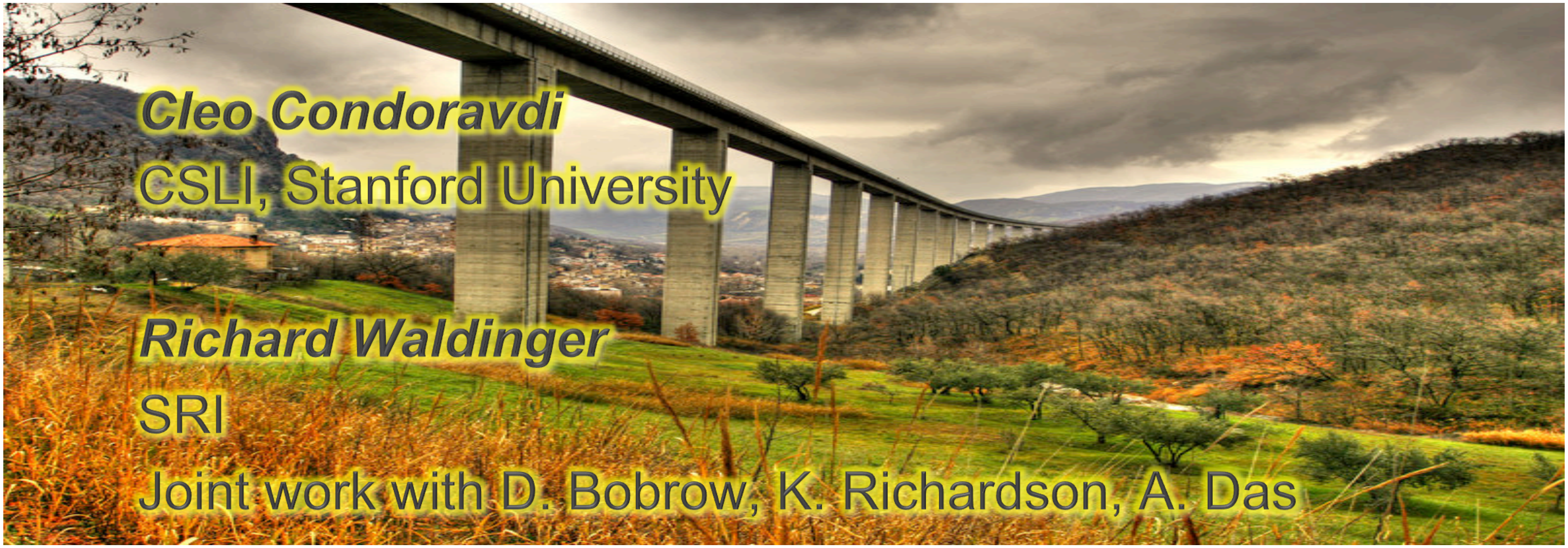
Domain-guided construction of semantic representations for model-based interpretation



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Quadri Project Team

Funding: National Institute of Health (NIH)

- PARC
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- SRI International
  - **Richard Waldinger** Artificial Intelligence Center
- Stanford University
  - **Amar Das** Biomedical Informatics Research
  - **Bob Shafer** Stanford HIV Database Curator
  - **Soo-Yon Rhee** Stanford HIV Database Curator

Textual Inference Task

Does premise *P* lead to conclusion *C*?

Does text *T* support the hypothesis *H*?

Does text *T* answer the question *H*?

… *without any additional assumptions*

P: *Every explorer failed to get to the South Pole.*
C: *No experienced explorer reached the South Pole.*
Yes

P: *Ed has been living in Athens for 3 years.*
Mary visited Athens in the last 2 years.
C: *Mary visited Athens while Ed lived in Athens.*
Yes

Inference Task

Does a given specifications of the world *D* support the statement *S*?

Is statement *S* true relative to a state of the world as specified by *D*?

What is the answer to the question *Q* relative to a dataset/ database *D*?

Which rivers flow through the states that border California?

Geobase

A small database of information about United States geography with about 800 facts, represented as Prolog assertions

States - their capitals, populations, areas, population densities, major cities, rivers and the bordering states

Cities - their populations and the states they are in

Rivers - their lengths and the states through which they flow

Mountains - their heights and the states they are in

Inference Task

What is the answer to question *Q* relative to a dataset/database *D*?

http://www.cs.utexas.edu/users/ml/geo-demo.html

Geoquery:

*Which rivers flow through the states that border California***?**

CHILL:

[colorado,columbia,gila,snake]

Formal Language Query:

```
  answer(_74,
(river(_74),traverse(_74,_75),state(_75),next_to(_75,_76),const(_76,stateid(california))))
```

X borders Y ➡ X next_to Y
X flows through Y ➡ X traverse Y

Inference Task

What is the answer to question *Q* relative to a dataset/database *D*?

Geoquery:
*How many states does the Mississipi run through***?**
CHILL:
[10]

Formal Language Query:

answer(_86,count(_87,
(state(_87),const(_88,riverid(mississippi)),traverse(_88,_87)),_86))

Inference Task

What is the answer to question *Q* relative to a dataset/database *D*?

http://www.cs.utexas.edu/users/ml/geo-demo.html

Geoquery:

Does California have at least 2 rivers?

CHILL:

[mississippi]

Formal Language Query:

answer(_82,(const(_83,stateid(california)),smallest(_83,river(_82))))

at least 2 rivers ➡ cardinality of rivers such that …

at least 2 rivers ➡ smallest river

Database table structure: temporally bound treatments

Regimen Table

Field	DB Type
Regimen Id	Key Id
Patient Id	Id
Start Date	String (D/M/Y)
End Date	String (D/M/Y)
Drug Set	String (D1+D2+D3)

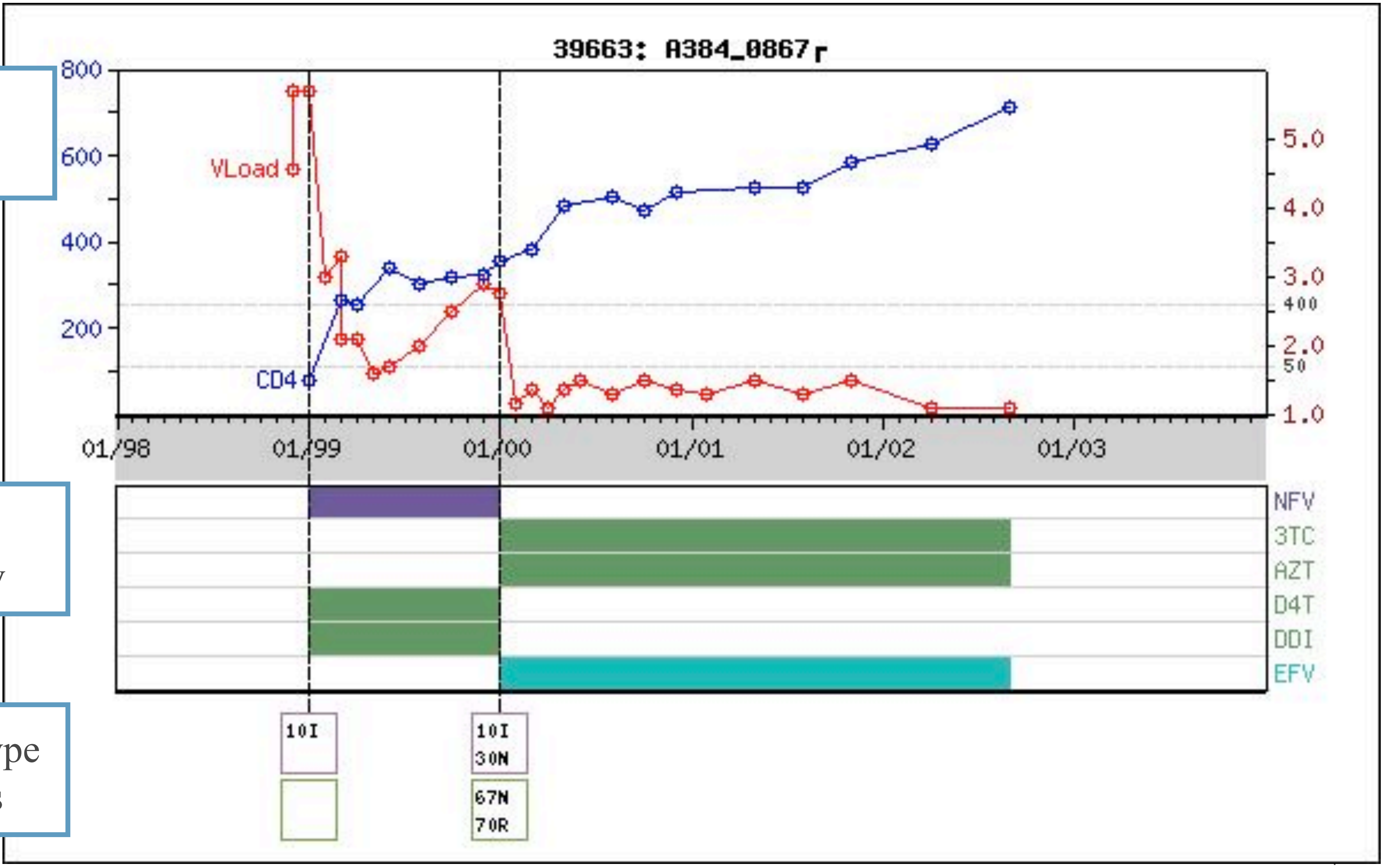
What regimens include drug AZT?
What patients had a regimen with at least 2 PIs?
What patients had a regimen with EFV for more than 24 weeks?

HIV drug resistance

- HIV has complex treatment patterns
- Drug-resistant mutations are a major obstacle to the success of treatment

- Stanford has useful databases in this domain
- Anonymized patient records
- Summaries of clinical trials
- Ontologies of drugs, treatments, terms

HIV Drug Resistance

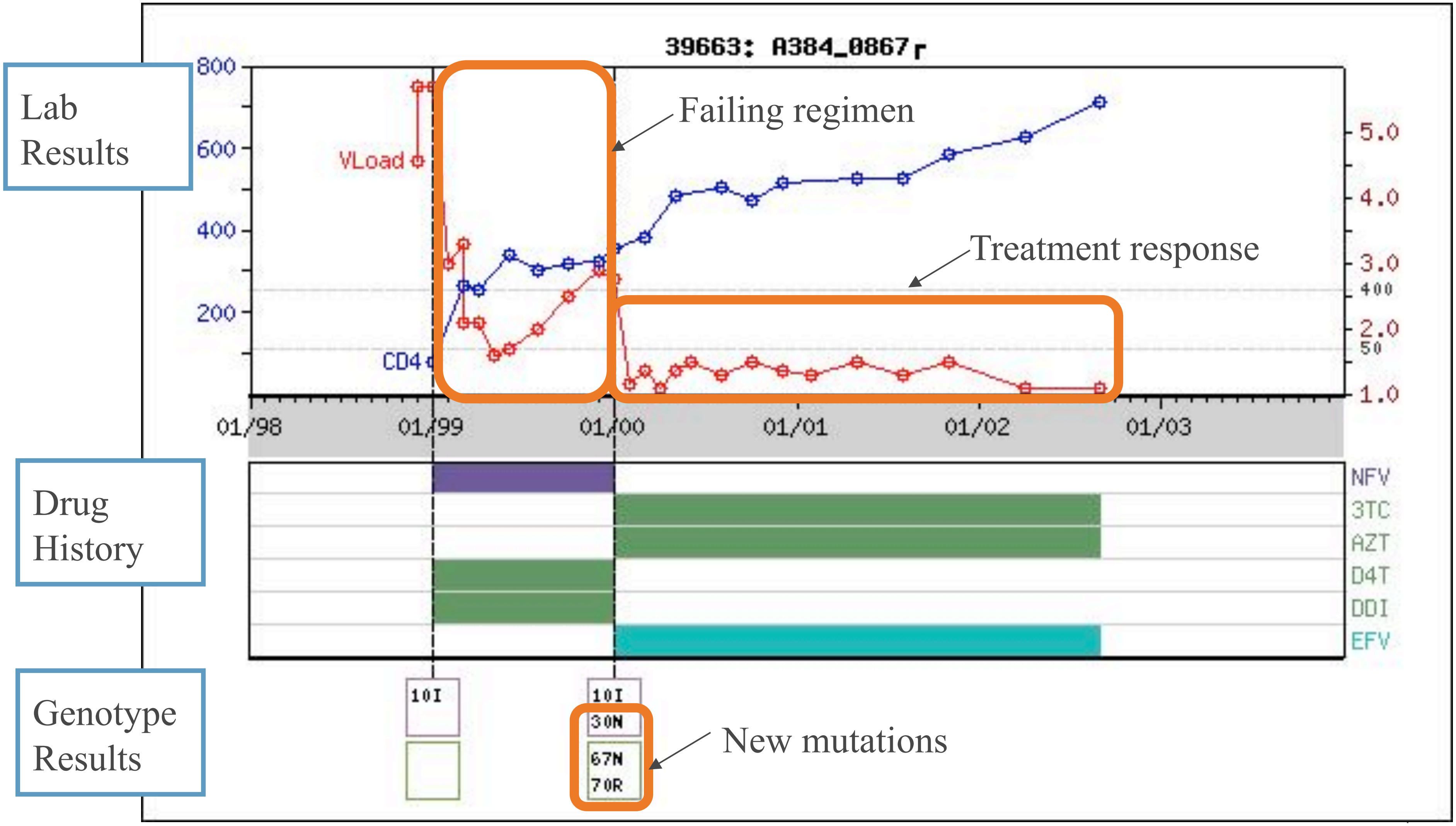


Lab Results

Drug History

Genotype Results

HIV Drug Resistance



Lab Results

Drug History

Genotype Results

Failing regimen

Treatment response

New mutations

Database table structure: temporally bound treatments

Regimen Table

Field	DB Type
Regimen Id	Key Id
Patient Id	Id
Start Date	String (D/M/Y)
End Date	String (D/M/Y)
Drug Set	String (D1+D2+D3)

What regimens include drug AZT?
What patients had a regimen with at least 2 PIs?
What patients had a regimen with EFV for more than 24 weeks?

Virtual tables support higher level queries

TCE (treatment change episode) Table

Field	DB Type
TCE Id	Key Id
Patient Id	Id
Failing Reg.	Id
Salvage Reg.	Id
Start Date	String (D/M/Y)
End Date	String (D/M/Y)
Baseline Duration	Number

What TCEs have a genotype of M184V during the failing regimen?

Motivation for NL Interface to databases
How can I see what is in those databases?

What patients on Atripla exhibited a high viral load?

Stanford HIV clinical data

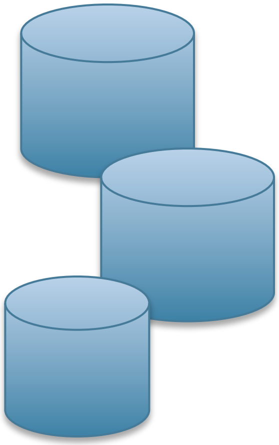
What makes it difficult to access?

What patients on Atripla exhibited a high viral load?

What are the databases that are available?

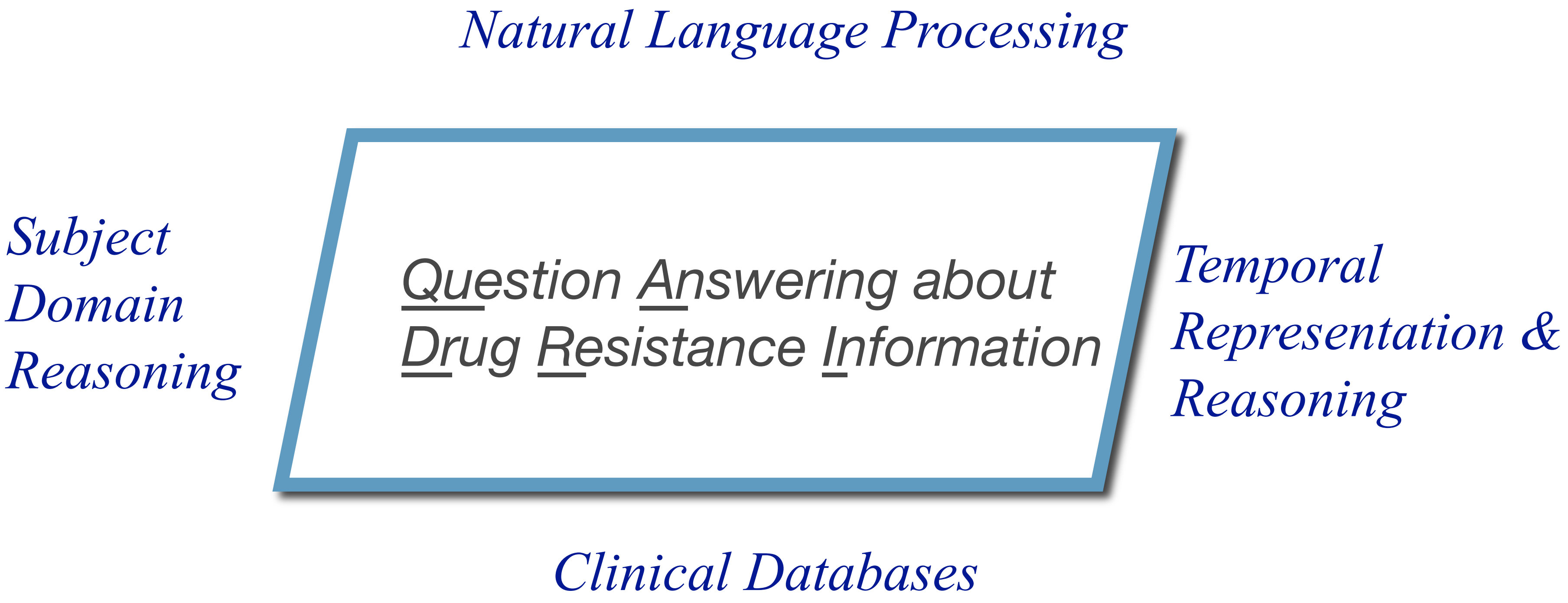
What is their structure?

How do I get information out of them?



Multiple Databases

Quadri: Intelligent Question Answering in the HIV Domain



Natural Language Processing

Subject Domain Reasoning

Question Answering about Drug Resistance Information

Temporal Representation & Reasoning

Clinical Databases

NIH Funding Support: 1RC1LM010583-01, 1R01LM009607-01A2, 5R01AI068581-04

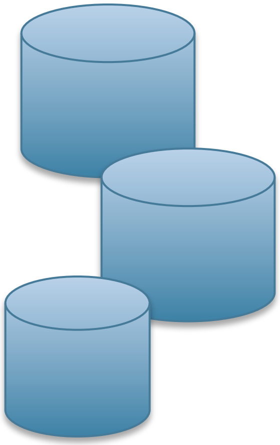
Quadri: simplifies access in HIV domain

Customizing general NL and Reasoning Systems

What patients on Atripla exhibited a high viral load?

PARC’s Bridge

SRI’s Snark



Stanford’s
HIV Databases
+ Other Resources

Transformations in processing a query

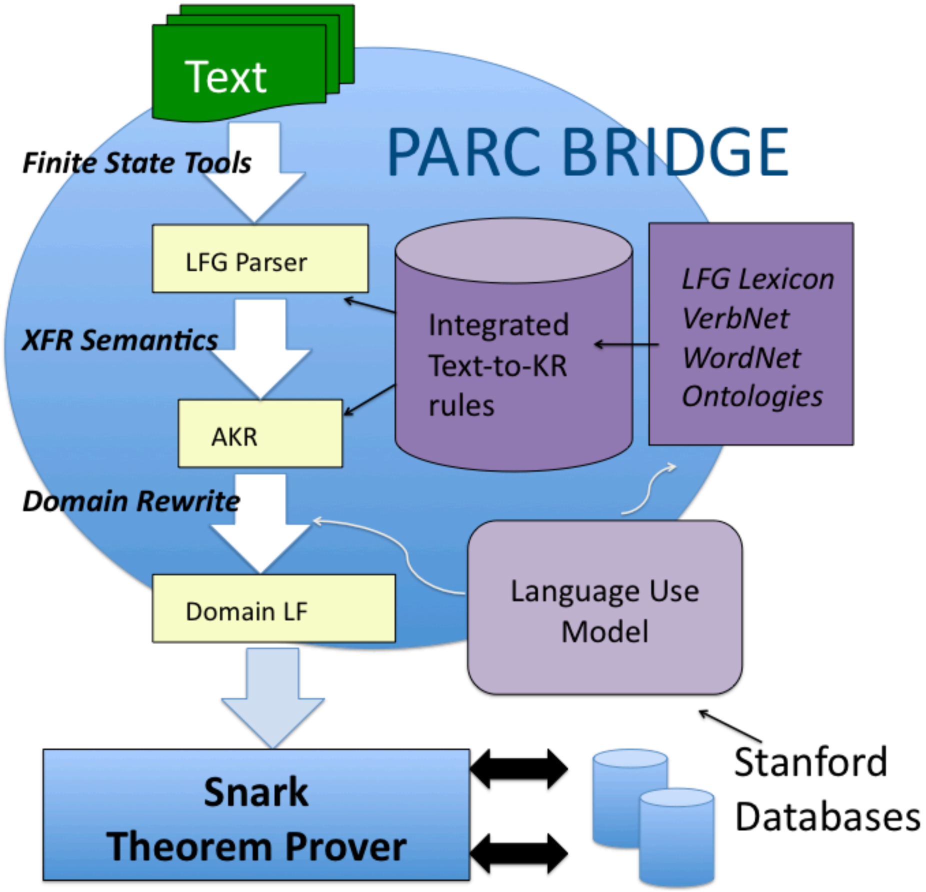
Language Processing

- Text query
- Dependency parse
- Abstract KR
- Flat logical form (LF)
  with domain-specific relations

Logic Processing

- Translation to nested LF
- Feedback to user
- Prove the theorem
  domain theory + DB facts
- Display the answer

Quadri architecture



Sample questions

- *What mutations were found in patients after they failed AZT?*

- *Find all patients who had a high viral load on a regimen with EFV after 24 weeks.*

- *Find patients who were on Atripla for at least 12 weeks. They failed that regimen. They were then switched to a new regimen.*

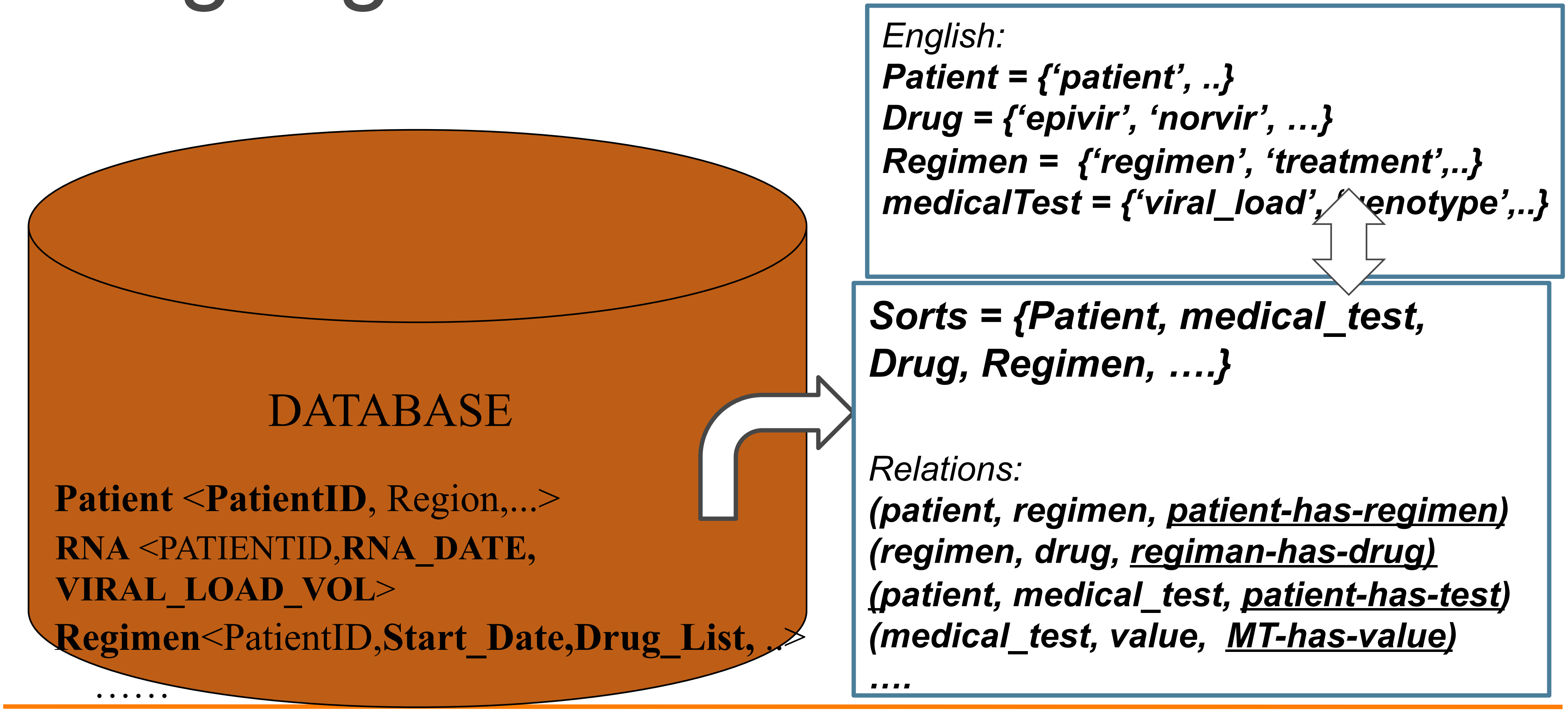
-

Axiomatic Subject-Domain Theory

- A domain-specific knowledge base where knowledge is expressed as *axioms*
- Higher level abstraction of the contents of the databases
  - Basic domain relations for which there is a correspondence in the databases, e.g. patient, patient-has-regimen
  - Derived domain relations, e.g. failing-regimen, AZT-naive
  - Translate qualitative specifications into quantitative specifications
  - Temporal axioms
  - Axioms relating regimens and their time spans

HIV Domain

Language Use Model



English:
Patient = {‘patient’, ..}
Drug = {‘epivir’, ‘norvir’, …}
Regimen = {‘regimen’, ‘treatment’,..}
medicalTest = {‘viral_load’, ‘genotype’,..}

DATABASE

Patient <**PatientID**, Region,...>
RNA <PATIENTID,**RNA_DATE, VIRAL_LOAD_VOL**>
Regimen<PatientID,**Start_Date,Drug_List,** ..>
……

Sorts = {Patient, medical_test, Drug, Regimen, ….}

Relations:
(patient, regimen, patient-has-regimen)
(regimen, drug, regiman-has-drug)
(patient, medical_test, patient-has-test)
(medical_test, value, MT-has-value)
….

Semantic link to databases

- Link symbol in axiomatic theory with database(s)
- Axiomatic “advertisements” describe content of database
- The ground formulas of the theory are the relations in the database(s)
- Procedural attachments convert from date stamps in the database to time intervals
- Database invoked as proof search is underway

Semantic types in the language

Regimen Table

Field	DB Type	Semantic Type
Field	DB Type	Regimen
Regimen Id	Key Id	
Patient Id	Id	Patient
Start Date	String (D/M/Y)	Time Point
End Date	String (D/M/Y)	Time Point
Drug Set	String (D1+D2+D3)	Drug

What regimens include drug AZT?

What patients had a regimen with at least 2 PIs?

What patients had a regimen with EFV for more than 24 weeks?

Reasoning needed to interpret query

*Find patients who had a **high viral load** after 24 weeks on a regimen with **Atripla**.*

Interpret qualitative terms wrt numbers

high viral load *means* viral_load > **1000**

Expand **Atripla** wrt standard drugs

EFV/FTC/TDF

efavirenz,emtricitabine, and tenofovir disoproxil fumarate

Example Axiom

```
(failing-regimen-for-patient ?regimen ?patient
  ?time-point ?viral-load)
          ⇔
(and (patient-on-regimen ?patient ?regimen)
  (has-test viral-load ?patient ?time-point ?viral-load)
  (near-end ?time-point ?regimen)
  (viral-load-has-level ?viral-load high))
```

A failing regimen for a patient is one in which the patient has a high viral load near the end of the regimen

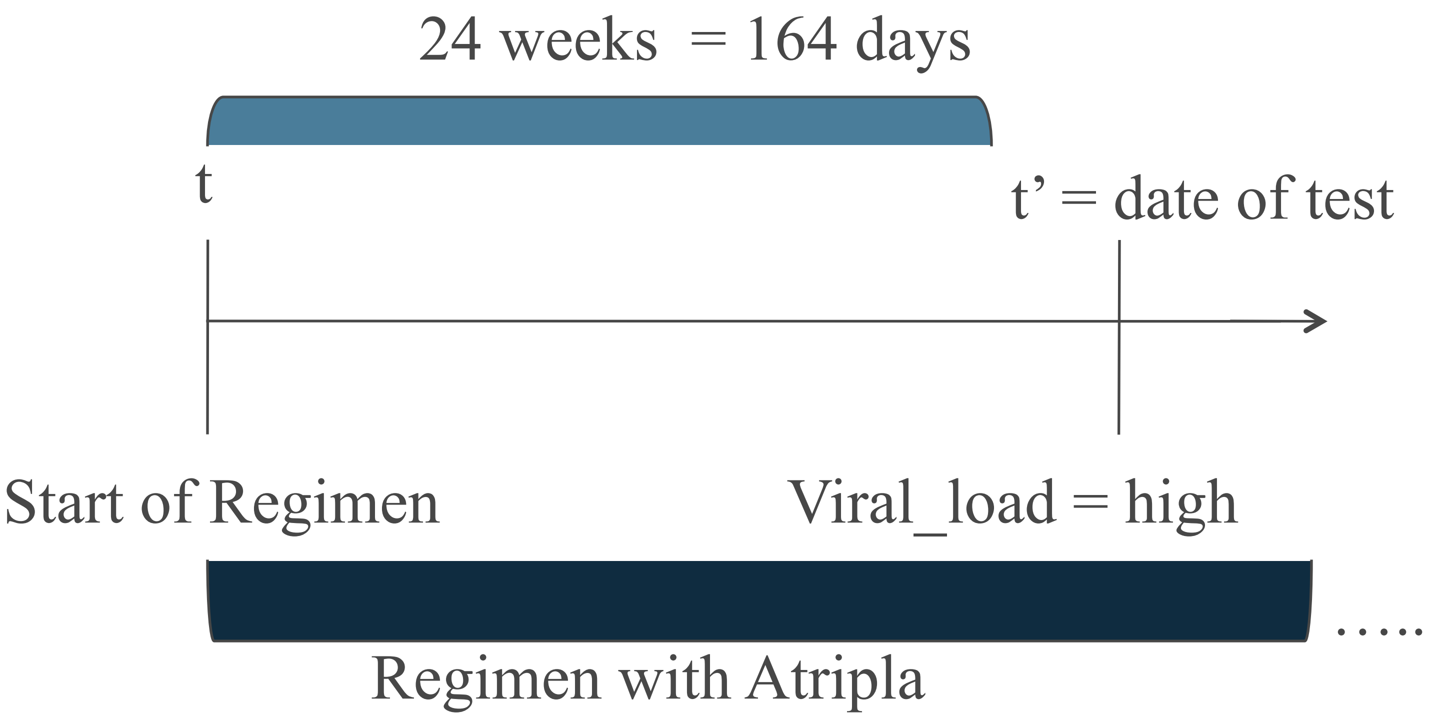
Example Axiom

```
(near-end ?time-point ?time-interval)
⇔
(and
    (within-pi ?time-point ?time-interval)
  (=< (* 4 (minus-time (finish-time ?time-interval) ?time-point))
  (duration ?time-interval))
```

A time-point is near the end of a time-interval if it is in the 4th quarter of the interval (can be changed)

Quantitative reasoning about time

Find patients who had a high viral load after 24 weeks on the regimen with Atripla



Temporal Reasoning

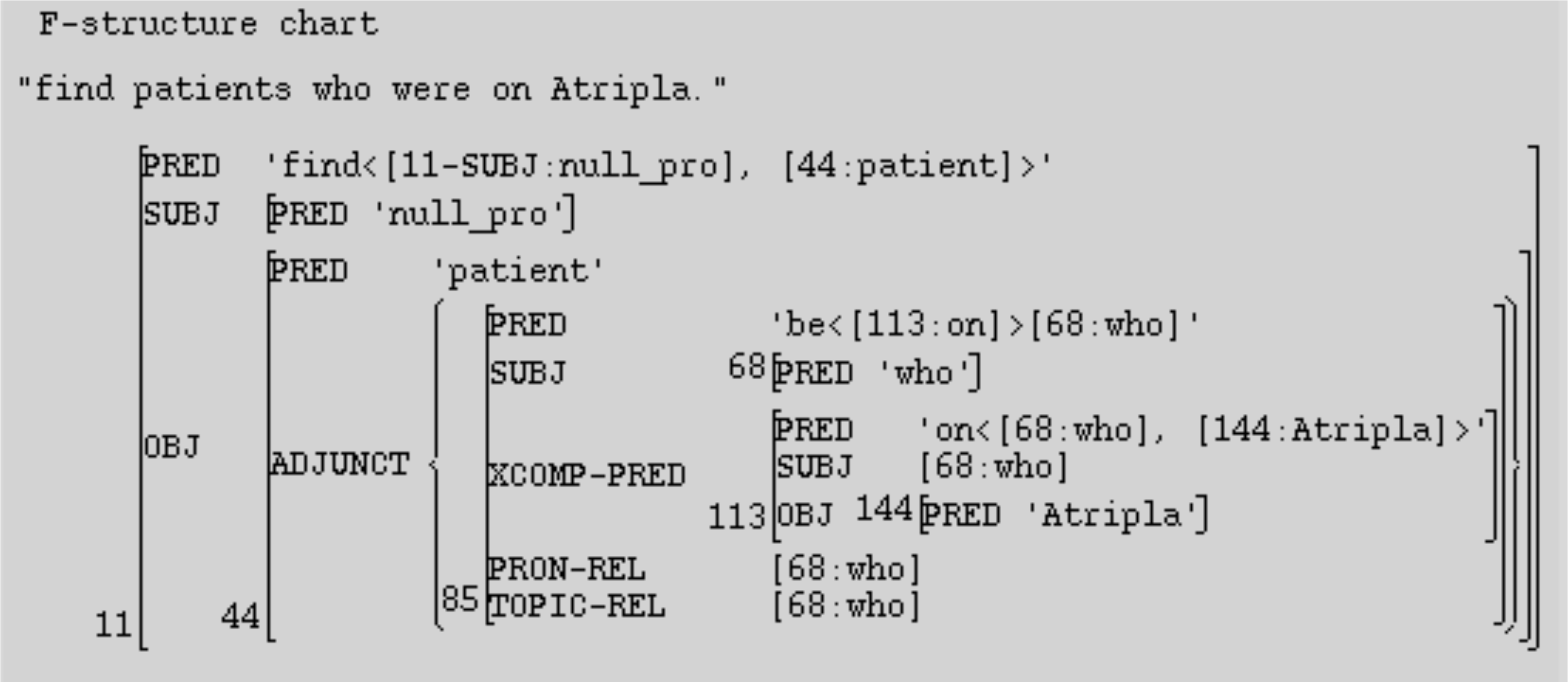
- Reasoning about time points and intervals (Allen calculus)
- Date and time computations
- Durations
- Unit conversion

BRIDGE system for language analysis

- BRIDGE is a broad coverage, general purpose natural language processing system.
- Stages of processing
  - Parsing
  - Abstract Knowledge Representation
- Bridge preserves ambiguities, marking local choices (packing).
- Customization
  - Task – Building Logical Forms
  - Domain – Recognizing HIV relations

Parsing produces functional structures

Find patients who were on Atripla.



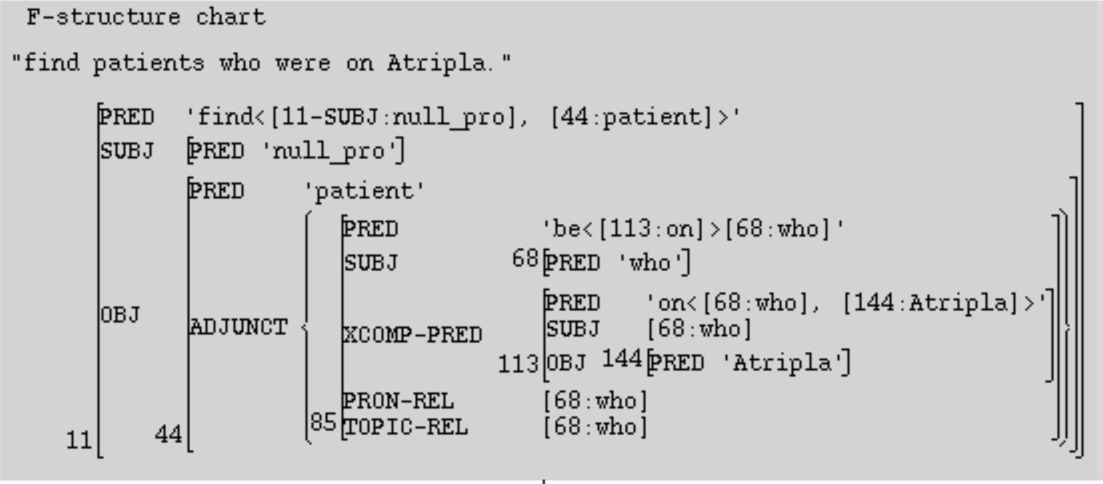
```
 F-structure chart

"find patients who were on Atripla."

      PRED   'find<[11-SUBJ:null_pro], [44:patient]>'
      SUBJ   PRED 'null_pro'
             PRED      'patient'
                          PRED          'be<[113:on]>[68:who]'
                          SUBJ        68 PRED 'who'
                                         PRED   'on<[68:who], [144:Atripla]>'
                                         SUBJ   [68:who]
      OBJ    ADJUNCT      XCOMP-PRED
                                     113 OBJ 144 PRED 'Atripla'
                          PRON-REL       [68:who]
                       85 TOPIC-REL      [68:who]
    11           44
```

F-structures mapped to Abstract KR

Find patients who were on Atripla.



```
 F-structure chart

"find patients who were on Atripla."

       PRED   'find<[11-SUBJ:null_pro], [44:patient]>'
       SUBJ   [PRED 'null_pro']
              PRED    'patient'
                        PRED             'be<[113:on]>[68:who]'
                        SUBJ          68 [PRED 'who']
                                          PRED    'on<[68:who], [144:Atripla]>'
       OBJ    ADJUNCT { XCOMP-PRED        SUBJ    [68:who]
                                      113 OBJ 144 [PRED 'Atripla']
                        PRON-REL          [68:who]
     11       44      85 TOPIC-REL        [68:who]
```

AKR subconcept(find-0, [find#v#1, detect#v#1, find#v#3])
subconcept(Atripla-15, [drug_combo#n#1])
alias(Atripla-15, [Atripla])
subconcept(patient-3, [patient#n#1, affected_role#n#1])
role(ob, find-0, patient-3)
role(prep(on), patient-3, Atripla-15)

AKR to Domain-Specific Logical Form

Find patients who were on Atripla.

AKR

subconcept(find-0, [find#v#1, detect#v#1, find#v#3]
subconcept(Atripla-15, [drug_combo#n#1]
alias(Atripla-15, [Atripla])
subconcept(patient-3, [patient#n#1, affected_role#n#1])
role(ob, find-0, patient-3)
role(prep(on), patient-3, Atripla-15)

↓

QUADRI

patient-has-drug-combo(patient-3, Atripla-15)
sort(patient-3, patient)
sort(Atripla-15, drugCombo)

Plus quantifier information…

Domain sort and relation mapping

- Domain relations have **argument signature**

  patient-has-regimen*(**patient, regimen**)*

  patient-has-test*(**patient, medical_test**)*

  regimen-has-drug-combo*(**regimen, drug_combo**)*

  test-time*(**medical_test, time_point**)*

  test-has-value*(**medical_test, test_result**)*

- Words (phrases) labeled for sort

  *patient_1:**patient***

  *viral_load_2:**medical_test***

Task-specific customization: AKR → logical form

- Identification of quantifiers

  e.g. *every, some, at least 2, many*, …

- Cardinality vs. Measure specification

  e.g. *at least 2 regimens, at least 8 weeks*, …

- Mapping of conditions associated with quantified terms
  - e.g. distinguishing between restriction and nuclear scope
  - *every patient who has property P (does X) :* $\forall x\ (\, patient(x)\ \&\ P(x) \rightarrow \ldots\,)$
  - *every patient has property P :* $\forall x\ (\, patient(x) \rightarrow P(x)\,)$

- Fix scope relations between quantifiers
  - AKR underspecifies the scope of quantified terms
  - Scoping restrictions imposed by the grammar
  - Heuristics for fixing scope underdetermined by the grammar

Task-specific customization: AKR → logical form

Donkey anaphora

every patient on a regimen with AZT failed the regimen after 24 weeks

Dependencies between terms do not align with syntactic structure

a patient with norvir had a high viral load

```
synlink(ob,have-6,viral_load_3)
synlink(sb,have-6,patient_8)
synlink(prep(with),patient_8,norvir_2)
synlink(nn_element,viral_load_3,high_7)
semlink(patient_8,regimen_9)
semlink(patient_8,viral_load_3)
semlink(regimen_9,norvir_2)
semlink(viral_load_3,high_7)
```

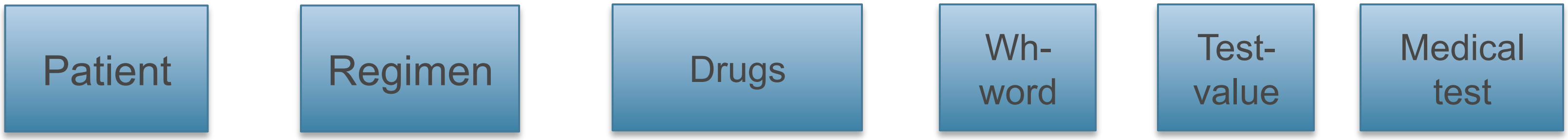
every patient had a high viral load after 8 weeks on a regimen with norvir

Interpretation in the domain

Disambiguation via interpretation in the domain

Illustration

Find a **patient** on a **regimen** with **norvir and epivir who** had a **high viral load**



Patient

Regimen

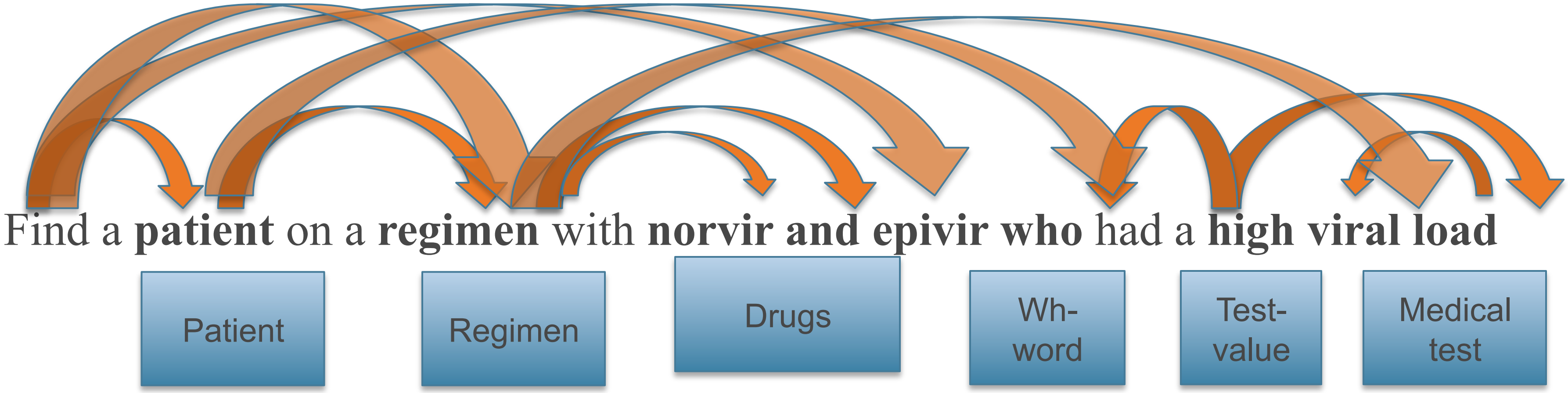
Drugs

Wh-word

Test-value

Medical test

Illustration



Find a **patient** on a **regimen** with **norvir and epivir who** had a **high viral load**

Patient

Regimen

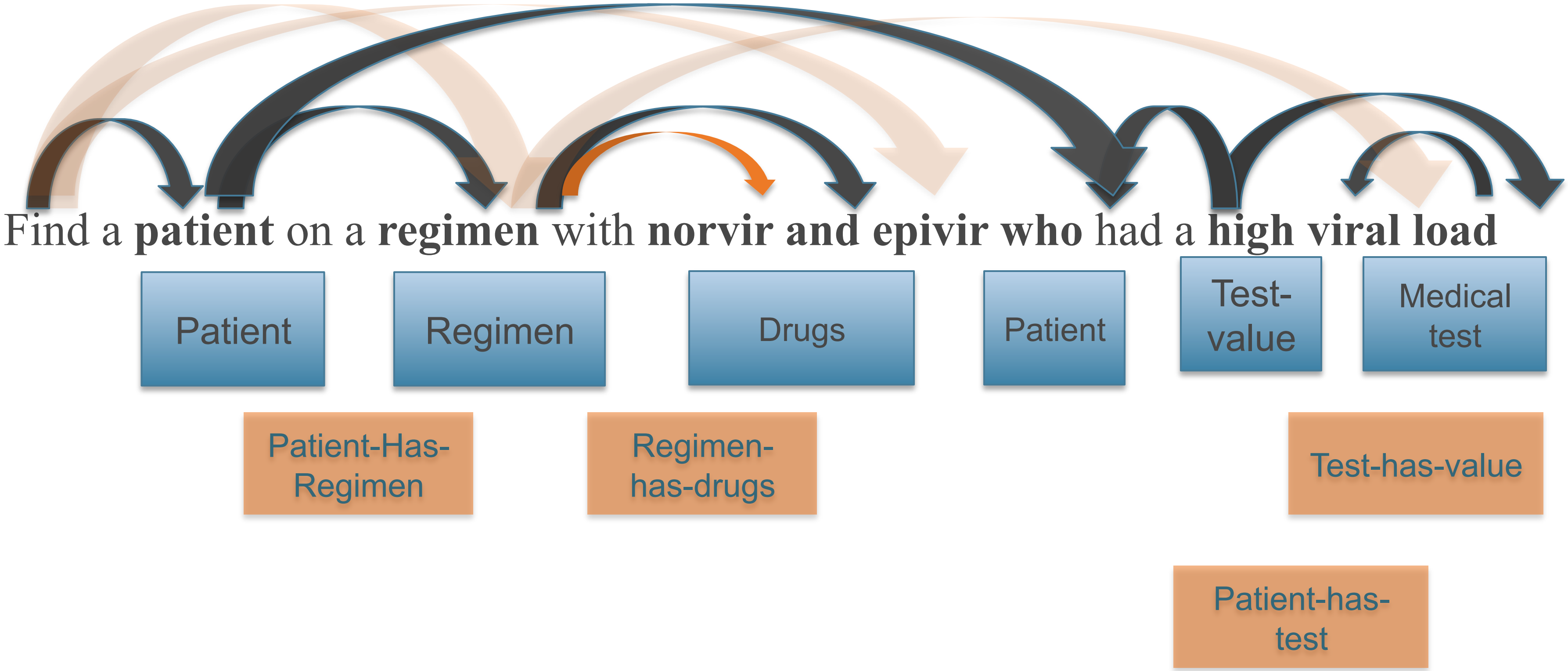
Drugs

Wh-word

Test-value

Medical test

Illustration



Find a **patient** on a **regimen** with **norvir and epivir who** had a **high viral load**

Patient

Regimen

Drugs

Patient

Test-value

Medical test

Patient-Has-Regimen

Regimen-has-drugs

Test-has-value

Patient-has-test

Find linguistic links between word-pairs that match argument signatures

Find patients who had a high viral load after 24 weeks on a regimen with Atripla.

Direct Link (e.g. preposition)

role(prep(with), regimen_3, atripla_4)

→**semlink(regimen_3, atripla_4, via(prep(with))**

record linguistic link

Coarguments of the verb

role(sb, have, patient_1)

role(ob, have, viral_load_2)

→**semlink(patient_1, viral_load_2, via(have))**

record linguistic link

Semlinks map to DS relations

- Independent of linkage structure

semlink(X, Y, Z) iff X:patient, Y:medical_test, Z:any

➔ patient-has-test(X, Y)

a patient (had / with) a high viral load

- Specific to linkage structure

semlink(X, Y, Z)
iff X:time_period, Y:regimen, Z:via(prep(on))

➔initial-interval(X,Y)

24 weeks on a regimen vs~~. 24 weeks after a regimen~~

Recovering implicit terms and relations

patient-has-test(M, Test)

➔

exists time_point TP,

test-time(M, Test, TP)

----

patient-has-drug(P, D)

➔

exists regimen R,

patient-has-regimen(P, R)

regimen-has-drug(R, D)

Ambiguity management

Options multiplied out

$$\left\{\begin{array}{l}\textit{The sheep-sg liked the fish-sg.}\\ \textit{The sheep-pl liked the fish-sg.}\\ \textit{The sheep-sg liked the fish-pl.}\\ \textit{The sheep-pl liked the fish-pl.}\end{array}\right\}$$

Options packed

$$\textit{The sheep}\left\{\begin{array}{c}\textit{sg}\\ \textit{pl}\end{array}\right\}\textit{liked the fish}\left\{\begin{array}{c}\textit{sg}\\ \textit{pl}\end{array}\right\}$$

Packed representation:

- – Encodes all dependencies without loss of information
- – Common items represented, computed once
- – Key to practical efficiency with broad-coverage grammars

Packing

- Calculate and represent compactly all analyses at each stage
- Pass all or N-best analyses along through the stages
- Mark ambiguities in a free choice space
- Choice space:
- $A1 \vee A2 \leftrightarrow \mathit{true}$
- $A1 \wedge A2 \rightarrow \mathit{false}$

Ambiguity passed on in AKR →LF mapping

The patient [had [a regimen [with norvir]]]

[had [a martini [with an olive]]]

The patient [had [a regimen] [with norvir]]

[had [a martini] [with Olivia]]

Choice: (A1 xor A2) iff 1

A1: role(prep(with), have-1, norvir-5)

A2: role(prep(with), regimen-12, norvir-5)

Reducing choice space via selection

(Regimen, Drug)

role(prep(with), R, D) *(R : regimen, D : drug)*

➔

semlink(R, D,via(prep(with))

Semantically meaningful attachments eliminate uninterpretable choices

role(prep(with), %%, D)

➔

stop.

Using interpretability to disambiguate

The patient [had [a regimen [with norvir]]]

~~*The patient [had [a regimen] [with norvir]].*~~

Choice: ~~***(A1 xor***~~ ***A2) iff 1***

subconcept(have-1, [have#v#1, use#v#1, have#v#3]

subconcept(norvir-5, [drug#n#1]

alias(norvir-5, [norvir])

subconcept(patient-3, [patient#n#1, affected_role#n#1])

role(sb, have-1, patient-3)

role(ob, have-1, regimen-12)

~~**A1:** role(prep(with), have-1, norvir-5)~~

A2: **role(prep(with), regimen-12, norvir-5)** *(Regimen, Drug)*

Ambiguities multiply
e.g. from prepositional attachment

Find patients who had a high viral load after 24 weeks on a regimen with norvir.

(62 ways ambiguous)

xor(A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, A24, A25, A26, A27, A28, A29, A30, A31, A32, A33, A34, A35, A36, A37, A38, A39, A40, A41, A42, A43, A44, A45, A46, A47, A48, A49, A50, A51, A52, A53, A54, A55, A56, A57, A58, A59, A60, A61, A62) iff 1

```
Conceptual Structure:
 or(A27,A29,or(or(A62,A61,A60,A59,A58,A57,A56,A55,A54,A53,A52,A51,A50,A49,A48),or(A47,A46,A45,A44,A43,A42,A41,A40),or(A35,A34),or(A33,or(A37,A36)),A39)):
    role(nn_element,viral_load-26,high-23,1)
    definite(regimen-47)
    subconcept(find-0,
     [find#v#1,detect#v#1,find#v#3,determine#v#1,find#v#5,witness#v#2,line_up#v#2,discover#v#2,discover#v#4,find#v#10,rule#v#4,receive#v#2,find#v#13,recover#v#1,f
     ind#v#15,find_oneself#v#1])
 or(A12,or(A14,or(or(A24,A23),A21),or(or(A26,A25),or(A28,A31))),or(A38,or(A45,A44),or(or(A55,A54),A52,or(or(A57,A56),A58,or(A62,A60))))):
    role(prep(with),find-0,norvir-50)
…
```

Meaningful attachments

~~or(or(or(A28,A29),A24),A23):~~

~~role(prep(after),patient-7,24-22)~~

~~or(or(or(A42,A43),or(A38,A39),A33,A32),A10,A9):~~

~~role(prep(after),patient-7,week-26)~~

~~or(or(A30,A31),A22,A21):~~

~~role(prep(after),viral_load_test-16,24-22)~~

or(or(or(A41,or(A44,A45)),A40,or(A35,A36,A37),A34)…

role(prep(after),viral_load_test-16,week-26) ***(Viral-load, Time-Period)***

➔ ***medical-test-has-time(viral_load_test-16, time_point-1)***

➔ ***occurs-after(time_point-1, week-26)***

or(A36,or(or(or(A27,A28,A29),…)

role(prep(during),week-26,regimen-37) ***(Time-period, Treatment)***

➔ ***occurs-during(week-26,regimen-37)***

~~or(or(A17,A18),or(or(A13,A14),A11,A12),A4,or(A1,A2,A3)):~~

~~role(prep(with),find-1,viral_load_test-16)~~

or(or(or(or(A28,A29),A24,….)

role(prep(with),patient-7,viral_load_test-16) ***(Patient, Medical-Test)***

➔ ***patient-has-test(patient-7, viral_load_test-16)***

…)

Meaningful analyses survive

(or(A32,or(or(or(or(A33,A34),A27,A25),A26….)….

role(cardinality_restriction,week-26,24) *(Time-Period, Cardinality)*

➔ *interval-has-duration(week-26,24 weeks)*

or(or(or(A45,or(A41,A42),A39)….)….

role(nn_element,viral_load_test-16,high-11,1) *(Medical-Test, Test-Value)*

➔ *medical-test-has-value(viral_load_test-16, high-11)*

or(or(or(A41,or(A44,A45)),A40,or(A35,A36,A37),A34)…

role(prep(after),viral_load_test-16,week-26) *(Viral-load, Time-Period)*

➔ *medical-test-has-time(viral_load_test-16, time_point-1)*

➔ *occurs-after(time_point-1, week-26)*

or(A36,or(or(or(A27,A28,A29),…)

role(prep(during),week-26,regimen-37) *(Time-period, Treatment)*

➔ *occurs-during(week-26,regimen-37)*

or(or(or(or(A28,A29),A24,….)

role(prep(with),patient-7,viral_load_test-16) *(Patient, Medical-Test)*

➔ *patient-has-test(patient-7, viral_load_test-16)*

Bridge flattened LF given to reasoner

Find patients who had a high viral load after 24 weeks on a regimen with Atripla.

(desired_answer patient_3)

(exists patient_3 sort patient)

(exists regimen_4 sort regimen)

(scopes-over restriction patient_3 regimen_4)

…

(in restriction patient_3 (patient-has-regimen patient_3 regimen_4)

(in restriction regimen_4 (regimen-has-drug-combo regimen_4 Atripla_2))

(in nscope patient_3 (patient-has-test-at-time patient_3 viral_load_5 high_1 time_point_7))

(in restriction time_point_7 (after time_point_7, week_6))

(in restriction week_6 (starts-at week_6 time_point_8))

(in restriction week_6 (starts-at regimen_4 time_point_8))

(in restriction week_6 (time_measure week_6 24 week))

Complex queries: multiple questions

- *Find patients who had a high viral load after 24 weeks on a regimen with Atripla;*
- *the patients exhibited M184v near the end of the regimen;*
- *the patients switched to a salvage regimen with boosted EFV.*

Points to remember

- Experts use many abstractions over information in DB

- A reasoner can link higher level abstractions found in natural queries with combinations of data base elements

- Mapping language in a specific domain can be guided by signatures of higher level domain relations
(only sometimes requiring specific constructs)

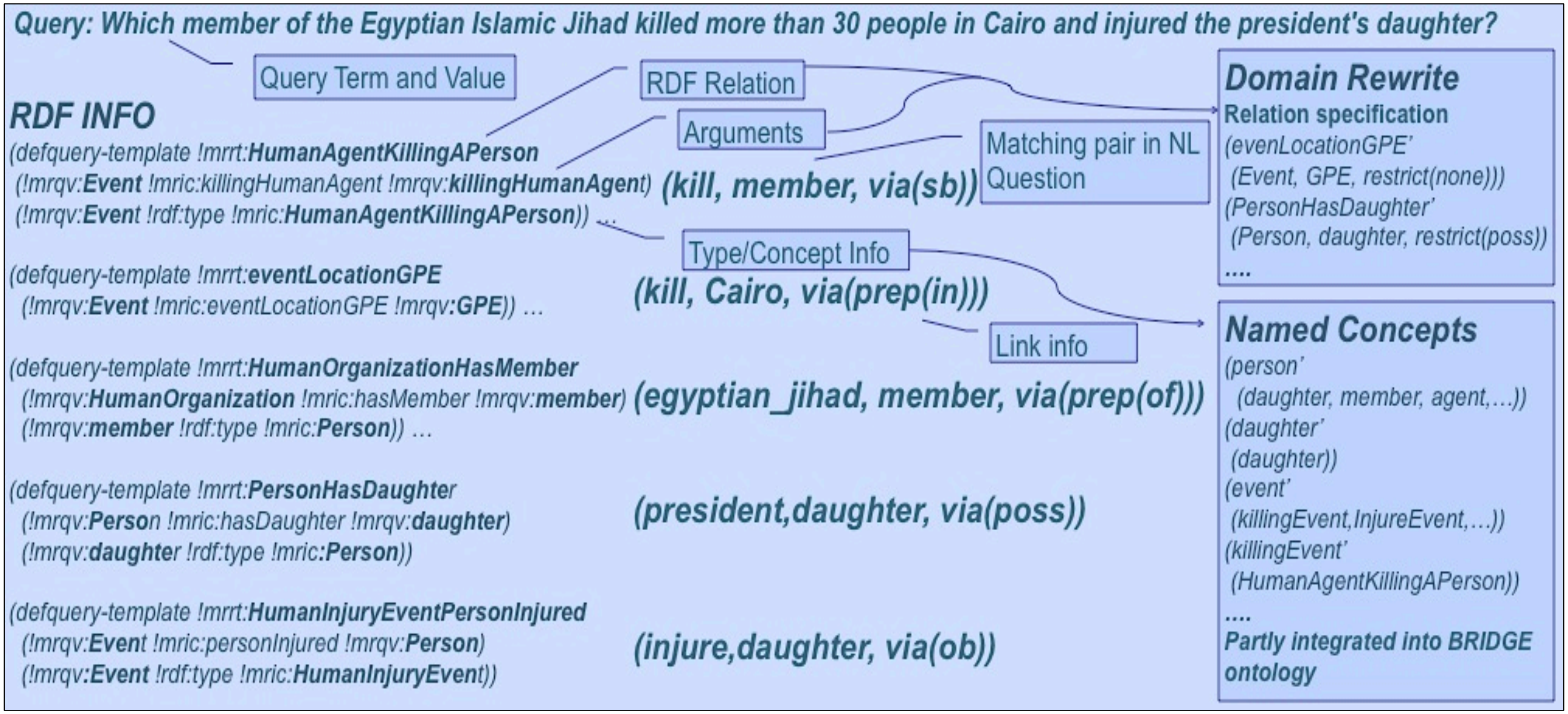
- Mapping to domain relations can be used to eliminate uninterpretable ambiguities

.

Porting to a new domain

- Requires being able to build a language model for that domain.
- This was tried in the intelligence community (IC) domain
- RDF class definition triples were used as our *argument signatures* over the existing Quadri system.

Terrorism



Query: Which member of the Egyptian Islamic Jihad killed more than 30 people in Cairo and injured the president's daughter?

RDF INFO

*(defquery-template !mrrt:**HumanAgentKillingAPerson***
*(!mrqv:**Event** !mric:killingHumanAgent !mrqv:**killingHumanAgent**)*
*(!mrqv:**Event** !rdf:type !mric:**HumanAgentKillingAPerson**)) …*

*(defquery-template !mrrt:**eventLocationGPE***
*(!mrqv:**Event** !mric:eventLocationGPE !mrqv:**GPE**)) …*

*(defquery-template !mrrt:**HumanOrganizationHasMember***
*(!mrqv:**HumanOrganization** !mric:hasMember !mrqv:**member**)*
*(!mrqv:**member** !rdf:type !mric:**Person**)) …*

*(defquery-template !mrrt:**PersonHasDaughter***
*(!mrqv:**Person** !mric:hasDaughter !mrqv:**daughter**)*
*(!mrqv:**daughter** !rdf:type !mric:**Person**))*

*(defquery-template !mrrt:**HumanInjuryEventPersonInjured***
*(!mrqv:**Event** !mric:personInjured !mrqv:**Person**)*
*(!mrqv:**Event** !rdf:type !mric:**HumanInjuryEvent**))*

(kill, member, via(sb))

(kill, Cairo, via(prep(in)))

(egyptian_jihad, member, via(prep(of)))

(president,daughter, via(poss))

(injure,daughter, via(ob))

Domain Rewrite

Relation specification

(evenLocationGPE'
(Event, GPE, restrict(none)))
(PersonHasDaughter'
(Person, daughter, restrict(poss))
….

Named Concepts

(person'
(daughter, member, agent,…))
(daughter'
(daughter))
(event'
(killingEvent,InjureEvent,…))
(killingEvent'
(HumanAgentKillingAPerson))
….

Partly integrated into BRIDGE ontology

System Output

```
((input In July a terrorist from Algeria who is associated with Al Qaeda killed nearly
30 people in Yemen.)
(quant exists Algeria_1 sort geo_political_entity)
(quant exists Yemen_2 sort geo_political_entity)
(quant exists terrorist_3 sort person)
(quant exists Al_Qaeda_4 sort human_organization)
(quant (complex_card nearly 30) people_5 sort people_group)
(quant exists July_6 sort date)
(definite Algeria_1)
(definite Yemen_2)
(HumanAgentKillingAPerson (kill:n 164 terrorist_3)
(HumanKillingEventPersonKilledUpperBound (kill:n 164 people_5)
(eventLocationGPE (kill:n 164 Yemen_2)
(organizationHasMember Al_Qaeda_4 terrorist_3)
(PersonHasBirthPlace terrorist_3 Algeria_1)
(EventHasDate (kill:n 164 July_6)
)
```

Thank you.