Automated Negotiation from Declarative Contract Descriptions

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Designing a Negotiation Mechanism

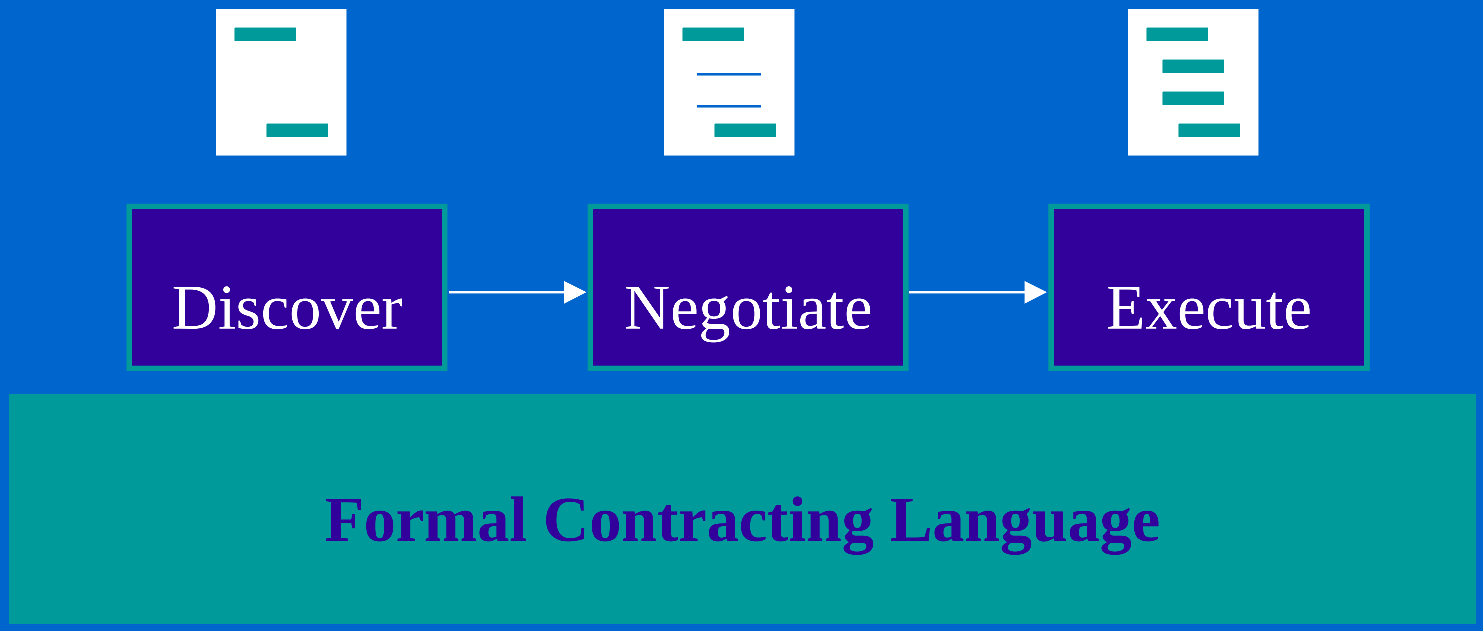
- Example: FCC spectrum auctions
- Alternative structures
  - Independent auctions for frequencies
  - Combinatorial mechanism
  - Simultaneous ascending auctions
- How (and why) to automate the construction of a negotiation mechanism…

Contracts

- Descriptions of goods and services
- Applicable terms and conditions
  - ancillary agreements detailing terms of a deal
  - customer service agreements, delivery schedules, conditions for returns, usage restrictions, other issues…
- *Partial Contracts* extend this
  - Intuitively: contracts with “blanks” to be filled in
  - More formally: defines space of possible negotiation outcomes

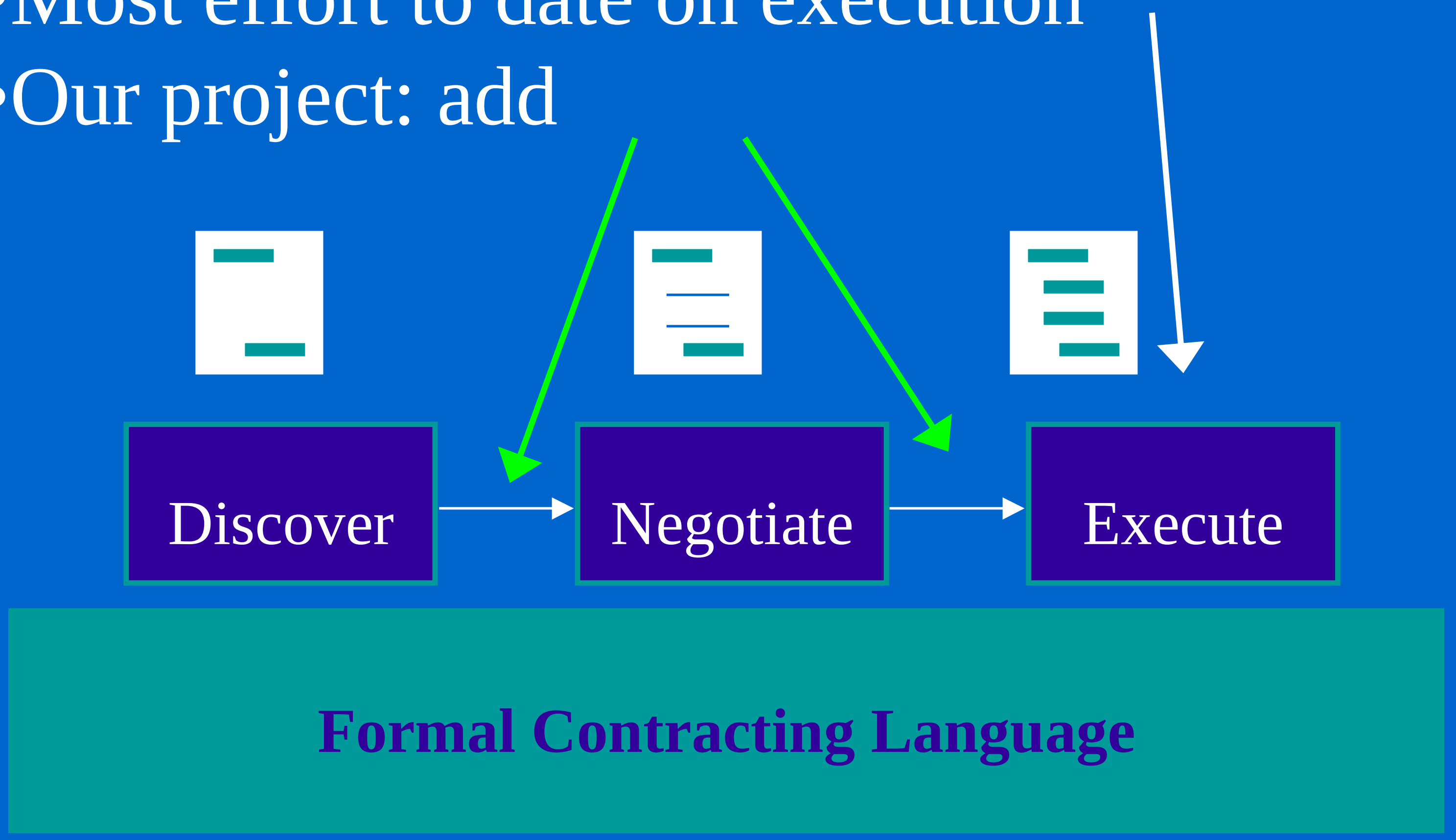
Contracting Infrastructure

- Contracting language supports all 3 stages of ecommerce
- Contract progressively more complete



Automated Contracting

- Most effort to date on execution
- Our project: add



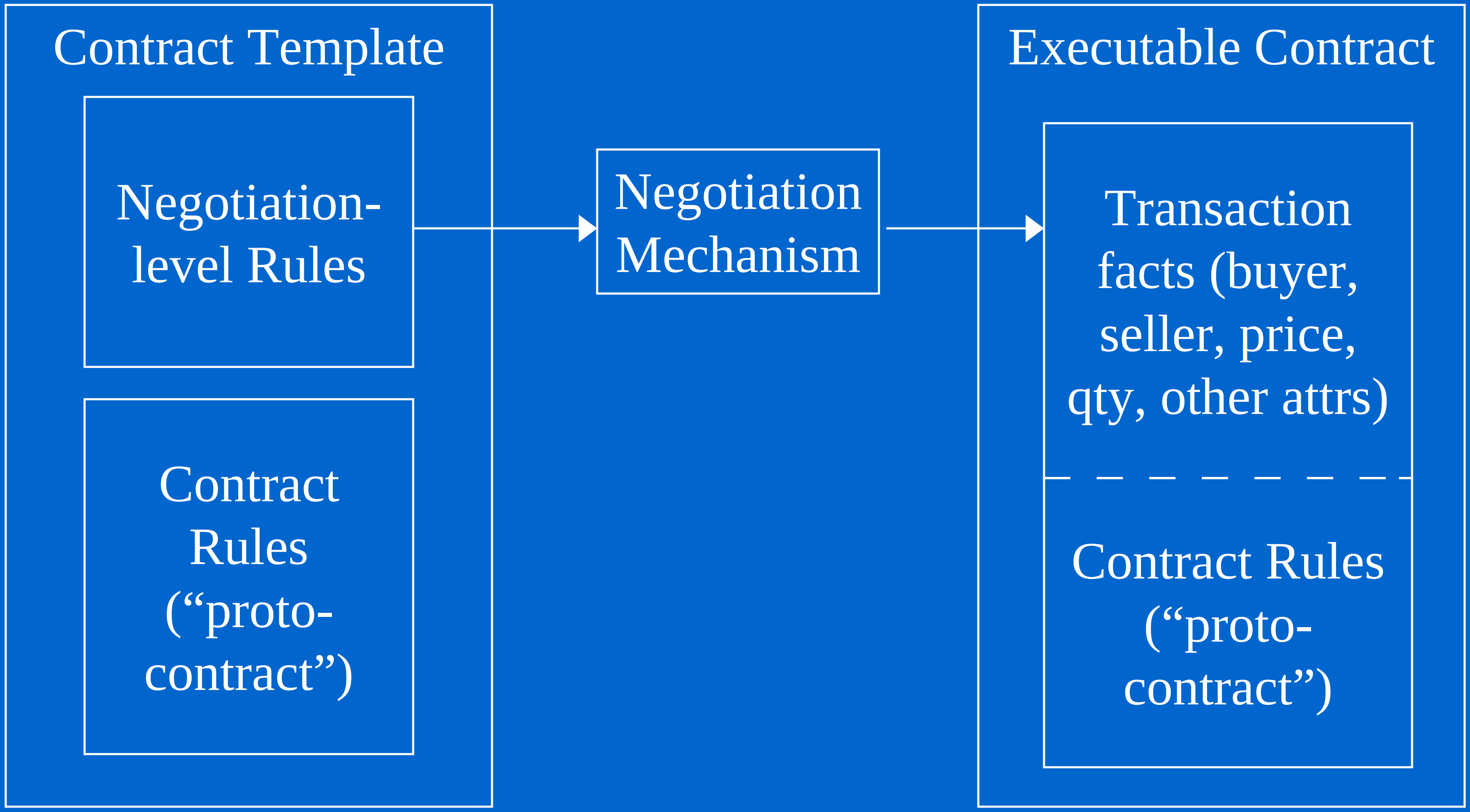
Formulating a Negotiation

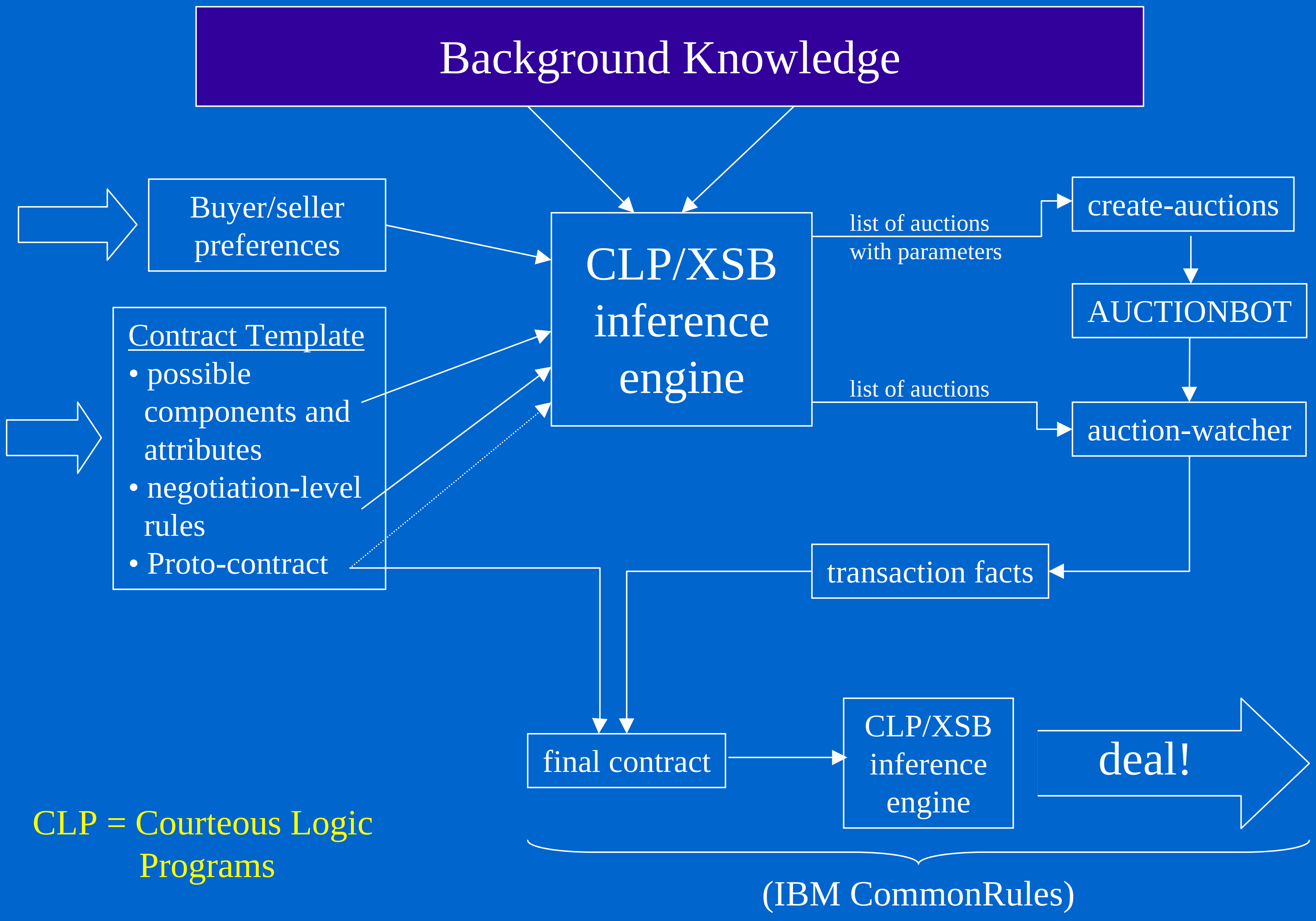
- *What* to negotiate
  - **Price** of an otherwise fully specified contract
  - **Everything** of a completely empty contract
  - *Something in between*…
- Negotiable parameters
  - Contracting issues to be determined in negotiation process
  - Flexibility/complexity tradeoffs

Formulating a Negotiation: Criteria

- Coherence/feasibility (e.g., size & color inseparable)
- Communication requirements
- Computational efficiency
- Allocation efficiency
- Examples:
  - ability to bundle (seller)
  - complementarities (buyer)
  - fewer/simpler markets (auctioneer)

Overall Process (Partial → Complete)


Contract Template
Negotiation-level Rules
Contract Rules (“proto-contract”)
Negotiation Mechanism
Executable Contract
Transaction facts (buyer, seller, price, qty, other attrs)
Contract Rules (“proto-contract”)



CLP = Courteous Logic Programs

Auction-Configuration Rulebase

- Partition negotiation into a set of components--separable bundle of goods
- Combine constraints between possible components, buyer/seller preferences
- Infer components to be negotiated
- Create arrays of 1-D auctions
- Priorities and mutual exclusion rules
  - E.g., only infer one value for each auction parameter

Auction-Space Rulebase: Domains, Defaults, and Constraints

- Domains for auction parameters
- Default values for all auction params (lowest priority rules)
- Conditional defaults (next lowest priority)
  - 1 seller implies multiple buyers and vice versa
- Hard Constraints

```
– <highest> auction(?ID, beatQuote, 0) <-
            auction(?ID, meetQuote, 1).
```

Improved Parameterization

- Current parameterization in AuctionBot created incrementally and slow to change due to backward-compatibility constraints
- Independent of actual AuctionBot parameters
- Provides more *flexible* and *extensible* structure than a flat and complicated parameter space

Higher-Level Knowledge

- Infer auction parameters from `negotiationType` facts
- `negotiationType` used in partial contract for meta-level knowledge about negotiation
- Example:

`negotiationType(continuous)` implies
`negotiationType(continuousQuotes)` implies
`auction(quoteMode, bid)`

Standard Auction Types

- Encodes well-known auction types
  - negotiationType(CDA) => negotiationType(double), etc
  - Uses exceptions and special cases
    - Example: Amazon-style auctions are like eBay *except* that there is no fixed final clear time.

Additional Benefits

- Advantage of rule-based approach: adding new structure to parameterization
- Example: inferring default parameter settings based on user profiles (business, consumer, skilled, novice, etc.)
- Succinct: AuctionBot requires 27 individual parameter settings, as opposed to a handful of rules for most auctions

AuctionBot Rulebase

- Maps Auction-Space parameters to AuctionBot parameters
- Example: “auction type” inferred from fundamental auction parameters

```
<chronmatch> auctionbot(type, 4)
  <- auction(matchingfunction, earliesttime).
<cda> auctionbot(type, 5)
  <- auction(matchingfunction, earliesttime)
     AND auction(intclearmode, 1).

overrides(cda, chronmatch).   /* special case */
```

Domain-specific Rules (Components, Attributes, Values)

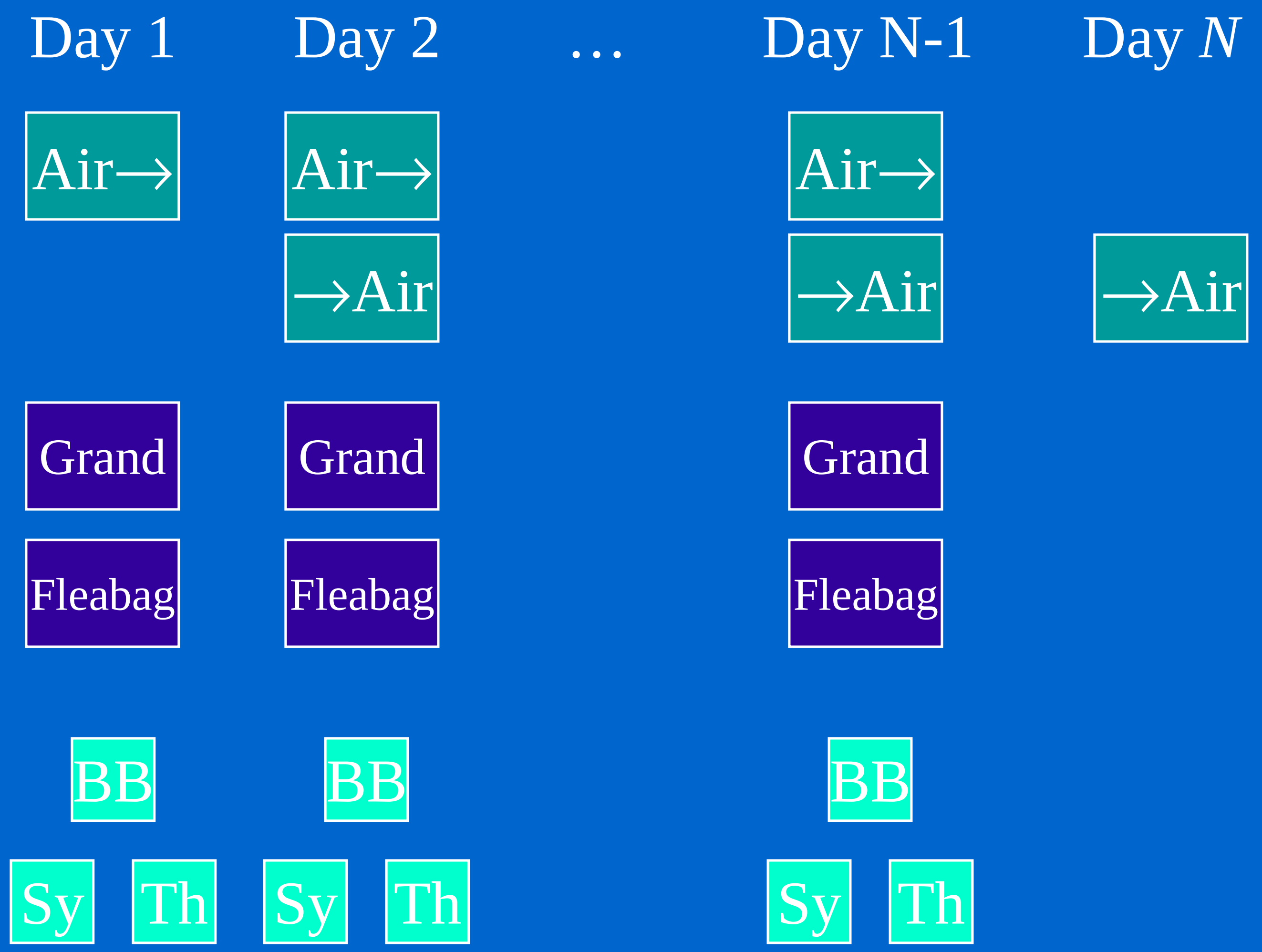
- Possible values
  - `value(quality, regular).`
  - `value(quality, deluxe).`
- Possible components and attributes
  - `component(widget).`
  - `attribute(widget, quality).`
- Possible values for widgets

```
value(?Component, quality, ?Q) <-
   component(?Component) AND
   value(quality, ?Q).
```

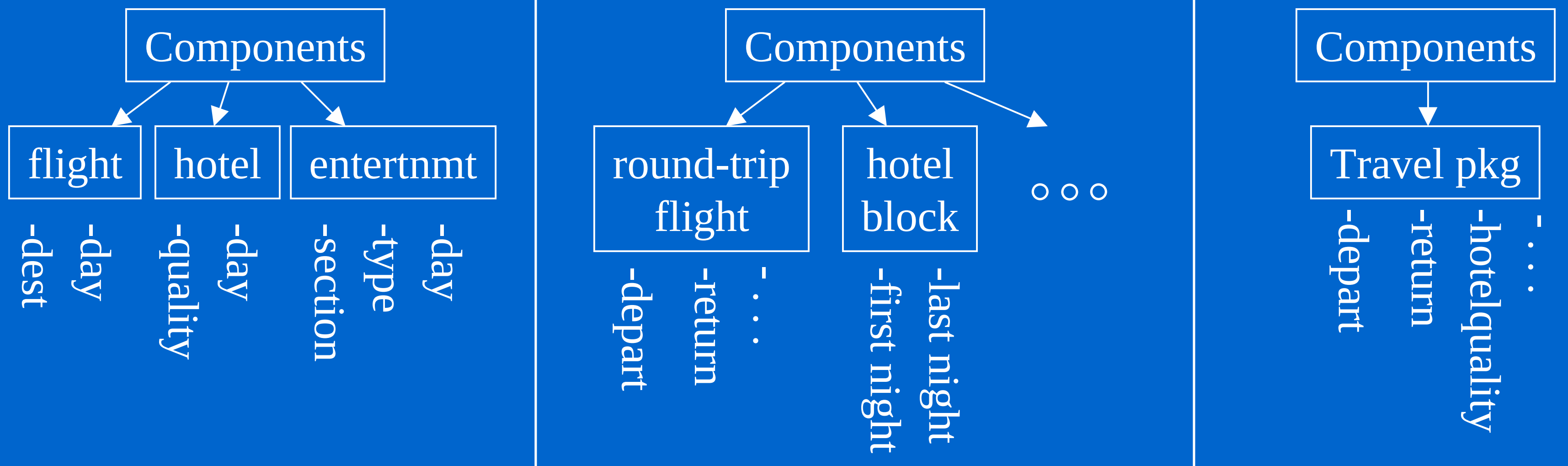
Trading Agent Example

- Generates all auctions for TAC
- 3 goods (flights, hotels, entertainment)
  - Each has attributes for day and for type
    - (2 flight types, in & out; 2 hotel types, good & bad; 3 entertainment types, baseball & symphony & theatre)
- Total auctions created per good:
  - [types]*[days]
- Negotiation-level rules included

Goods in TAC Domain



Alternative Negotiation Structures

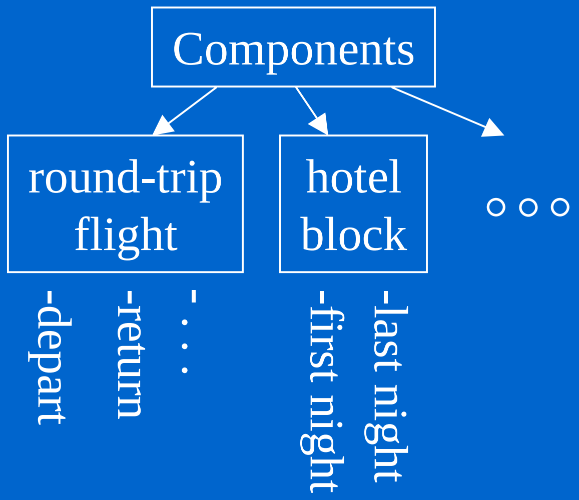


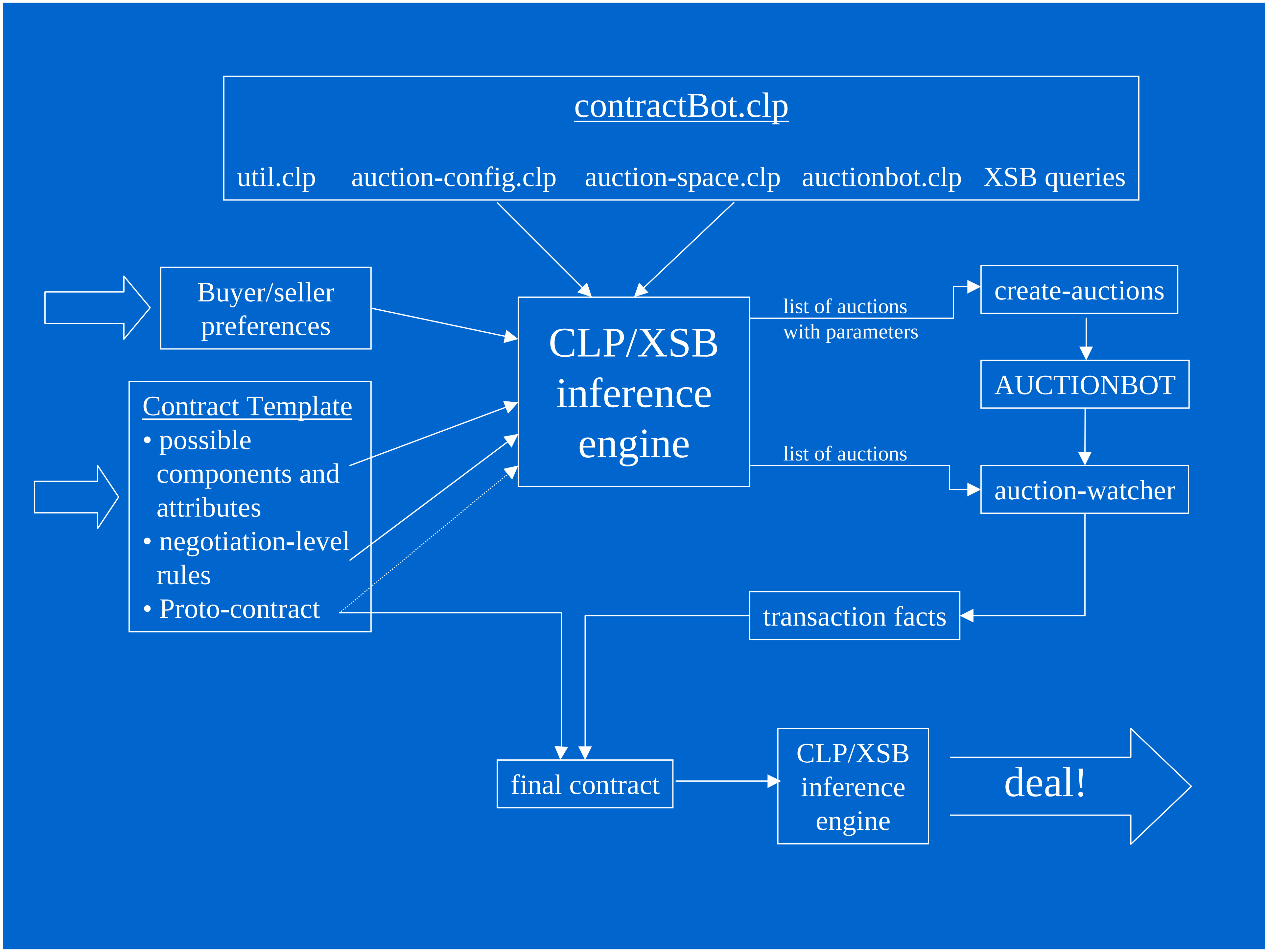
Agent Example

- Possible components: hotelblock, roundflight, flighthotel, entpackage, fullpackage, etc
  - (components may inherit features from each other)
- Constraints between components, e.g., buyers want hotelblocks xor individual rooms
- Buyer/seller preferences, e.g.:
  - `buyer(traveler2, hotelblock).`
  - `seller(airline1, roundflight).`

Simple Buyer/Seller Rules for Alternative Negotiation Structure

```
buyer(traveler1, roundflight).
buyer(traveler2, hotelblock).
buyer(traveler1, entpackage).
seller(airline1, roundflight).
seller(hotel1, hotelblock).
seller(agent3, entpackage).
```




contractBot.clp
util.clp
auction-config.clp
auction-space.clp
auctionbot.clp
XSB queries
Buyer/seller preferences
Contract Template
• possible components and attributes
• negotiation-level rules
• Proto-contract
CLP/XSB inference engine
list of auctions with parameters
list of auctions
create-auctions
AUCTIONBOT
auction-watcher
transaction facts
final contract
CLP/XSB inference engine
deal!

Summary

- Contracting language as infrastructure for automated contracting
- Contracting framework
  – Partial to complete contracts
- Rule-based auction generation/configuration
- Alternative negotiation structures for TAC
- ContractBot prototype

Future Work

- Support for richer negotiation mechanisms (e.g., combinatorial and multiattribute auctions)
- Extend ontology (e.g., orthogonality/separability)
- Analyze agent strategies for submitting rules influencing the choice of negotiation mechanism

BACKUP SLIDES

Prototype details

Auction Constraints (additional details)

- Rules about rule priorities
  - 4-5 levels of priority useful in this application for expressing defaults, exceptions, overrides
    - low, medium, high/very-high
    - also: “standard “ (no label)
- Mutual exclusion (similar to integrity constraint):
  - at most one value for each auction param

Creating a Batch of Auctions

```
require “auctionGenerator.pl”;  # simple Perl library

for($i = 1; $i <= $ARGV[1]; $i ++) {
  beginAuction();
  addRule(“negotiationType(cda).”);
  addRule(“negotiationType(revealAll).”);
    # could also have the rules in a file and use:
    #   addFile(“filename.clp”);
  addParam(“auctionname”, “auction$i”);  # uses override priority
  endAuction();
}
```

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Detailed ontology and configuration criteria

Configuration Criteria

- Feasibility/coherence
    - Will it result in valid/sensible contracts?
- Expected performance
    - Will it lead to desirable outcomes?
        - Pareto efficiency
        - Other measures of social utility
- Complexity
    - How costly, for both operators and participants?

Configuration Criteria: Complexity

- Agent complexity
  - Incentive compatibility
  - Bid format, iterations
- Computational complexity of mechanism
  - E.g., time complexity in number of agents/attributes
- Communication costs
- “Cognitive” complexity

Configuring the Mechanism (exploiting information from the contract template)

- Attribute hierarchy
- Orthogonality (w.r.t. siblings in hierarchy)
  - additive utility
  - vastly reduces search (eg, 10^4 vs. 2*10^2)
- Separability
  - suggests combinatorial mechanisms
  - can be reasoned about (example)

Hints from Contract Template, continued

- Privacy (example)
- “Negotiability” of attributes
  - E.g., seller/buyer chooses
- Constraints
  - Declarative language well-suited
  - E.g., ~hotel <- ~flight

Questions and Future Work [NWU]

- Parameterize the space of negotiation mechanisms
- Other hints from the partial-contract language for configuring the negotiation
  - Reducing search costs
  - Meta-level hints/specifications
  - Other information influencing design choices

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Negotiation-level predicates and examples of making aspects of an executable contract negotiable

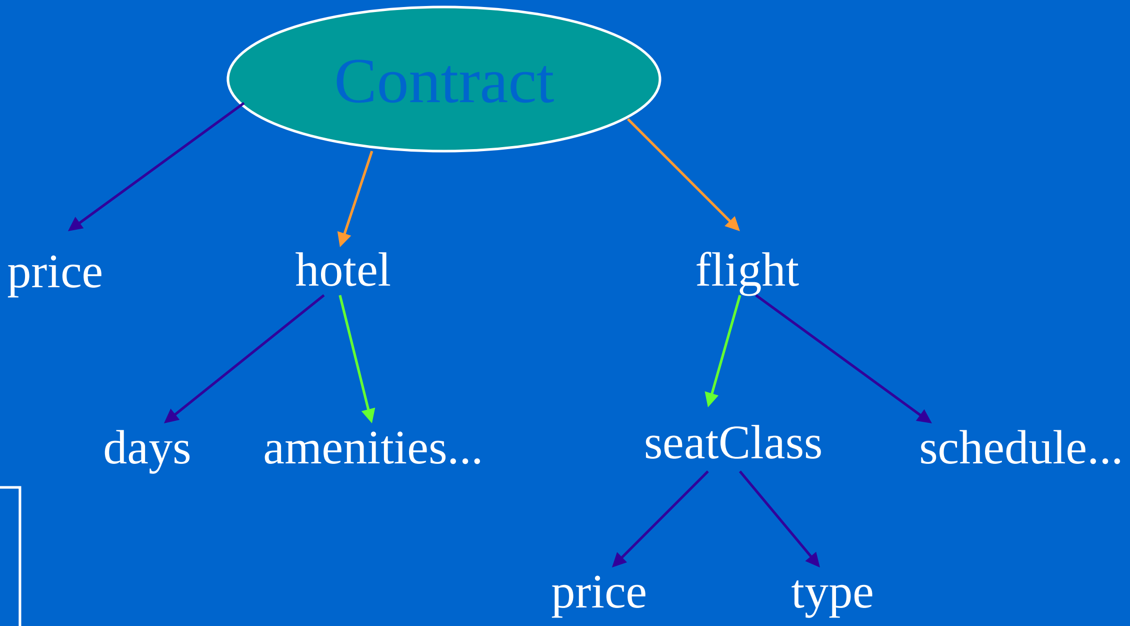
Negotiation-level Predicates:

attribute, separableComponent, orthogonalComponent

attribute(?Parent, ?Child).

separableComponent(hotel)…

orthogonalComponent(seatClass)...



price, quantity: *distinguished*

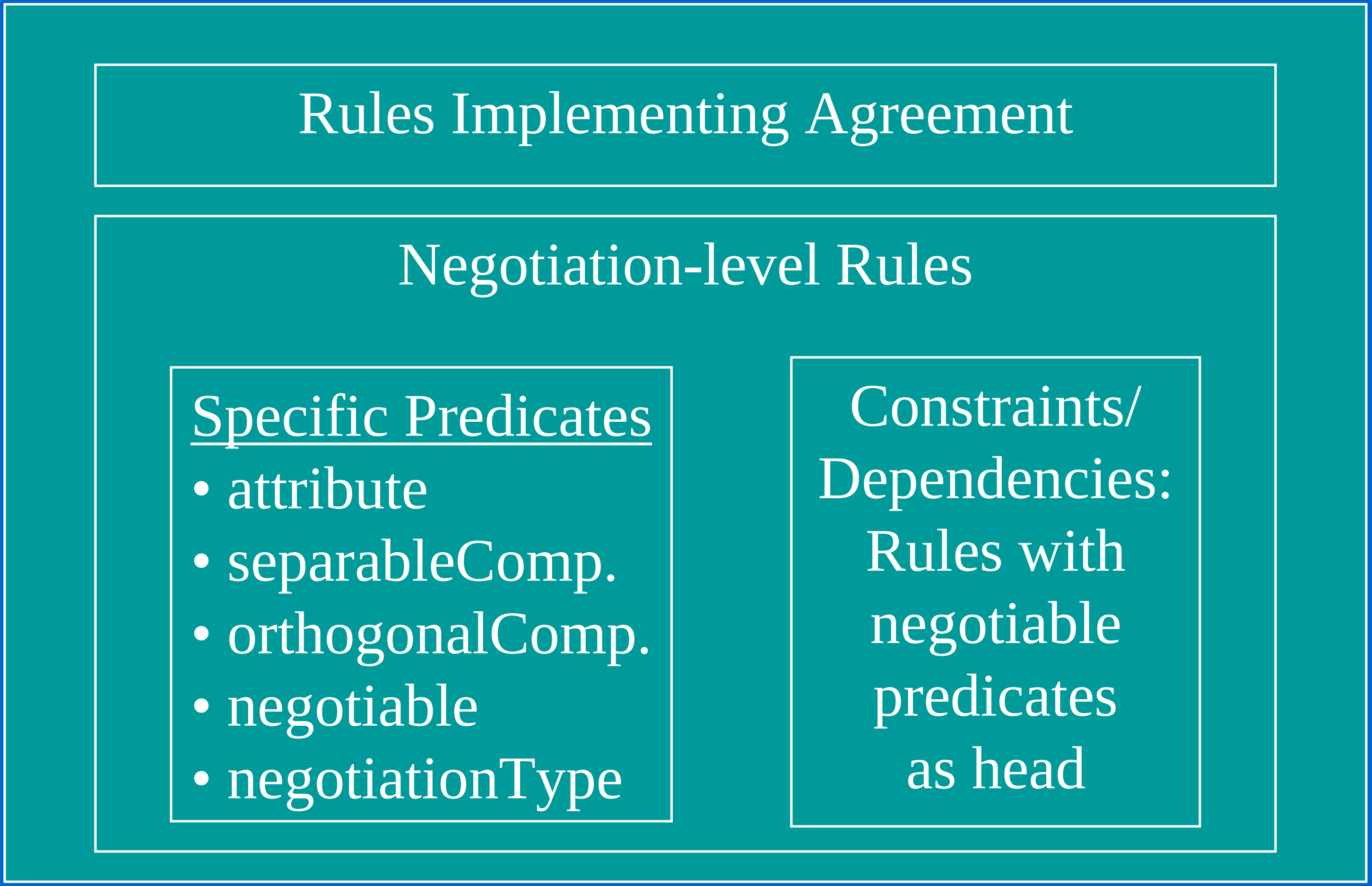
Negotiation-level Predicates: **negotiable**

```
negotiable(?PredicateName).

flight(?Airline, ?FromCity, ?ToCity, ?Stopovers) ←
    airline(?Airline) AND stopovers(?Stopovers) AND
    possibleRoute(?Airline, ?FromCity, ?ToCity).

negotiable(’airline).
negotiable(’stopovers).
```

Negotiation-level Predicates: **negotiationType**

```
negotiationType(?PredicateName, ?TypeOfNegotiation).

  negotiable(’hotelCost).
  negotiationType(’hotelCost, sellerChooses).
```

Composition of Contract Template (a.k.a., Partial Contract)



Adding Negotiation Constructs to Existing Contracts

- Negotiating the form of a rule

ruleHead ← ruleBody AND isRuleIncluded(yes).

negotiable(’isRuleIncluded).

$$\begin{tikzcd}
& \boxed{\text{Negotiation Mechanism}} \arrow[dl] \arrow[dr] & \\
\text{isRuleIncluded(yes).} & & \text{isRuleIncluded(no).}
\end{tikzcd}$$

Adding Negotiation Constructs to Existing Contracts (continued)

- Making constants negotiable

```
foo(constant1, constant2) ← conditions.

            becomes

foo(?Var1, ?Var2) ← conditions AND
   var1(?Var1) AND var2(?Var2).
negotiable('var1).
negotiable('var2).
```

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CLP details and general "rules motivation"

Why Rules?

- Contract terms involve conditional relationships
  - Terms and conditions, e.g., rules for price discounting
  - Service provisions, e.g., rules for refunds
  - Surrounding business processes, e.g., rules for lead time to place an order
- Shared semantics
- Existing executable contracts can be easily parameterized without a meta-language

Courteous LPs: Advantages

- Facilitate updating and merging.
- Expressive: classical negation, partially-ordered prioritization, reasoning to infer prioritization.
- Set of conclusions guaranteed consistent, unique.
  - **Mutual exclusion is enforced**. E.g., never conclude both p & ¬p.
- Efficient: low computational overhead beyond ordinary LPs.
  - Tractable given reasonable restrictions (Datalog, max vars/rule)
  - Extra cost is equivalent to increasing v to (v+1) in ordinary LPs.

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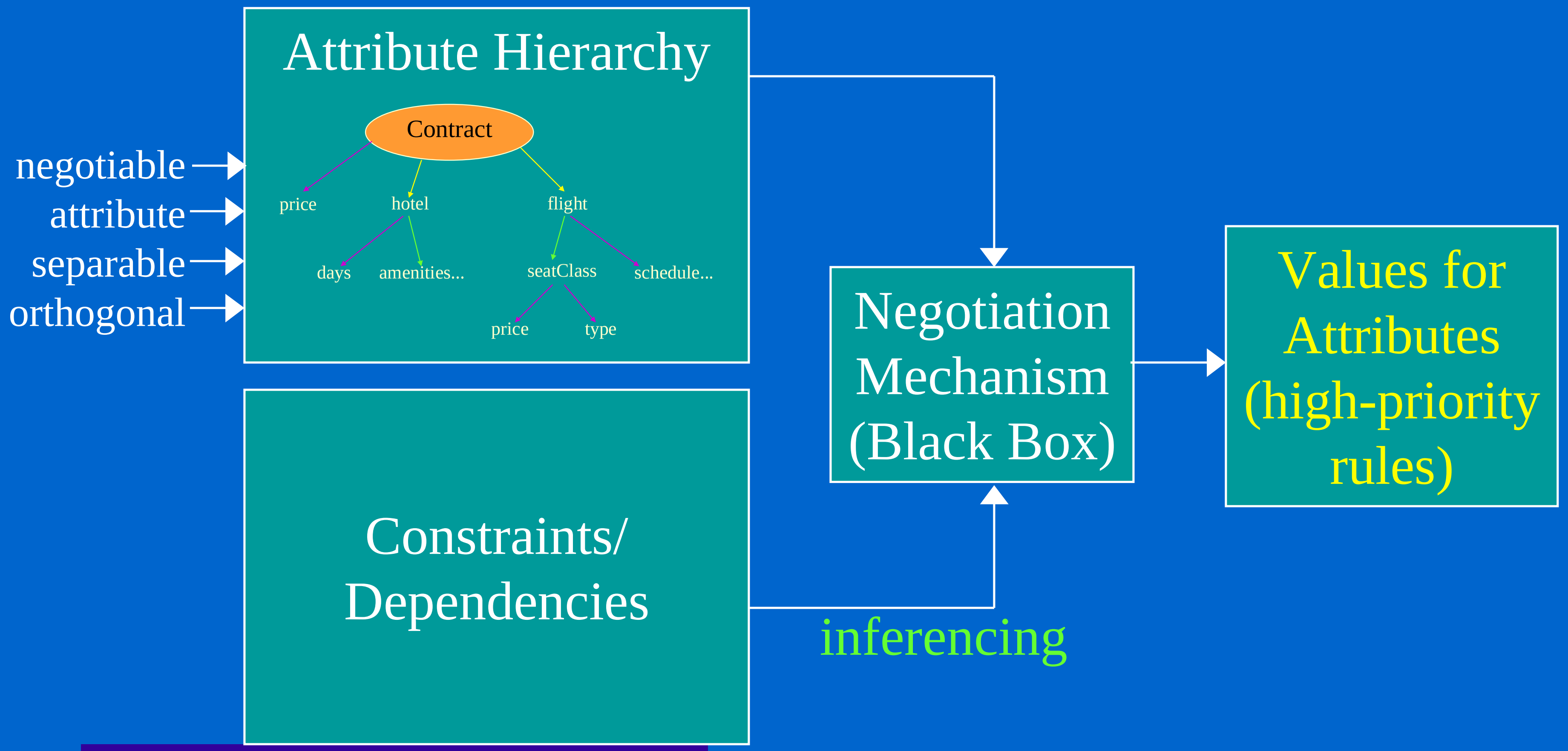
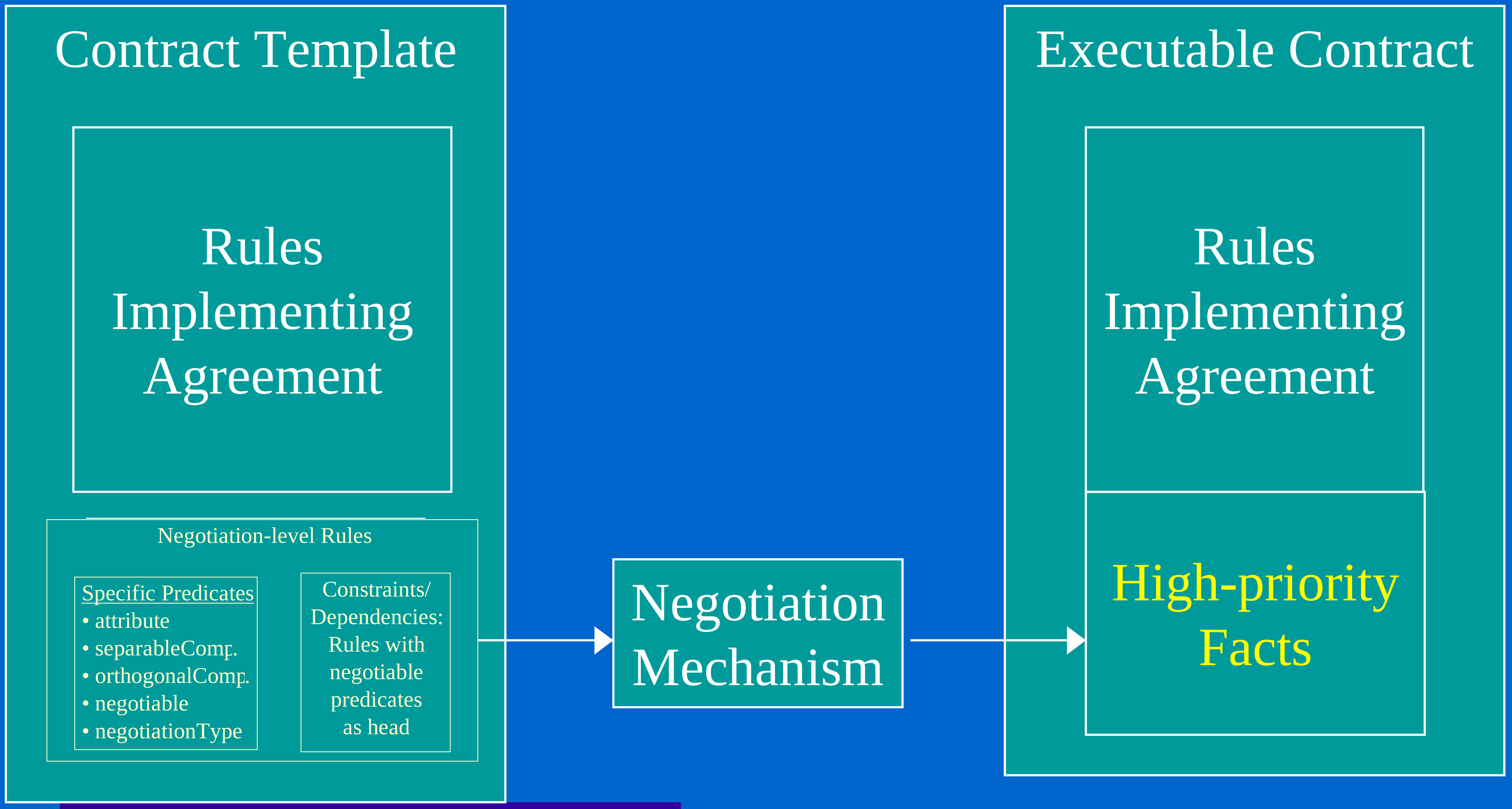
Detailed process (partial to complete)

Negotiation Process



Overall Process (Partial → Complete)



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Miscellaneous

Multidimensional Auctions

- *How* to negotiate
  - Auctions: mediated, well-defined, market-based
  - Multidimensional: resolve multiple issues
- Types
  - Multiple single-dimensional
  - Combinatorial
  - Multiattribute

Size of Possible-Outcome Space

- Too big!
- Contract language can help
  - Declarative language well-suited for expressing constraints
  - Orthogonalities (eg, 10^4 vs. 2*10^2)
  - Negotiation types (eg, sellerChooses)

Definition of Negotiation

- Negotiation = establishing a contract
- Example: Auction
  - Description of good with blanks for price/quantity
- Example: Negotiating ecommerce transactions
  - Results in an executable piece of code that executes the transaction

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Intro/Motivation, General Contracting

Definition of a Contract

- Contract = Set of attributes and values
- Partial Contract: values unspecified
- Includes seemingly structural aspects
  - Example: whether to include a rule in a declarative contract

Formal Contracting Language

- Partial vs. Complete Contracts (Contract Templates vs. Executable Contracts)
- Unspecified terms reduced to “negotiable parameters”
  - Attributes with specified domains
- Contract language expresses both partial and complete contracts
  - Additional ontology for parameterizing the negotiable aspects

Negotiation from Contract Templates

- Structural aspects can be parameterized
  - Rule-based language allows boolean attributes to effectively include or omit clauses/terms from the contract
- Negotiation reduces to assignment of values to attributes

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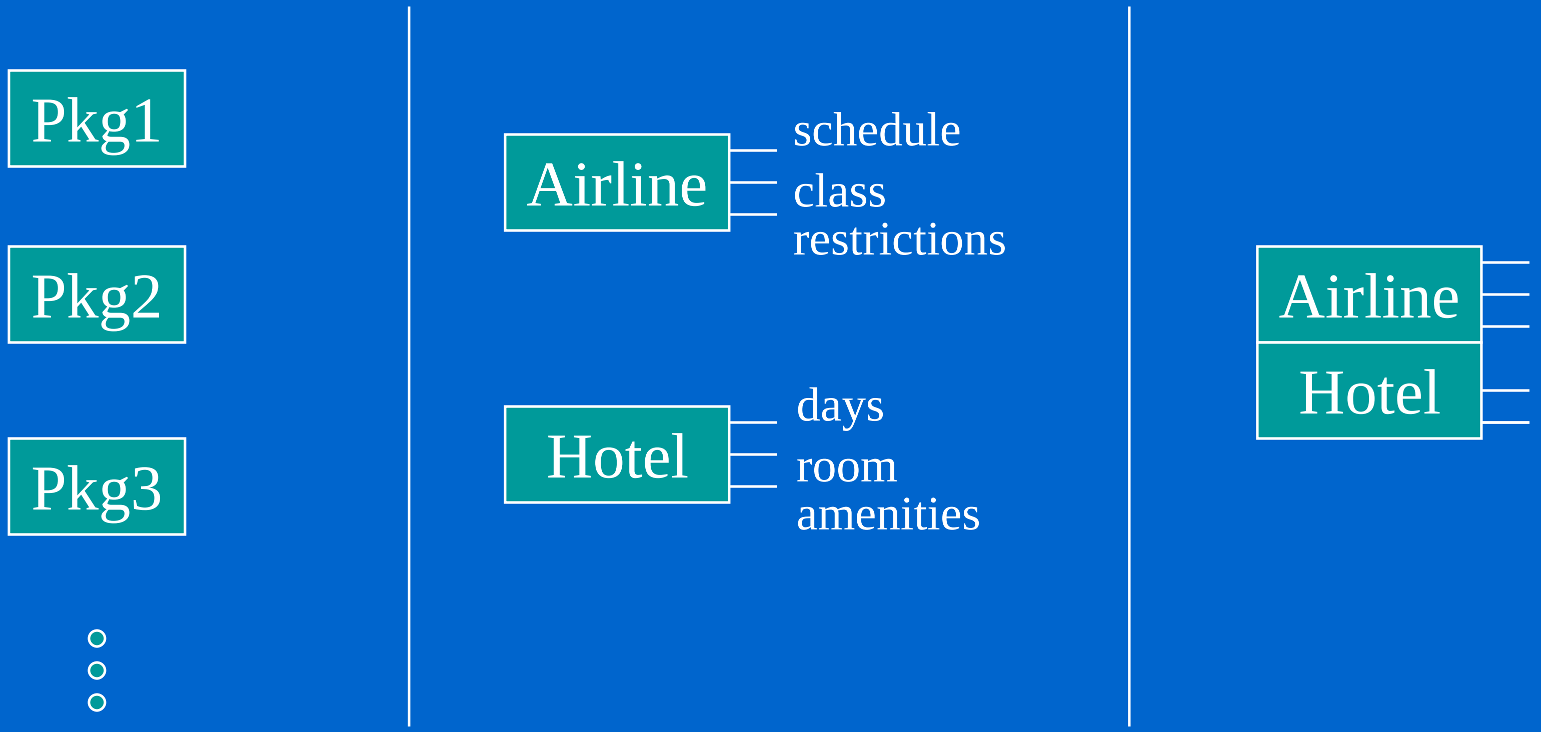
Old stuff

Alternative Negotiation Structures: Travel Packages Example

TODO: subset of possible TAC components



…and combinations thereof.

Summary [NWU]

- Contracting language as infrastructure for automated contracting
- Partial contract reduces negotiation to attribute assignment
- Alternative negotiation structures and criteria for mechanisms
- How the contracting language can guide the configuration of mechanisms and improve their efficiency

Discussion and Future Work

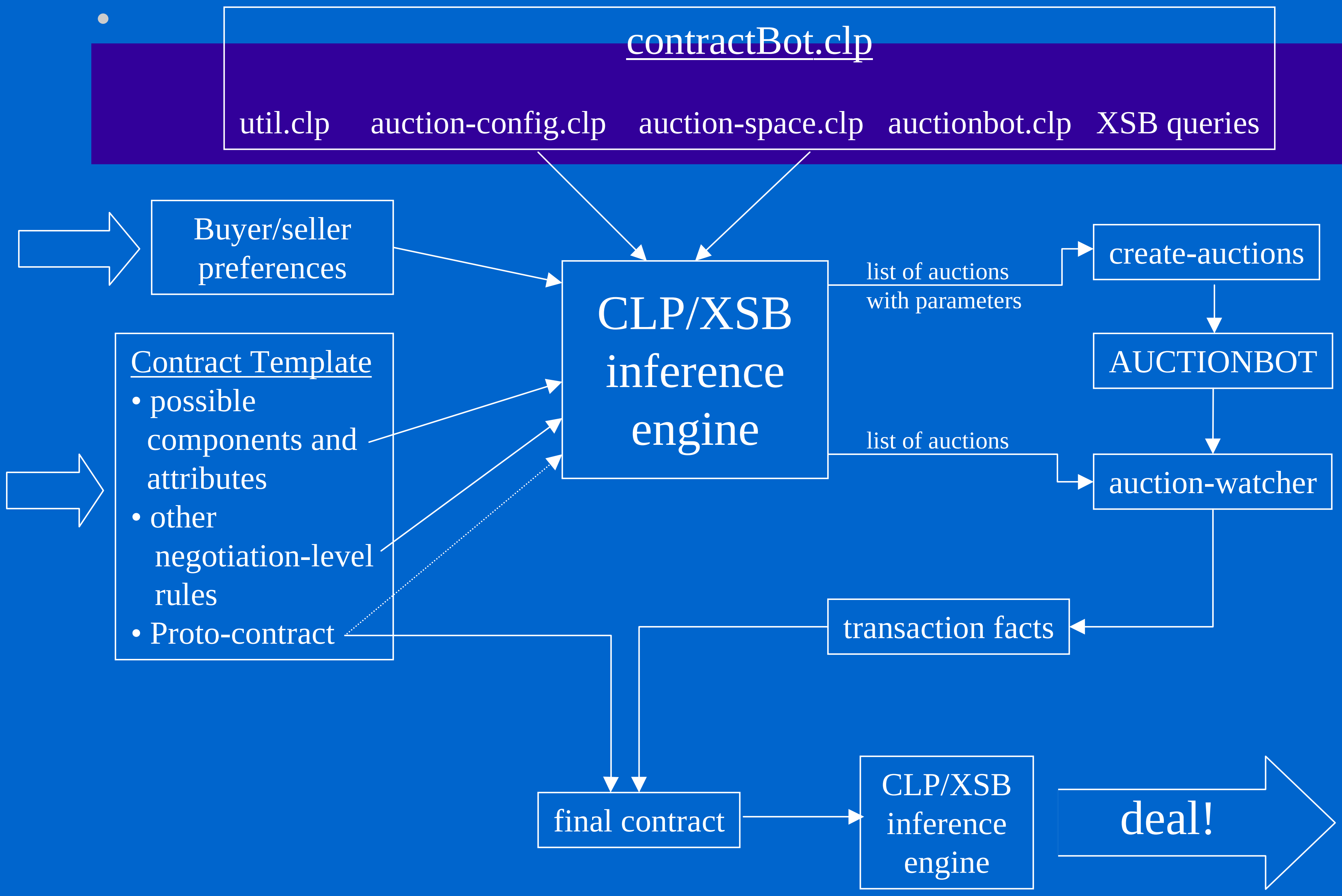
- Iterative negotiation
- Situated Courteous Logic Programs:
  - procedural attachments for actions, queries
- XML as common interlingua
- Multidimensional negotiation mechanisms

Summary [AIEC]

- CLP as basis for executable contracts
- CLP's prioritized conflict handling also facilitates modification during negotiation
- Introduced specific predicates for negotiation
  - Hierarchy of negotiables
  - Reason about what is negotiable and how
- Constraints and dependencies handled naturally
- Demonstrated how negotiation mechanism can transform a contract template to a fully executable contract
- Showed how to make an existing contract negotiable

SCRATCH

Figures for paper and other miscellania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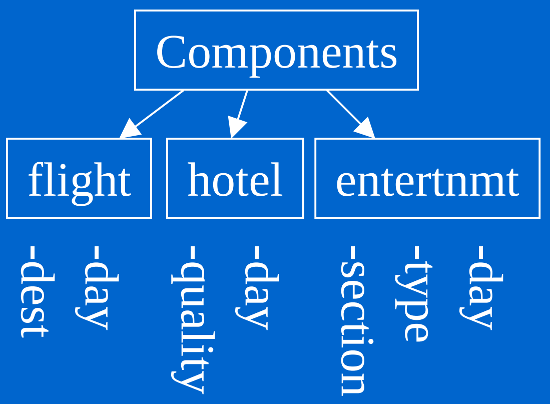
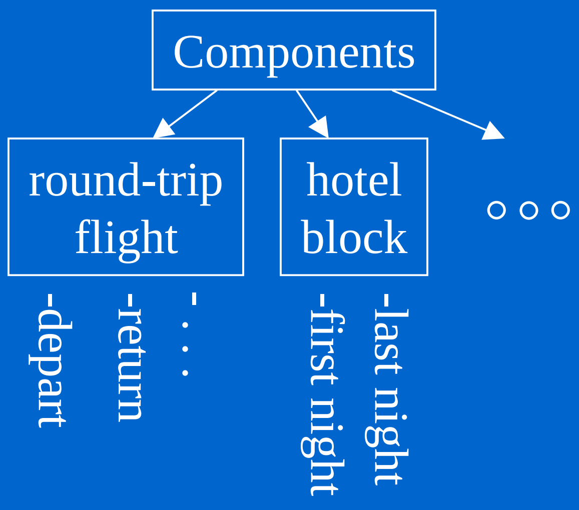
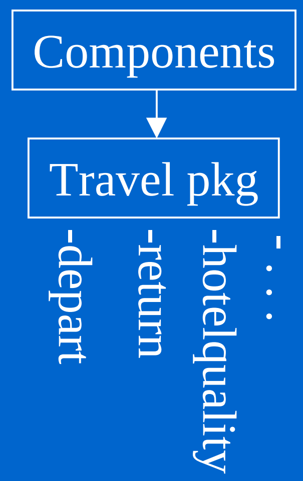

Components
flight
hotel
entertnmt
-dest
-day
-quality
-day
-section
-type
-day

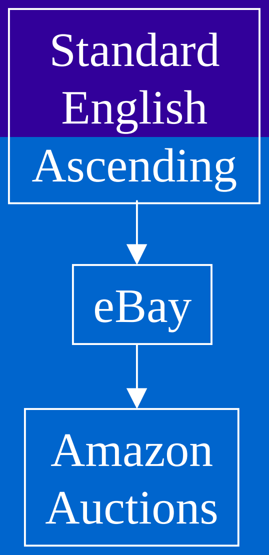
(a)


Components
round-trip flight
hotel block
-depart
-return
- . . .
-first night
-last night

(b)


Components
Travel pkg
-depart
-return
-hotelquality
- . . .

(c)


Standard English Ascending
eBay
Amazon Auctions

Rule-based Contracts for E-commerce

- Rules as way to specify business processes as part of contract terms.
- Facilitates specification
  - by multiple authors, cross-enterprise, cross-application
  - by non-technical authors
  - dynamically
- Existing executable contracts can be easily parameterized without a meta-language

Courteous Logic Programming

- Generalization of Logic Programming to include **prioritized conflict handling.**
- Rules may override other rules
  - special cases / exceptions / defaults
  - more recent updates
  - higher-authority (and/or more reliable) sources
  - closed world: lowest priority for catch cases

Example of Conflicting Rules

Vendor’s rules that prescribe how buyer must place or modify an order:

A) 14 days ahead if

- buyer is a preferred customer

B) 2 days ahead if

- the modification is to reduce the quantity, and
- the item is in backlog at the seller.

Resolved by **precedence** between the rules.

Often only *partial* order of precedence is justified.

Example of Conflicting Rules in CLP

```
<leadTimeRule1>
orderModificationNotice(?Buyer, ?Seller, ?Order, 14days) ←
    preferredCustomerOf(?Buyer, ?Seller).

<leadTimeRule2>
orderModificationNotice(?Buyer, ?Seller, ?Order, 2days) ←
    preferredCustomerOf(?Buyer, ?Seller) AND
    orderModificationType(?Order, reduce) AND
    orderItemIsInBacklog(?Order).

Overrides(leadTimeRule2, leadTimeRule1).
```

Configuring the Negotiation
Example: Orthogonality vs. Separability

	separable	NOT separable
orthogonal	Maps w/ car	Car color
NOT orthogonal	Flight (whether to get car depends on arrival city)	Car base price depends on time needed, etc

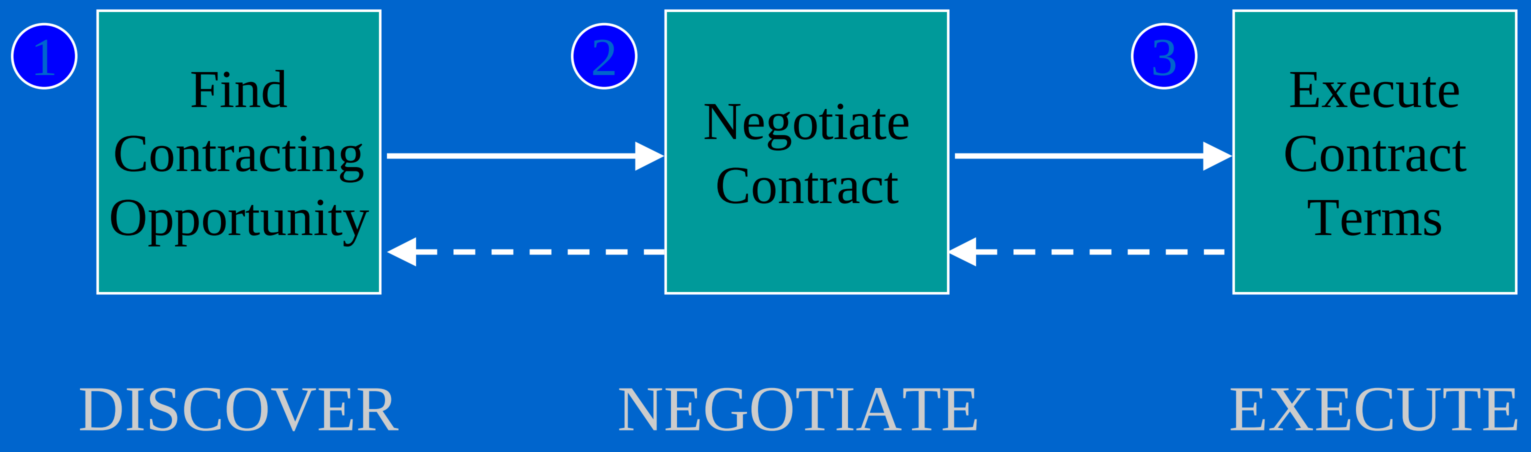
TODO (BillB)

- How does our approach scale?
  - Grosof complexity results
  - the straightforward way to express possible negotiation outcomes doesn’t scale… lots of things about our ontology address this
- How and what does the language make it easier to express?
- How have we exploited structure in a problem?
  - Component hierarchy, flight structure, etc

Other Uses for Prototype

- Generalization of Economy Generator
  - A few lines of CLP rules instead of 27 parameters
    - Rules of the form `auction(param,val)` also allowed, for specifying low-level parameters
  - Perl library for creating batches of auctions
- Support for reasoning about alternative negotiation structures

Contracting 1-2-3



Applies to any contracting, electronic or not.
May iterate or interleave these steps.
Boundaries not necessarily sharp.