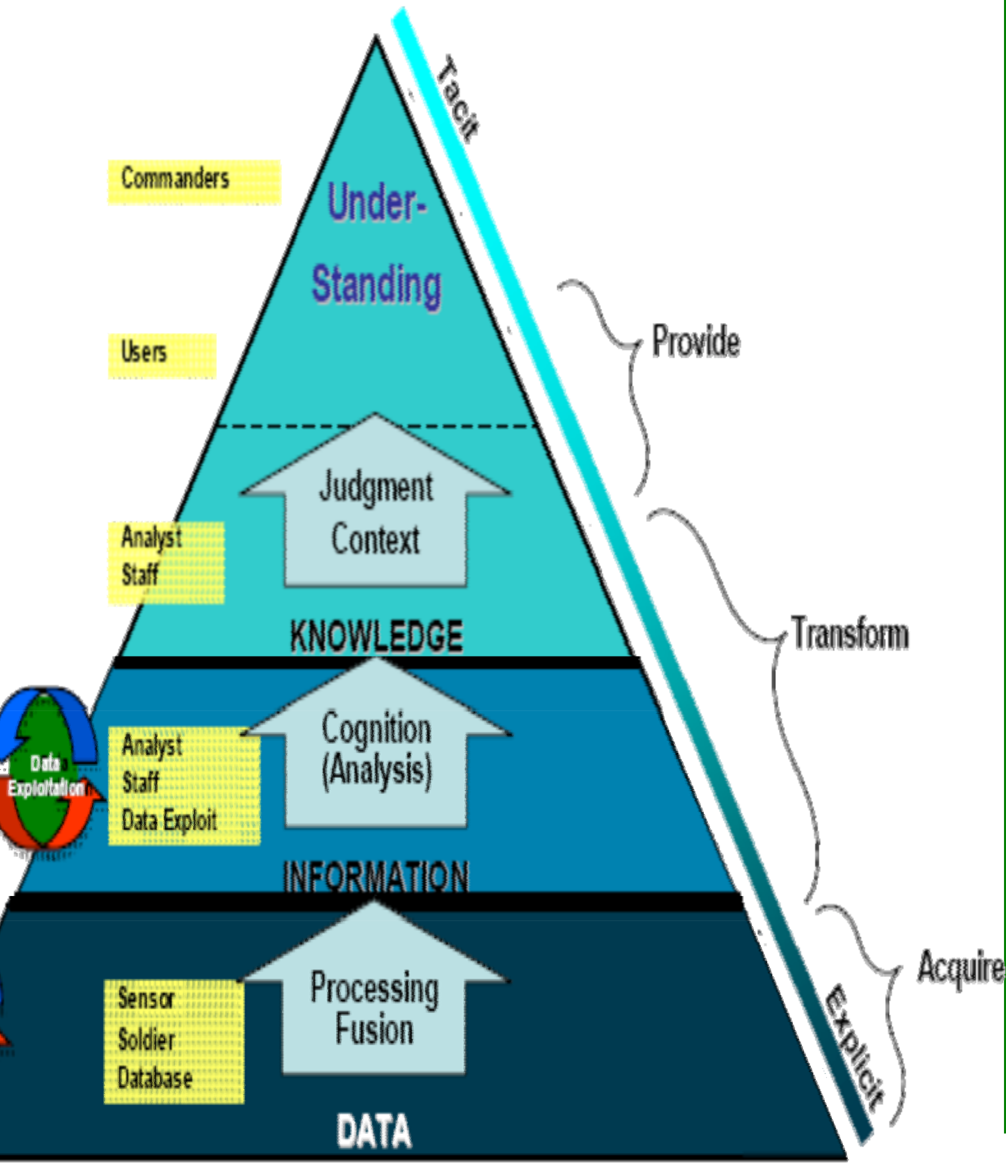
- Knowledge Exchange in C^2
- Ontologies
- Probabilistic Ontologies
- Pragmatic Frames

nability to produce a dynamic, comprehensive, and
ccurate battlespace picture for the warfighter that
ntegrates tactical data from multiple intelligence
ources.

ack of automated techniques to integrate data
geolocation, detection, and identification) from mult
ntelligence sources, in a consistent and timely man

ack of accurate and timely information about
attlespace objects and events to support warfighte
ecision making in an asymmetric warfare.

ainty



Cognitive Hierarchy

Data Fusion Level	Association Process	Estimation Process	
L3 Impact Assessment	Evaluation (situation to actor's goals)	Game-Theoretic Interaction	E S
L2 Situation Assessment	Relationship (entity-to-entity)	Relation	E S
L1 Object Assessment	Assignment (observation-to-entity)	Attributive State	E E
L0 Signal Assessment	Assignment (observation-to-feature)	Detection	E Si

JDL Data fusion leve

6-0: Mission Command: Command and Control of

White, F.E., "A Model for Data Fusion", Proc. 1st N

rtfalls of Current Approaches

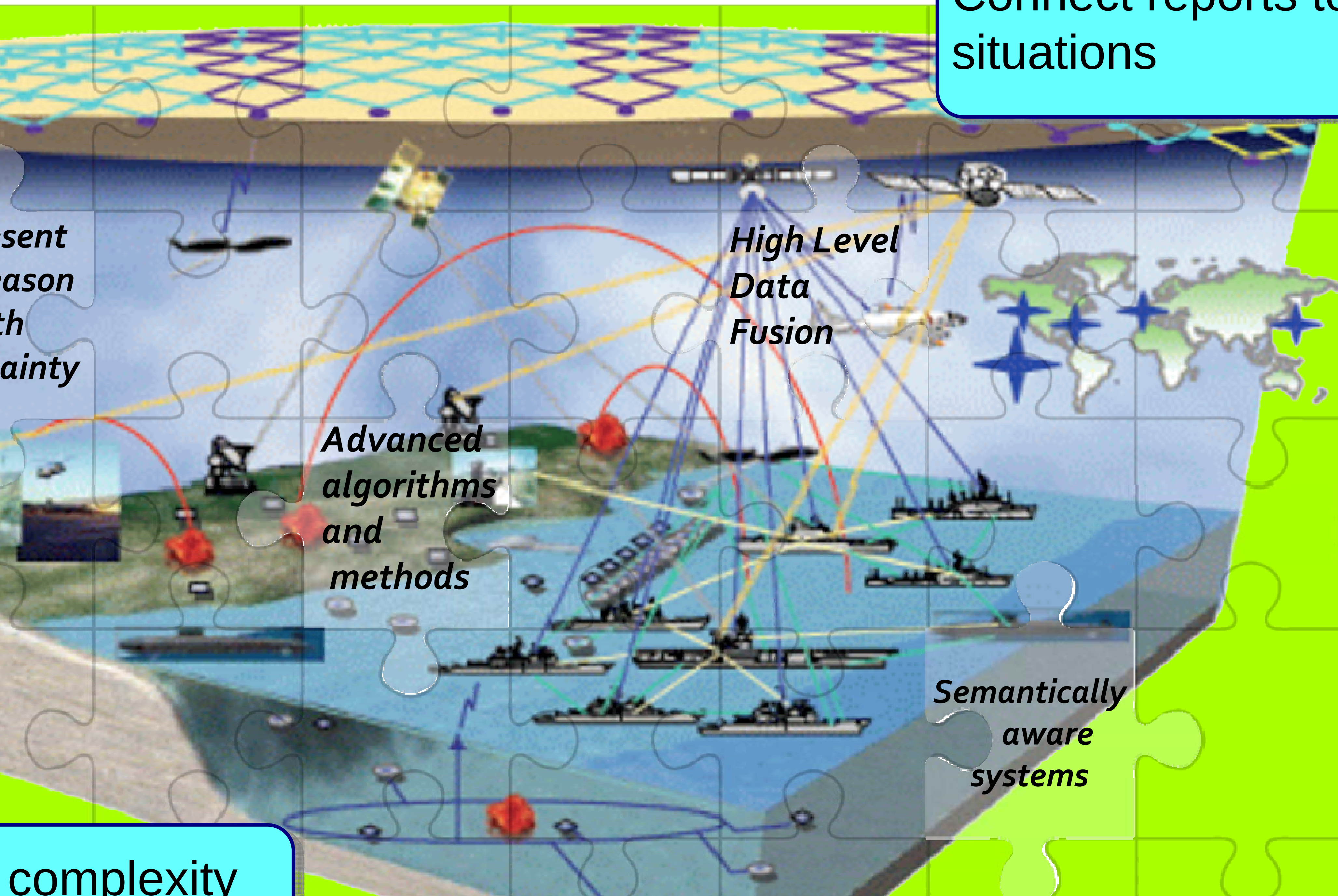
r cannot achieve fusion levels 2 and above
model), or can do so only in controlled
onments (limited scalability and expressivity).

ed ability to cope with uncertainty, typically
ng or mishandling it.

handle only standardized messages, special-
scenarios, and specific sensor types, leading
eroperability issues and less than optimal use
ailable information.

The Missing Pieces

Connect reports to situations



complexity

The Way Forward

s mathematical foundation and efficient algorithms to
e data from diverse sources for reliable predictive
n assessment

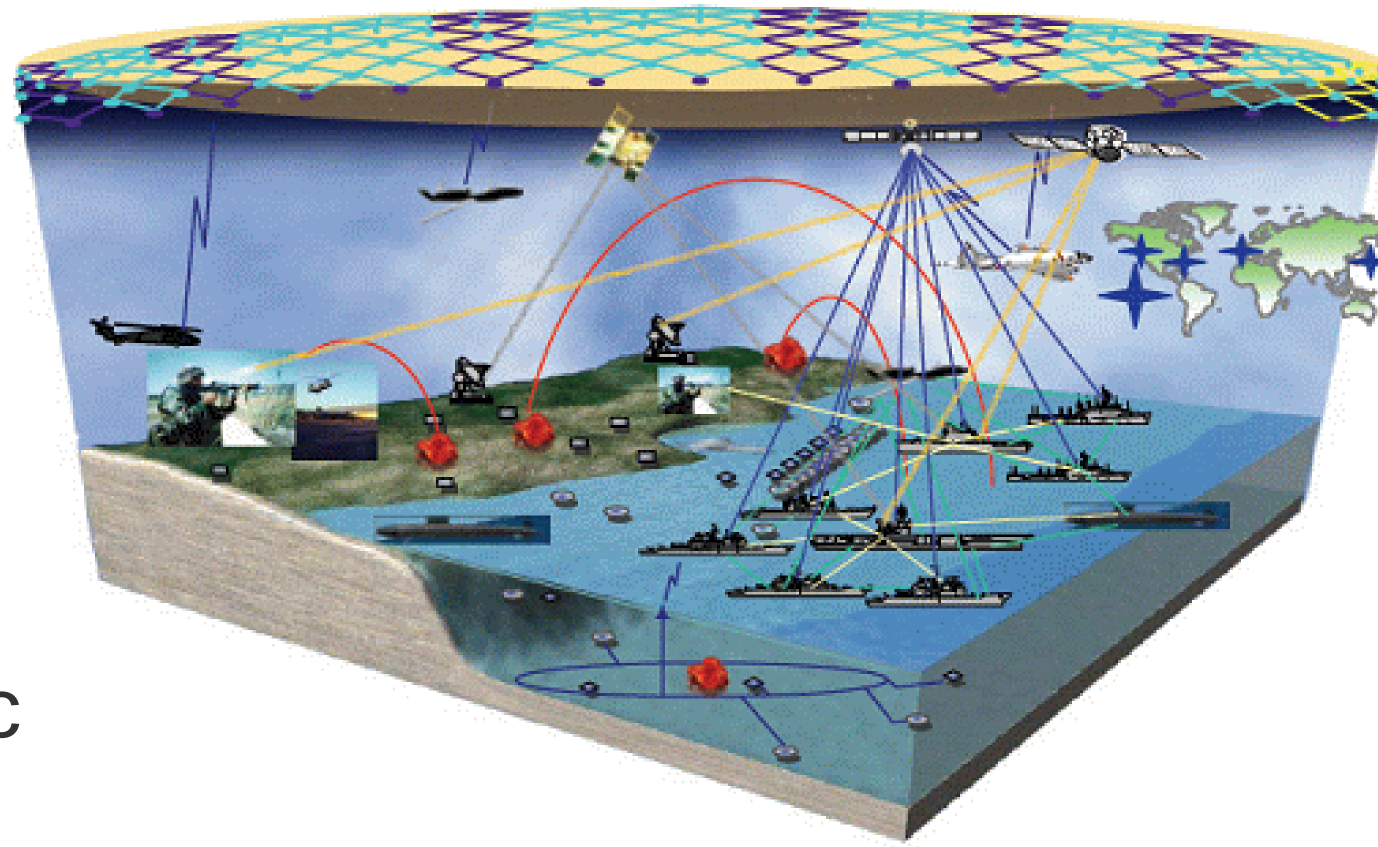
ted techniques to reduce warfighter's information
ing load and provide timely actionable knowledge to
n makers

erable methodologies for propagating uncertainty
the integration process to characterize and distinguish
nal conditions for predictive analysis and impact
nent under various behaviors and environments

ically aware systems for interoperability in net-centric
ment

nter's Multi-Disciplinary Approach

ng interoperable
technologies based
entity Bayesian
, Probabilistic
es, and pragmatic
support Net Centric
s



ng mathematically rigorous and computationally
lgorithms based on Spatio-Temporal Hypothesis
nent and Efficient Hybrid Inference to provide
ble predictive situational awareness Developing formal
es and tools to represent command intent and to

teroperation vs. Integration

ration of systems

- nain autonomous and
- l
- s are soft coded and
- bularies and ontologies for ersist
- on via mediation
- data transfer

Integration of systems

- participants are assimilated into whole, losing autonomy and independence
- tightly coupled
- interaction rules are hard coded and co-dependent
- global data vocabulary and ontology for interpretation adopted
- share information conforming to strict standards
- synchronous data transfer

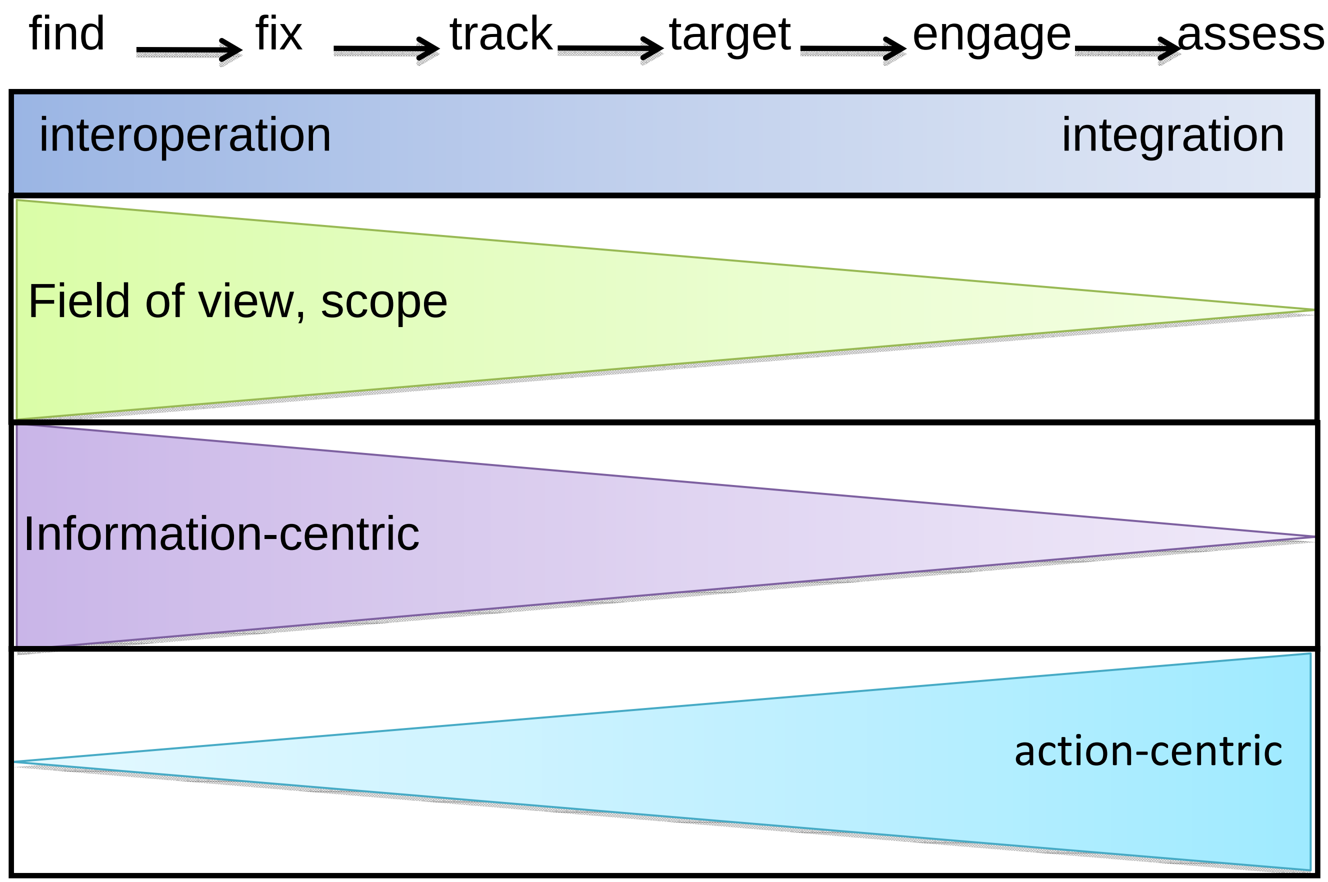
Vs.

fit-to-purpose responsiveness

NOT Polar Opposites!

SPECTRUM of INTERACTION MODES

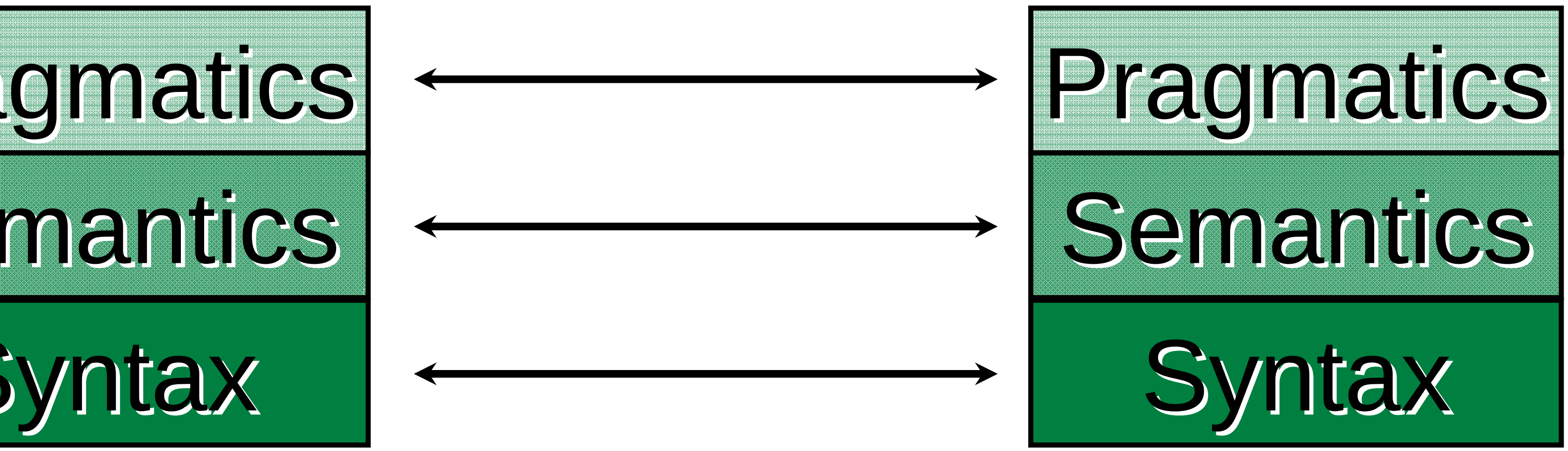
Example: Kill chain



n illustrates the co-existence of interoperation and integration mponent interaction.

es in the chain are characterized by larger field of view and nformation-centric functions than do later activities. They need upling and flexibility of interoperation.

guistic Levels of Information
change and Interoperability



m Participant System Participant

stic Level of tion Exchange	A System of Systems interoperates at this level if :
ormation in messages is	The receiver re-acts to the message in a manner that the sender intends (assuming non-hostility in the collaboration).
derstanding of meaning of	The receiver assigns the same meaning as the sender did to the message.

Agenda

Knowledge Exchange in C^2

Ontologies

Probabilistic Ontologies

Pragmatic Frames

Ontologies

Philosophy: the study of nature of being and knowing

nformation Systems: many definitions

ation on how to
cepts, and other
to exist in some
tionships among
y.com)

ntology is the
rmulate an
eptual schema
y is typically a
ntaining all the
ationships and
kipedia.org).

an ontology is a set of concepts - such as things, events, and relations - that are specified in some way (such as specific natural language) in order to create an agreed-upon vocabulary for exchanging information. (whatis.com)

Is a formal specification of a conceptualization (Gruber)

An ontology models the vocabulary and meaning of domains of interest: the objects (things) in domains; the relationships among those things; the properties, functions, and processes involving those things; and constraints on and rules about those things (DaConta et al., 2003)

An Ontology formally defines a commo set of terms that are used to describe an represent a domain. Ontologies can be used by automated tools to power advanced services such as more accura Web search, intelligent software agents and knowledge management. (Owl Use Cases)

A partial specification of a conceptual vocabulary to be used for formulating knowledge-level theories about a domain of discourse. The fundamental role of an ontology is to support knowledge sharing and reuse. (The Internet Reasoning Services project - IRS)

Semantics in Data Fusion

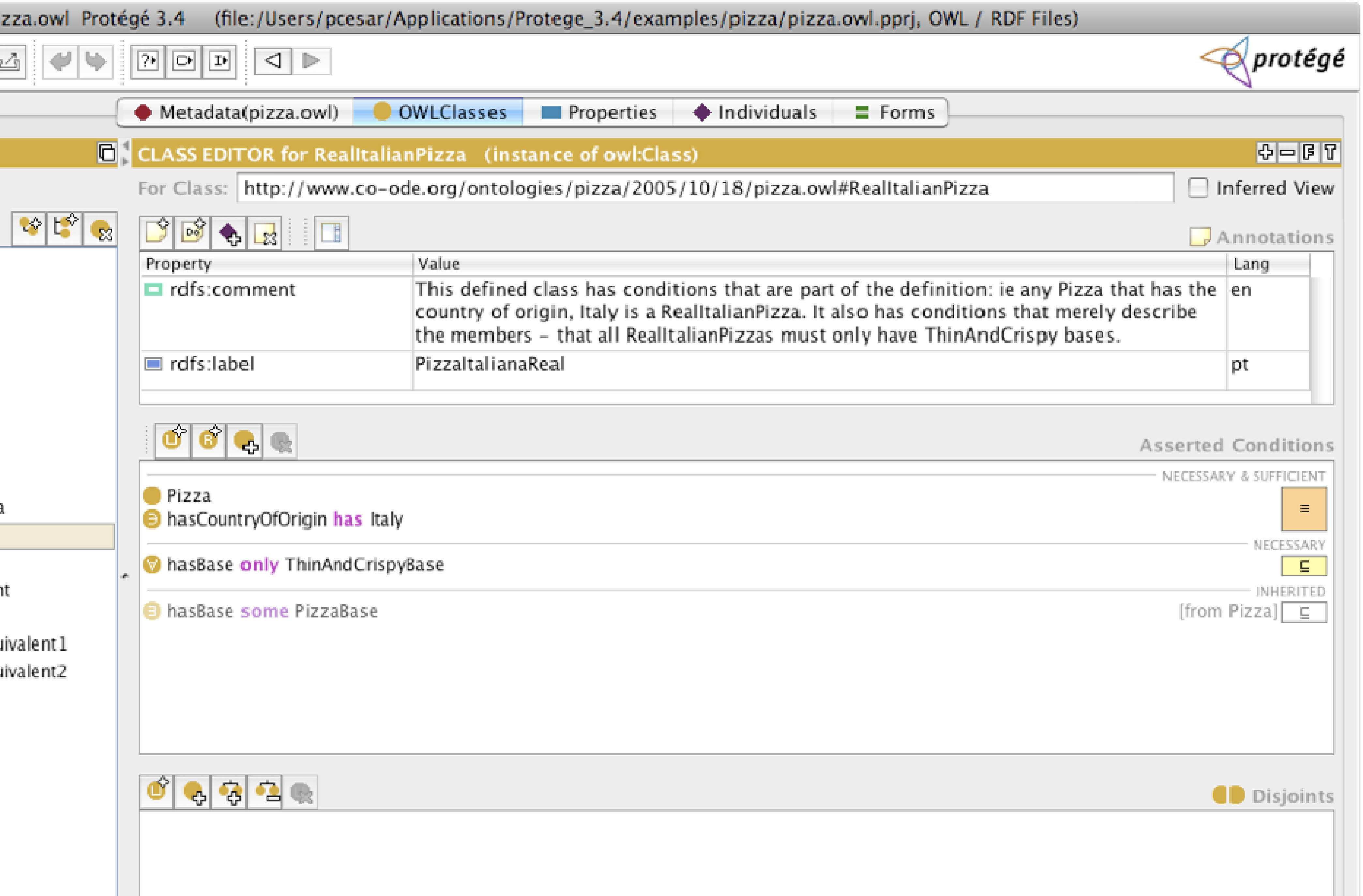
mation in the battlefield comes from reports
diverse sources, in distinct syntax, and with
rent meanings.

ctive interoperability requires understanding the
onship between reports from different systems
the events reported upon

antically aware systems are essential to
buted knowledge fusion.

ologies are a means to semantic awareness

Asserted vs. Inferred



Ontologies vs. OO

logies

ogical reasoners to
s relationships and
membership

ormat that adapts
structure as new
on is learned

orld Assumption /
ed for open

Databases / OO

- Rigidly defined classes that govern the system behavior
- All instances are created as members of some class.
- Changing a class affects all of its instances
- Closed World Assumption / Well suited for top down governance

ntologies and Uncertainty

e many kinds of uncertainty, e.g.:

- sensors
- t, incomplete, deceptive human intelligence
- understanding of cause and effect mechanisms in the world

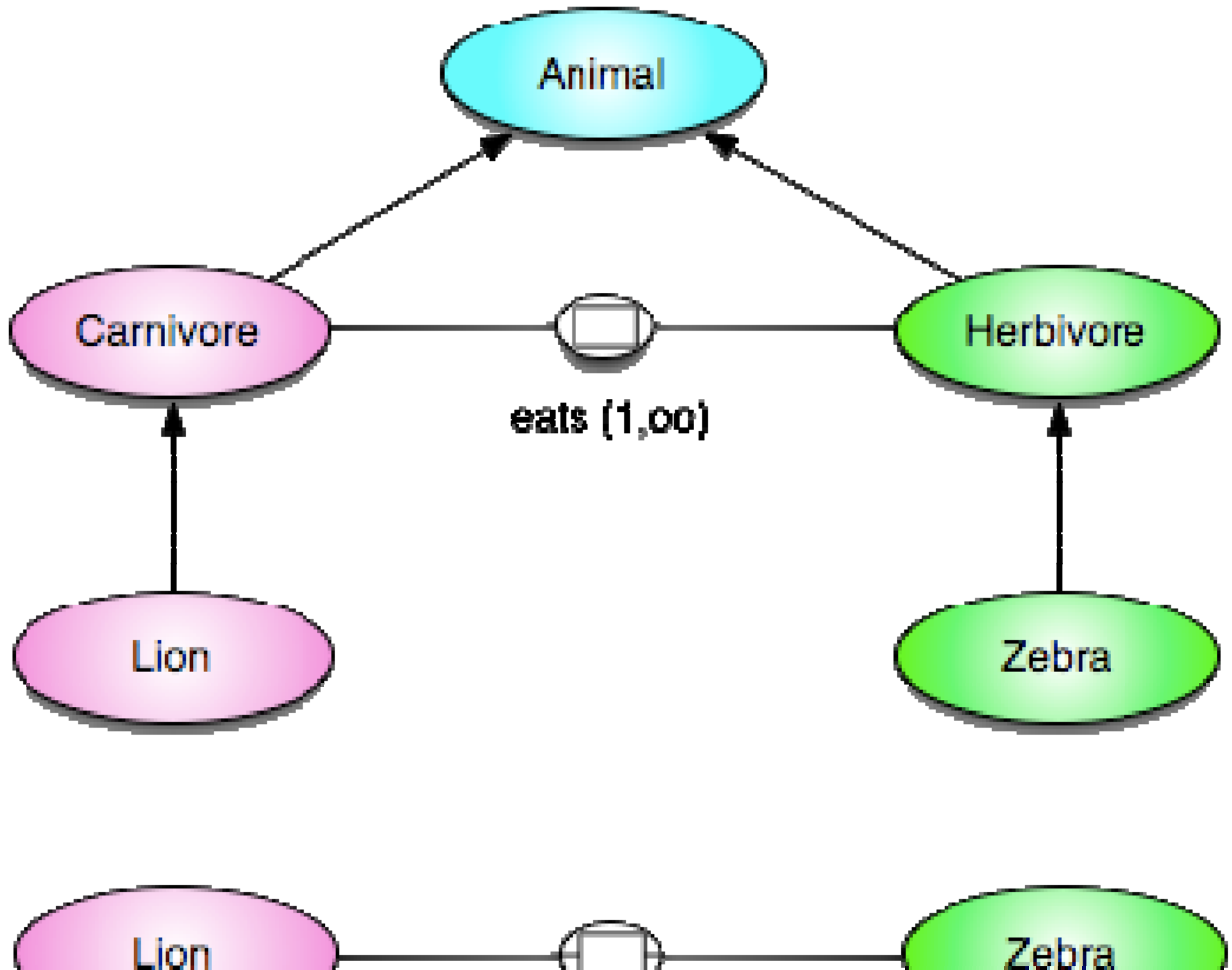
nting and reasoning with uncertainty is essential

ditional ontological Engineering methods
rovide no support for representing and

Deterministic Reasoning

re, herbivore

animal
animal
herbivore
ore
ivore



Agenda

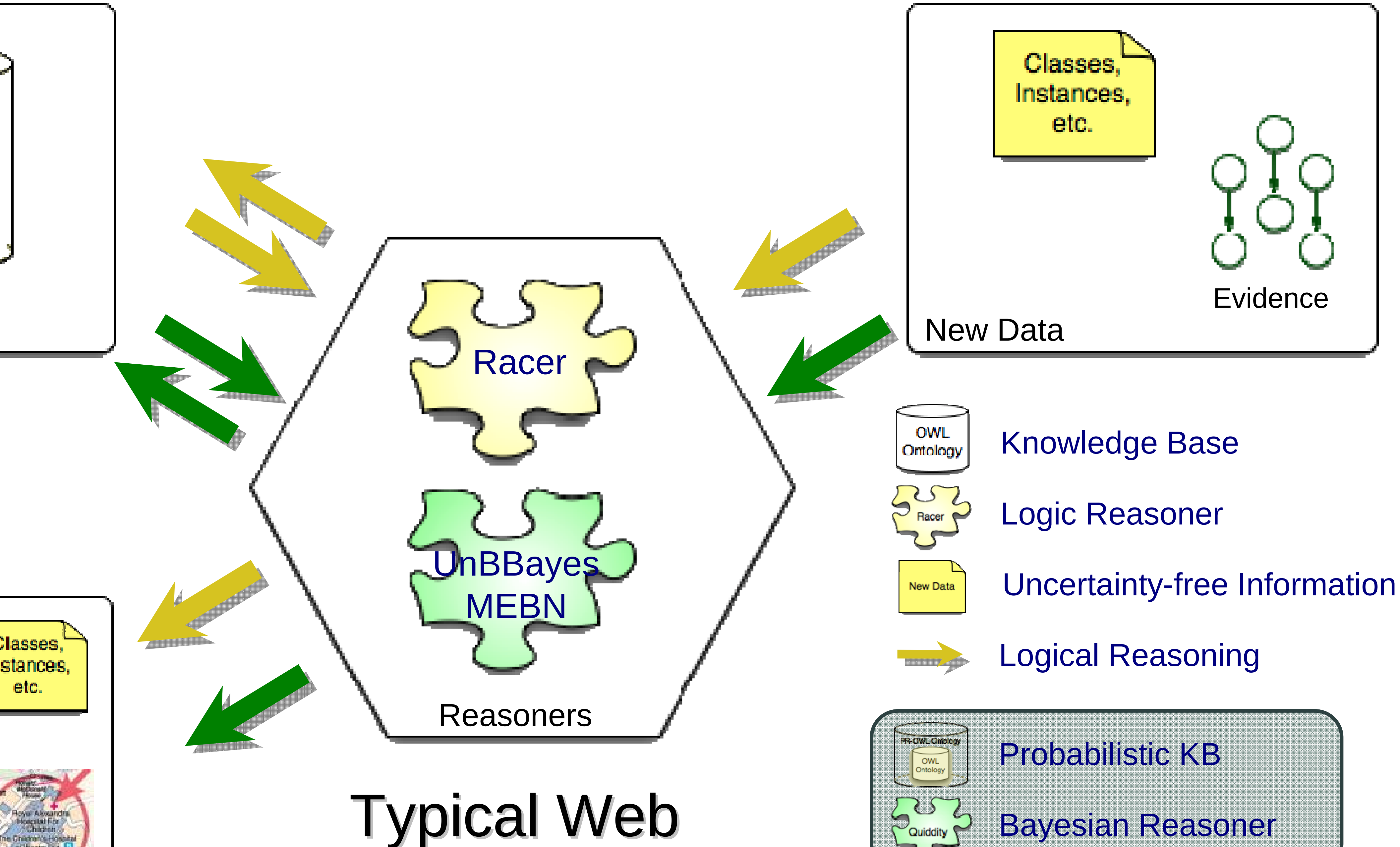
Knowledge Exchange in C^2

Ontologies

Probabilistic Ontologies

Pragmatic Frames

A Pragmatic View



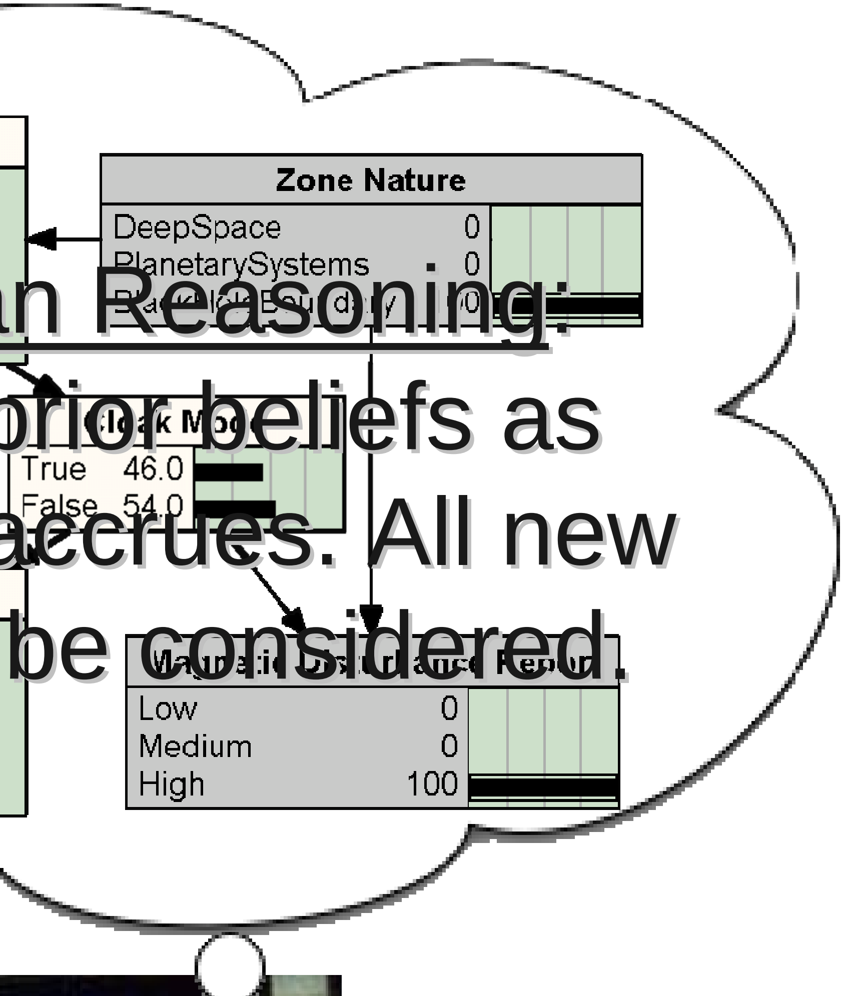
v about Bayesian Networks?

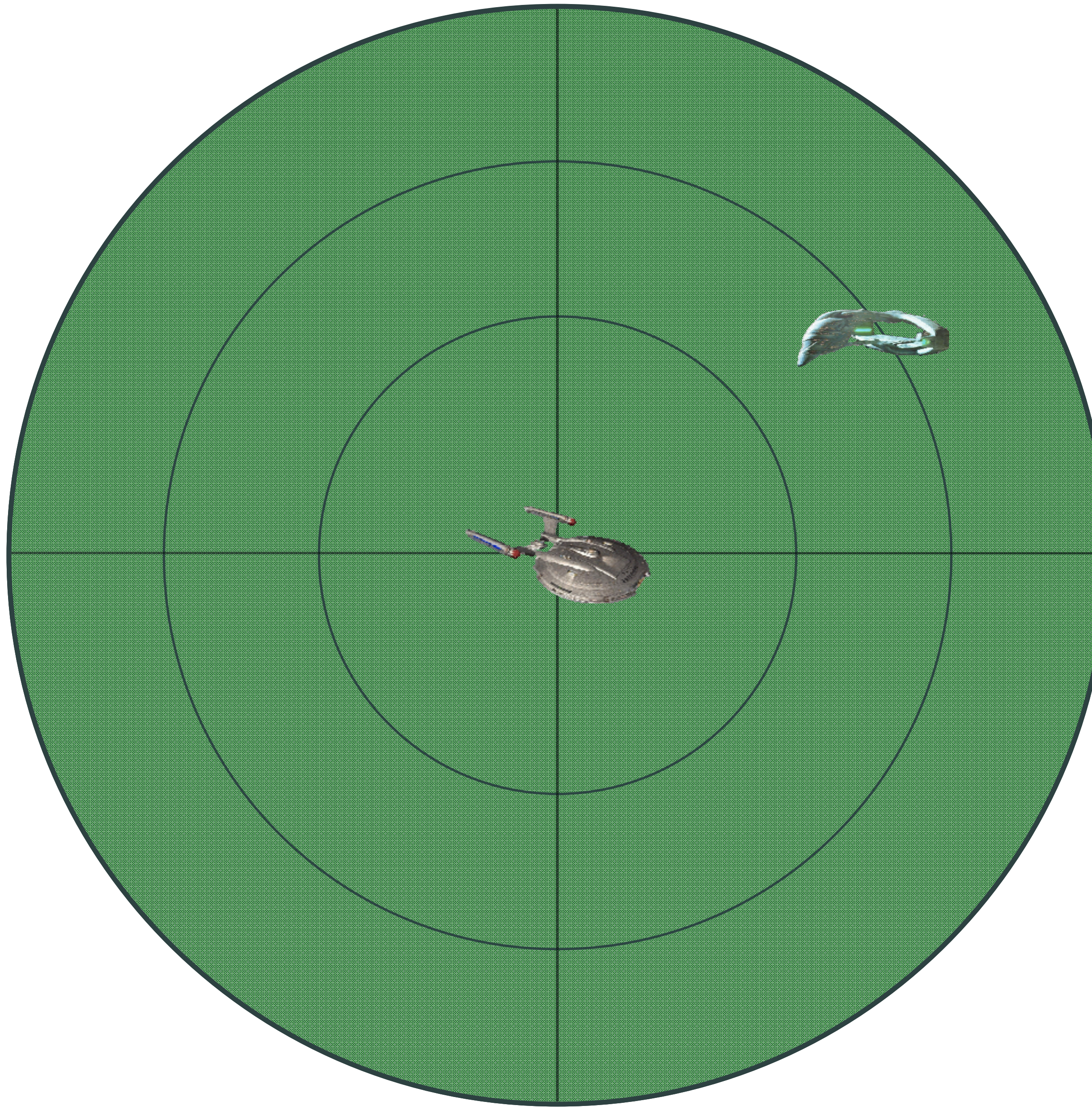
an Reasoning:

prior beliefs as

accrues. All new

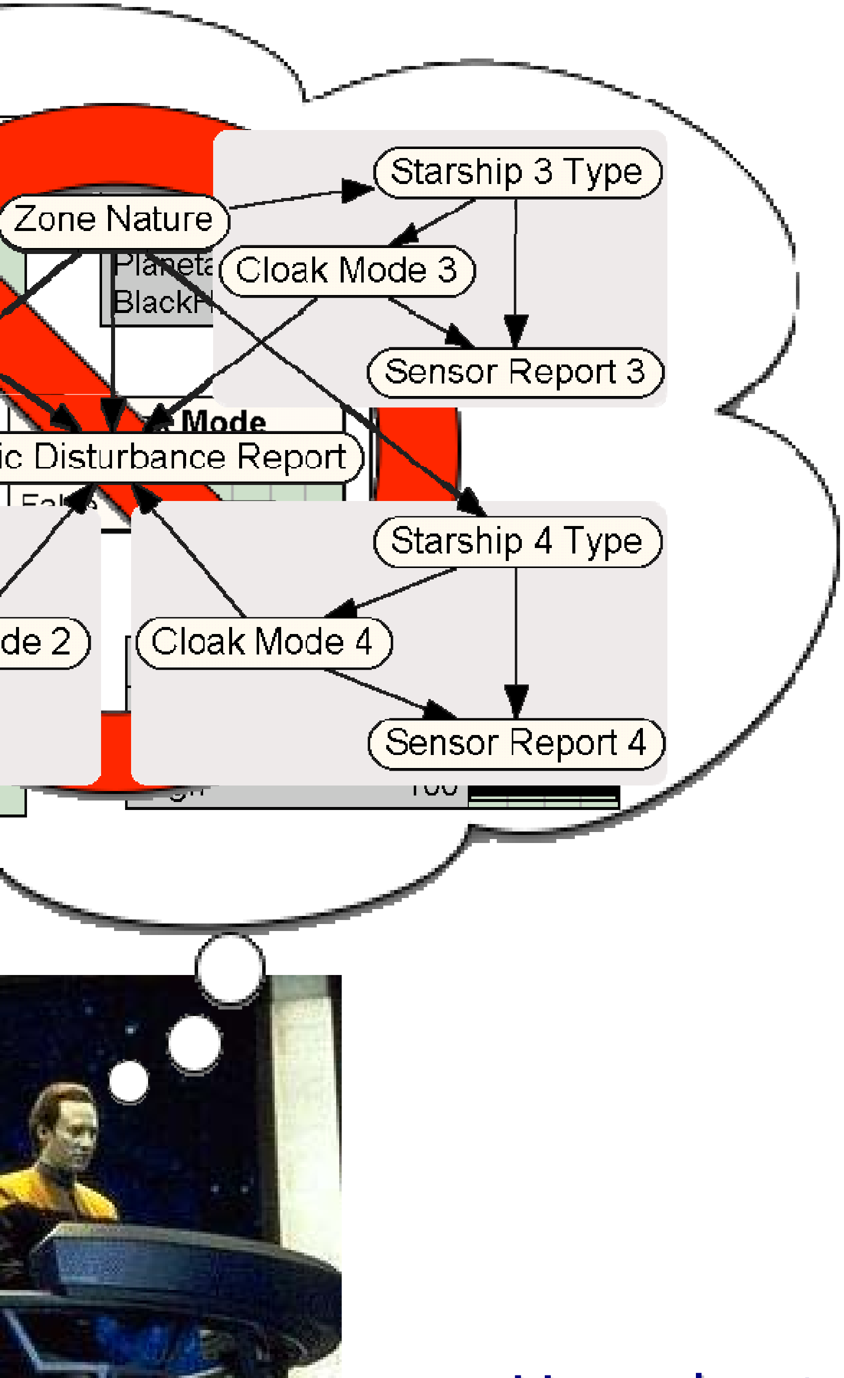
be considered.

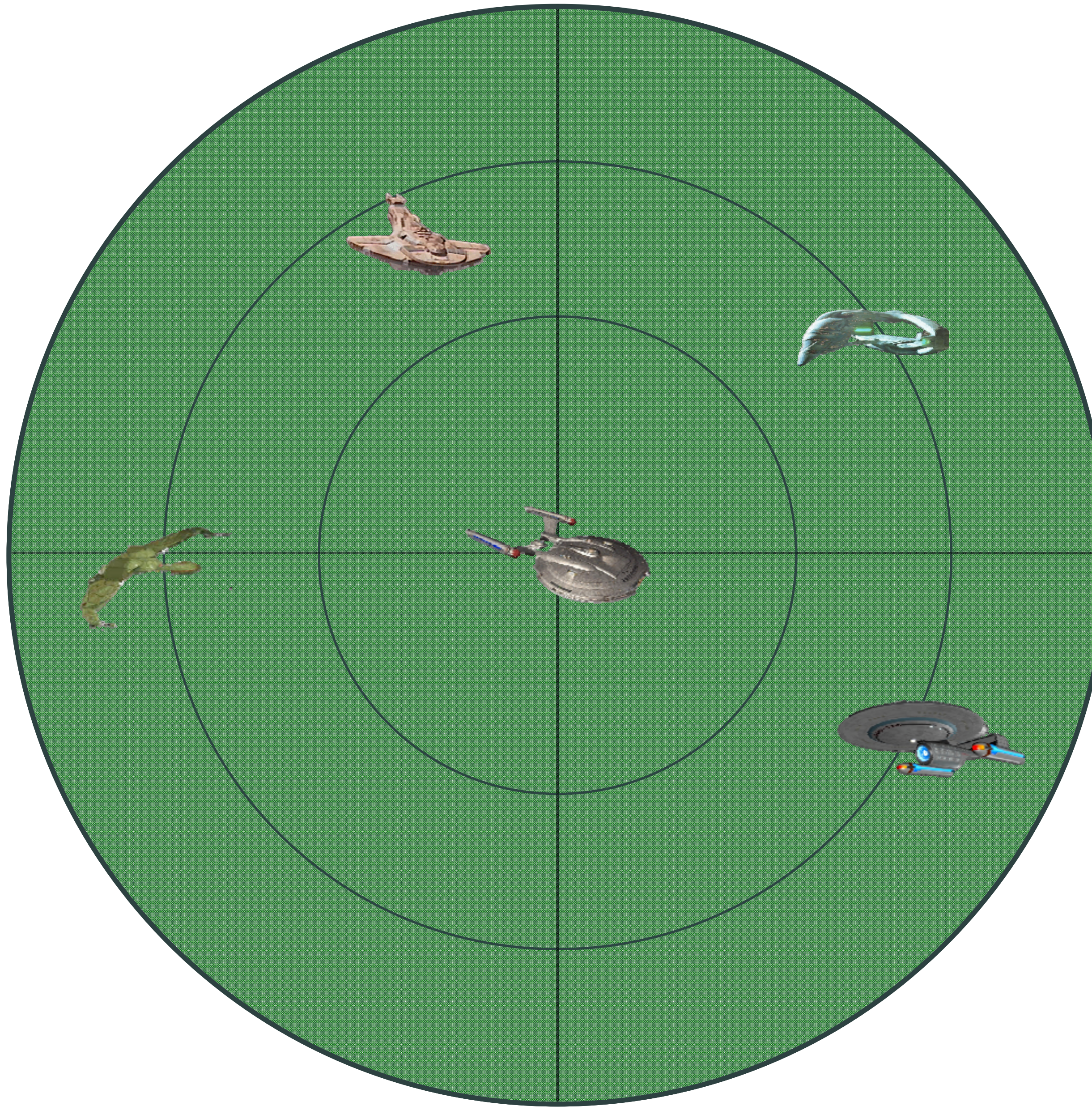




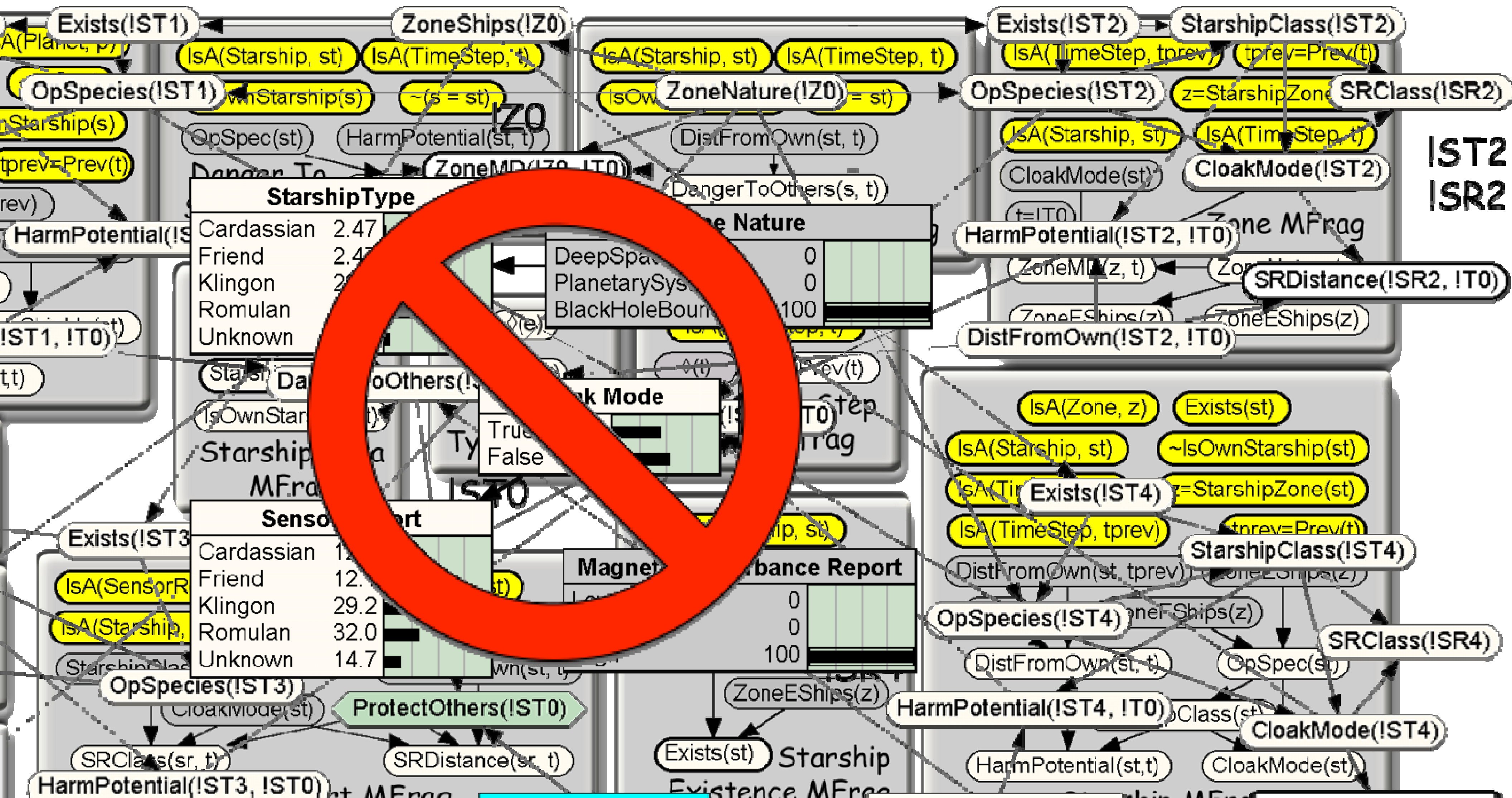
The Star Trek Problem: Discriminating Starships and making

Why not BNs?

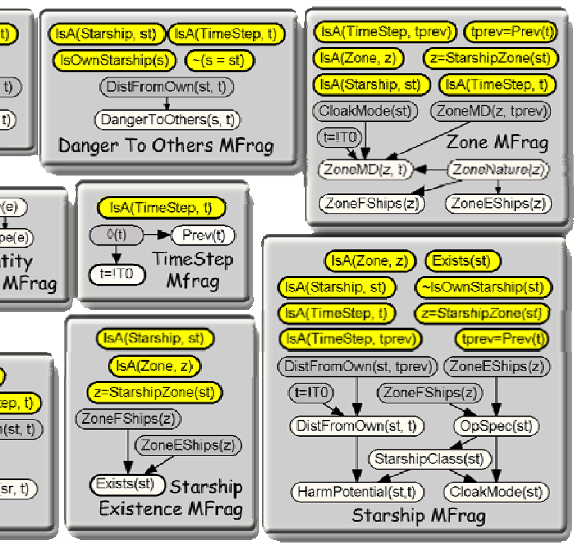

Starship 3 Type
Zone Nature
Cloak Mode 3
Sensor Report 3
Starship 4 Type
Cloak Mode 4
Sensor Report 4



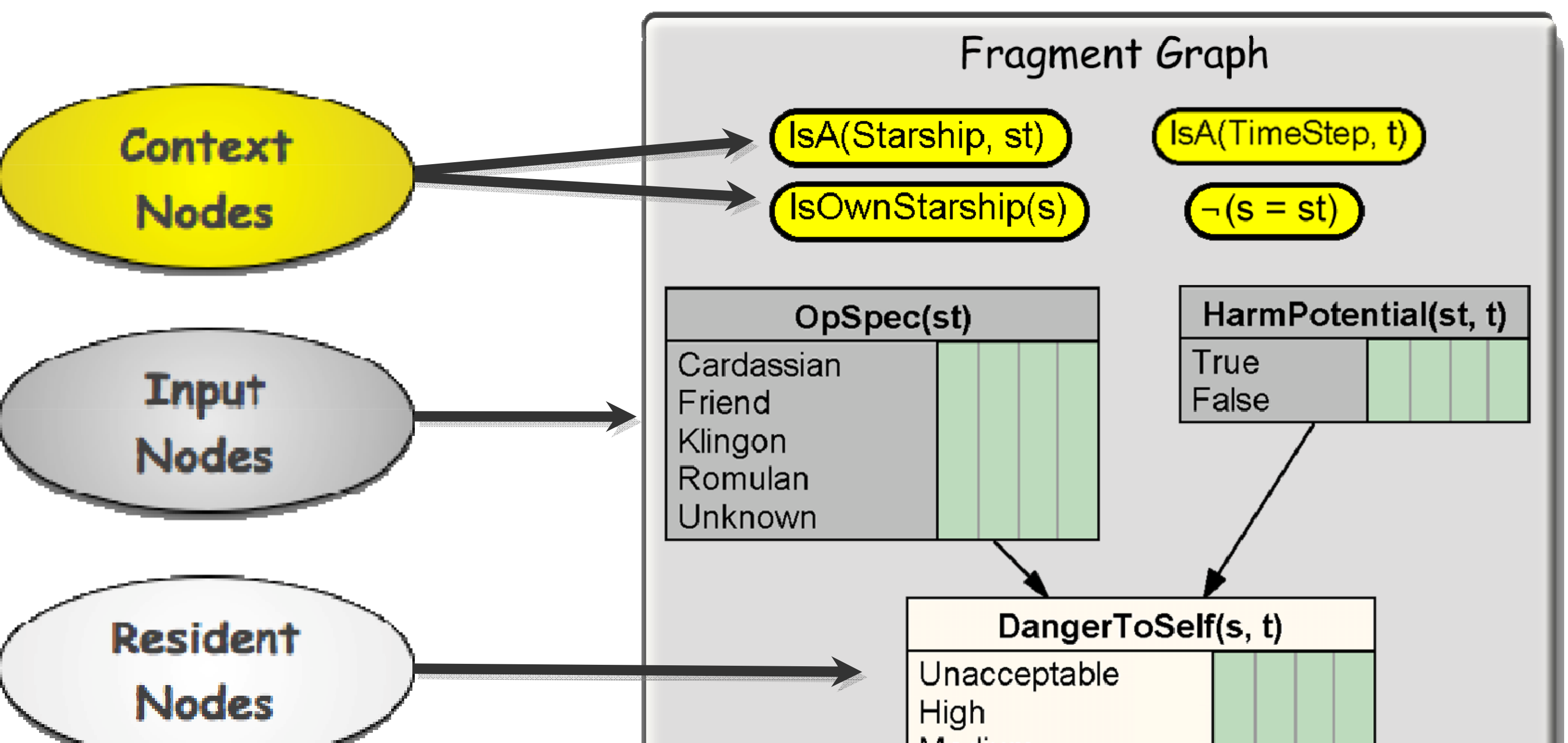
lti-Entity Bayesian Networks



MEBN Fragments



- Building blocks that collectively form a model (MTheory)
- Each one stores a specific "Chunk of knowledge"



. Probabilistic Ontology Language

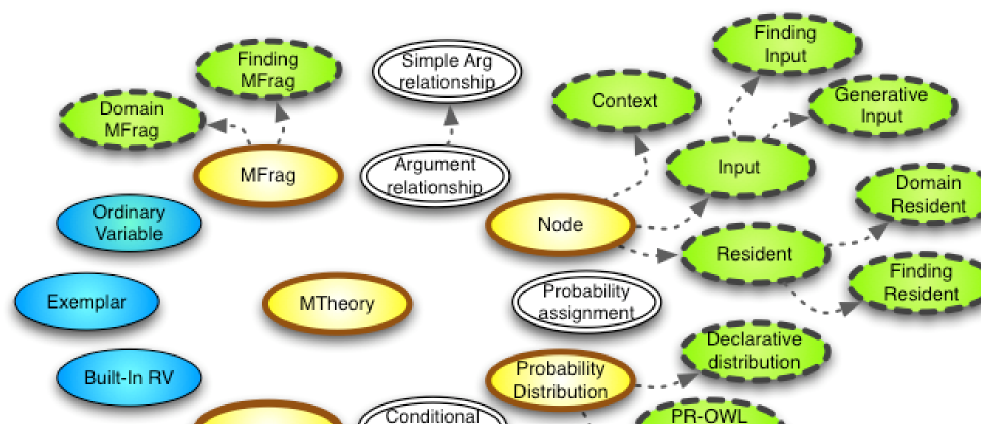
ntology written in W3C-recommended OWL ontology
e.

nts probabilistic knowledge in XML-compliant format.

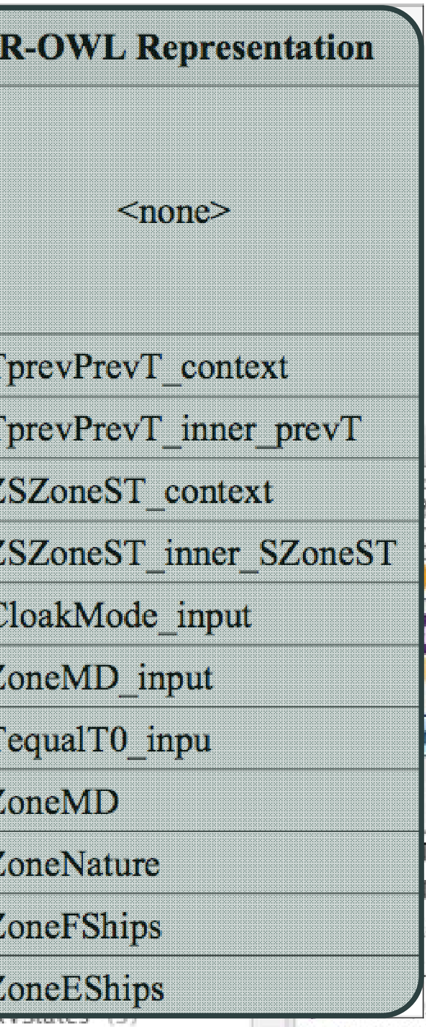
n MEBN, a probabilistic logic with first-order
ve power

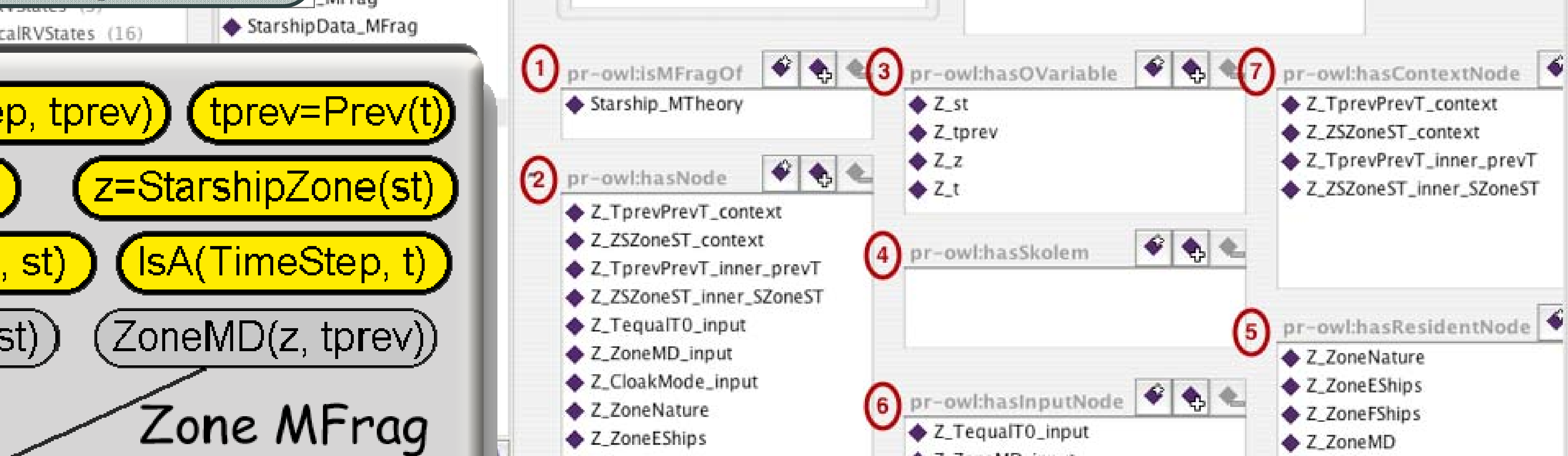
urce, freely available solution for representing
ge and associated uncertaint

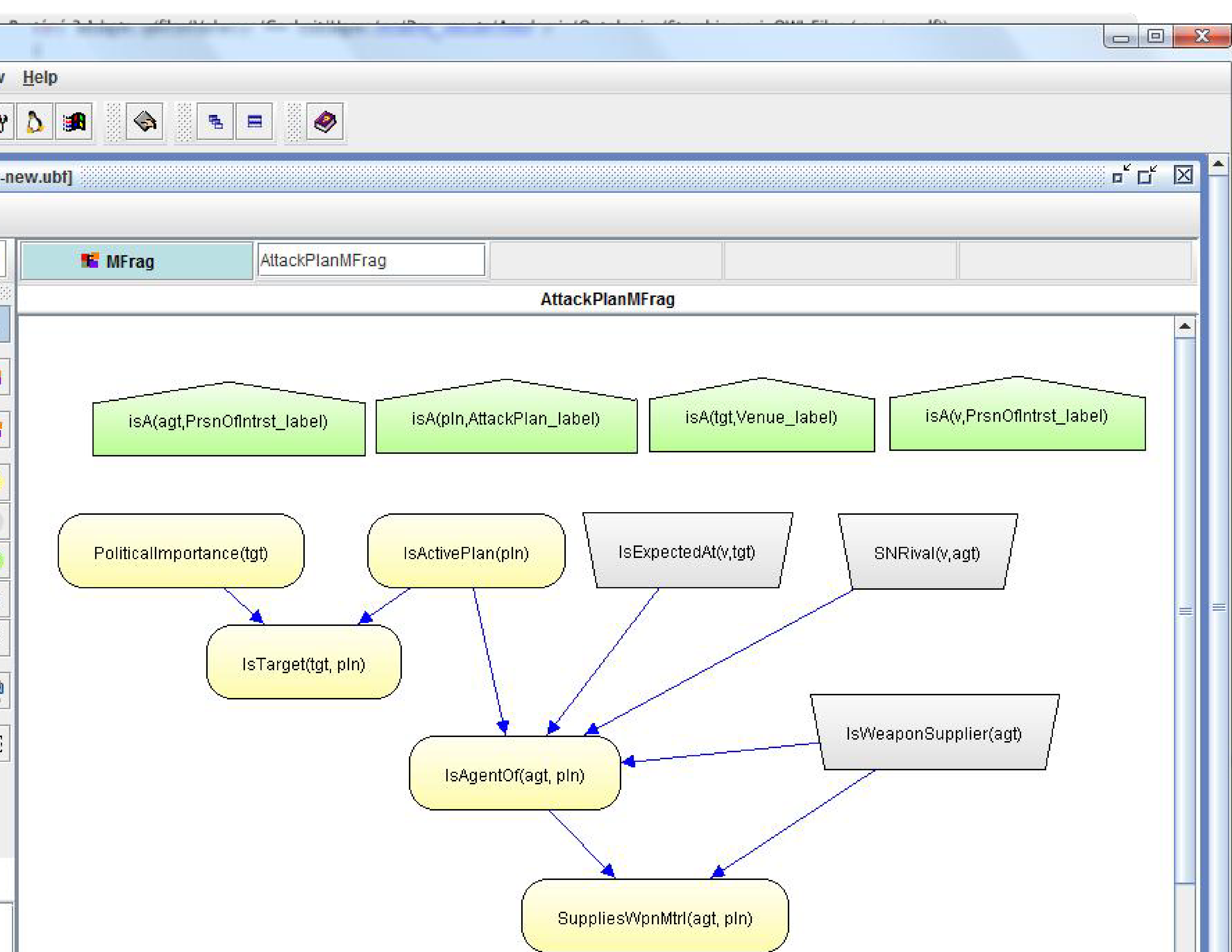
er under development
oration with University
a



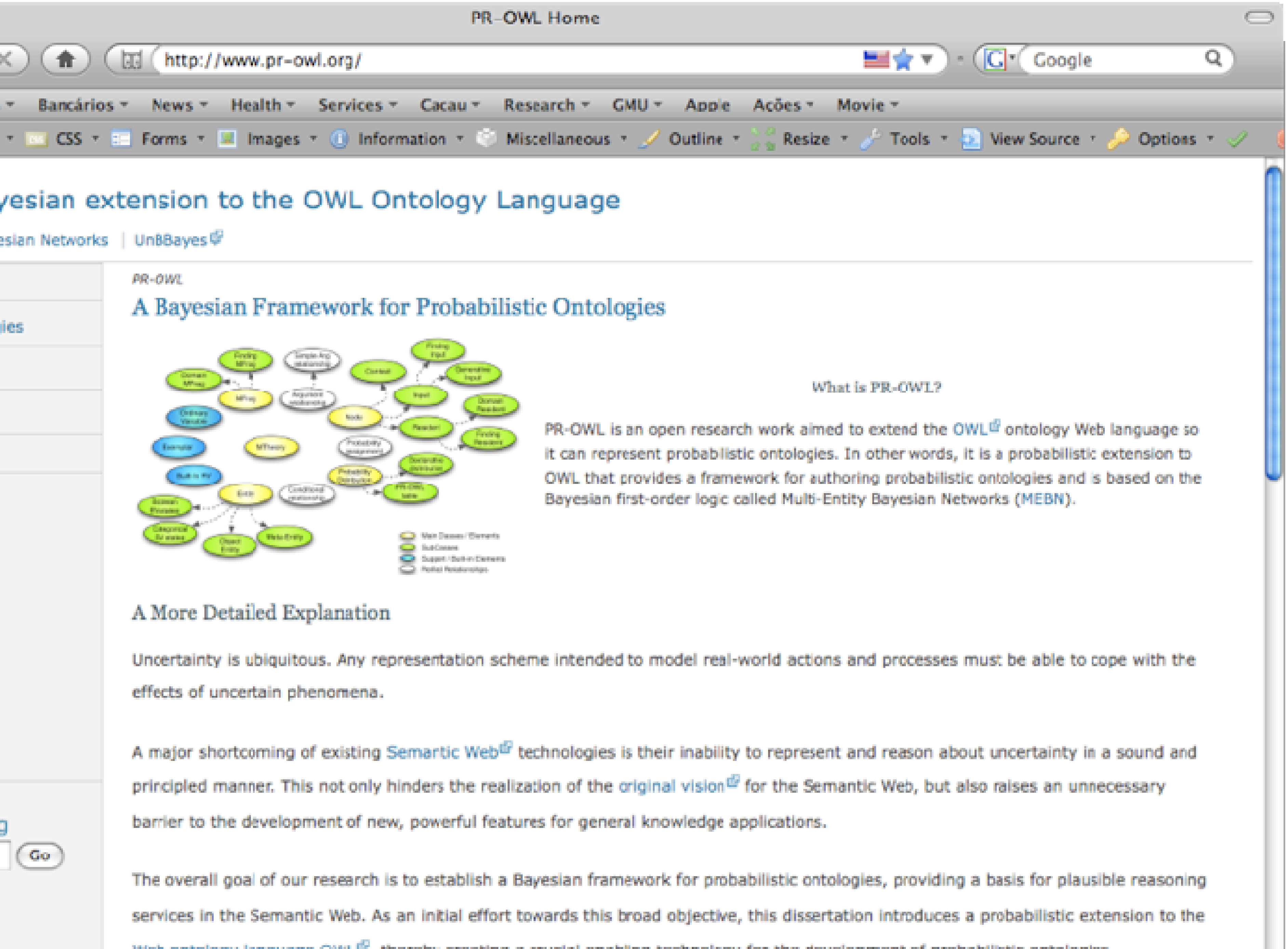
PR-OWL vs. OWL


R-OWL Representation
<none>
TprevPrevT_context
TprevPrevT_inner_prevT
ZSZoneST_context
ZSZoneST_inner_SZoneST
CloakMode_input
ZoneMD_input
TequalT0_inpu
ZoneMD
ZoneNature
ZoneFShips
ZoneEShips


beta (file:/Users/pc/Documents/Academia/Ontologies/Starship.pprj, OWL Files (.owl or .rdf))
protégé
OWLClasses
Properties
Forms
Individuals
Metadata
BROWSER
INDIVIDUAL EDITOR
pr-owl:Domain_M...
For Individual Zone_MFrag (instance of pr-owl:Domain_MFrag)
Inferred
Name
SameAs
DifferentFrom
Annotations
Property
Value
Lang
Zone_MFrag
rdfs:comment
ToOthers_MFrag
ToSelf_MFrag
eport_MFrag
MFrag
_MFrag
StarshipData_MFrag
calRVStates (16)
1
pr-owl:isMFragOf
Starship_MTheory
2
pr-owl:hasNode
Z_TprevPrevT_context
Z_ZSZoneST_context
Z_TprevPrevT_inner_prevT
Z_ZSZoneST_inner_SZoneST
Z_TequalT0_input
Z_ZoneMD_input
Z_CloakMode_input
Z_ZoneNature
Z_ZoneEShips
3
pr-owl:hasOVariable
Z_st
Z_tprev
Z_z
Z_t
4
pr-owl:hasSkolem
6
pr-owl:hasInputNode
Z_TequalT0_input
7
pr-owl:hasContextNode
Z_TprevPrevT_context
Z_ZSZoneST_context
Z_TprevPrevT_inner_prevT
Z_ZSZoneST_inner_SZoneST
5
pr-owl:hasResidentNode
Z_ZoneNature
Z_ZoneEShips
Z_ZoneFShips
Z_ZoneMD
ep, tprev)
tprev=Prev(t)
z=StarshipZone(st)
, st)
IsA(TimeStep, t)
st)
ZoneMD(z, tprev)
Zone MFrag


Help
-new.ubf]
MFrag
AttackPlanMFrag
AttackPlanMFrag
isA(agt,PrsnOfIntrst_label)
isA(pln,AttackPlan_label)
isA(tgt,Venue_label)
isA(v,PrsnOfIntrst_label)
PoliticalImportance(tgt)
IsActivePlan(pln)
IsExpectedAt(v,tgt)
SNRival(v,agt)
IsTarget(tgt, pln)
IsWeaponSupplier(agt)
IsAgentOf(agt, pln)
SuppliesWpnMtrl(agt, pln)

sources - PR-OWL Website



Agenda

Knowledge Exchange in C^2

Ontologies

Probabilistic Ontologies

Pragmatic Frames

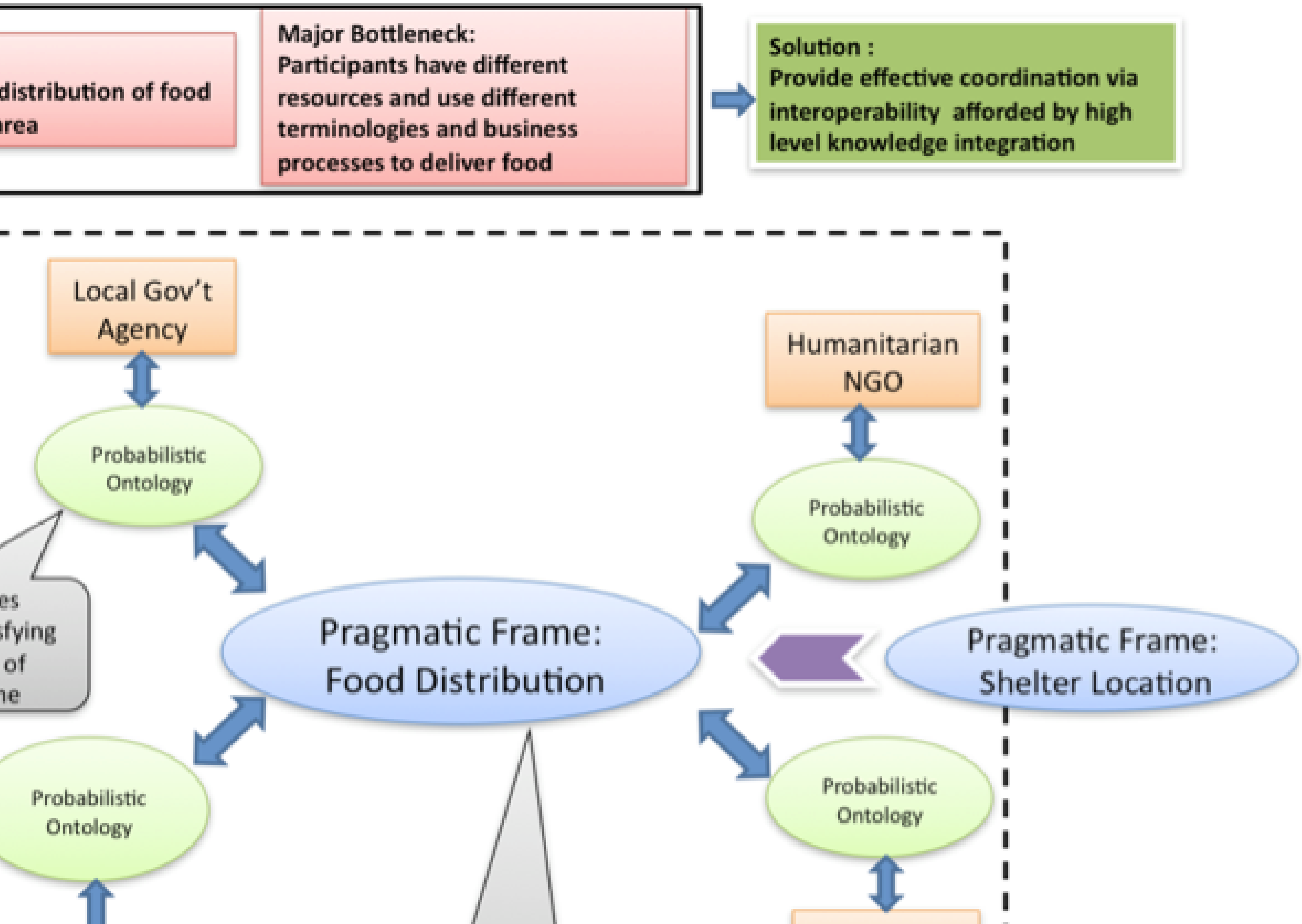
ding Context to Semantics

gmatics be seen as the use of context rmation to disambiguate meaning

gmatic frames are a means to convey gmatics through an ontological nework

ontology supports (or is applicable to) agmatic frame if the world states (or e changes) that it can describe include

ple: Disaster Relief Operations



hanks for your Attention!!!