Abduction and Contraction

Concept Abuduction and Contraction for Semantic-Based Discovery of Matches

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based on a paper by
Colucci, Di Noia, Di Sciascio, Donini, Mongiello
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Contraction

- Given: Supply S and demand D
- What to do if conjunction is unsatisfiable?

Starting with the concepts S and D, if their conjunction $S \sqcap D$ is unsatisfiable in the TBox $\mathcal{T}$ representing the ontology, our aim is to retract requirements in S to obtain a concept K (for Keep) such that $K \sqcap D$ is satisfiable in $\mathcal{T}$.

Contraction (2)

- Weakening

Intuitively, the supplier is "weakening" his/her requests, to investigate whether what is left of the original request is still worth an interest. Clearly, a user is interested in *what* s/he must trade to initiate the transaction — a concept G (for Give up) such that S was made by G and K, that is, $S \equiv G \sqcap K$.

Every argument in what follows could be restated exchanging supplier and demander, depending on who is actively starting the search.

Concept Contraction Problem

DEFINITION 1. *Let* $\mathcal{L}$ *be a DL,* S*,* D*, be two concepts in* $\mathcal{L}$*, and* $\mathcal{T}$ *be a set of axioms in* $\mathcal{L}$*, where both* S *and* D *are satisfiable in* $\mathcal{T}$. A Concept Contraction Problem *(CCP), identified by* $\langle \mathcal{L}, S, D, \mathcal{T} \rangle$*, is finding a pair of concepts* $\langle G, K \rangle \in \mathcal{L} \times \mathcal{L}$ *such that* $\mathcal{T} \models S \equiv G \sqcap K$*, and* $K \sqcap D$ *is satisfiable in* $\mathcal{T}$*. We call* K *a* contraction *of* S *according to* D *and* $\mathcal{T}$.

Solutions to CCPs (1)

We use $\mathcal{Q}$ as a symbol for a CCP, and we denote with $SOLCCP(\mathcal{Q})$ the set of all solutions to a CCP $\mathcal{Q}$. We note that there is always the trivial solution $\langle G, K \rangle = \langle S, \top \rangle$ to a CCP. This solution corresponds to the most drastic contraction, that gives up everything of S. In our e-commerce setting, it would model the (infrequent) situation in which, in front of some very appealing counteroffer D, incompatible with mine, I just give up completely my specifications S in order to meet D.

Solutions to CCPs (2)

On the other hand, when $S \sqcap D$ is satisfiable in $\mathcal{T}$, the "best" possible solution is $\langle \top, S \rangle$, that is, give up nothing — if possible. Since usually one wants to give up as few things as possible, some minimality in the contraction must be defined. We do not delve into details, and just mention that there exists an algorithm $contract(S, D, \mathcal{T})$ [19] to compute a minimal G (and a maximal K) for a given supply S with respect to a demand D and a TBox $\mathcal{T}$.

Entailment of subsumption?

Once contraction has been applied, and consistency between the supply and the demand has been regained, there is still the problem with partial specifications, that is, it could be the case that the supply — though compatible — does not imply the demand. Then, it is necessary to assess what should be hypothesized in the supply in order to start the transaction with the demand. We call this non-standard inference *Concept Abduction*, in analogy to Charles Peirce's Abduction [46, 39].

Abduction

DEFINITION 2. *Let $\mathcal{L}$ be a DL, S, D, be two concepts in $\mathcal{L}$, and $\mathcal{T}$ be a set of axioms in $\mathcal{L}$, where both S and D are satisfiable in $\mathcal{T}$. A* Concept Abduction Problem *(CAP), identified by $\langle \mathcal{L}, S, D, \mathcal{T} \rangle$, is finding a concept $H \in \mathcal{L}$ such that $\mathcal{T} \models S \sqcap H \sqsubseteq D$, and moreover $S \sqcap H$ is satisfiable in $\mathcal{T}$. We call H a* hypothesis *about S according to D and $\mathcal{T}$.*

Abduction (2)

Also for Concept Abduction, there exist algorithms [21, 19] that can compute H for $\mathcal{ALN}$ concepts S, D and a simple TBox $\mathcal{T}$. We also note that numerical versions $rankPotential(S, D, \mathcal{T})$ of the algorithm exist [23], computing the number of concept names in a Concept Abduction H, thus providing a score to the similarity between supply and demand.

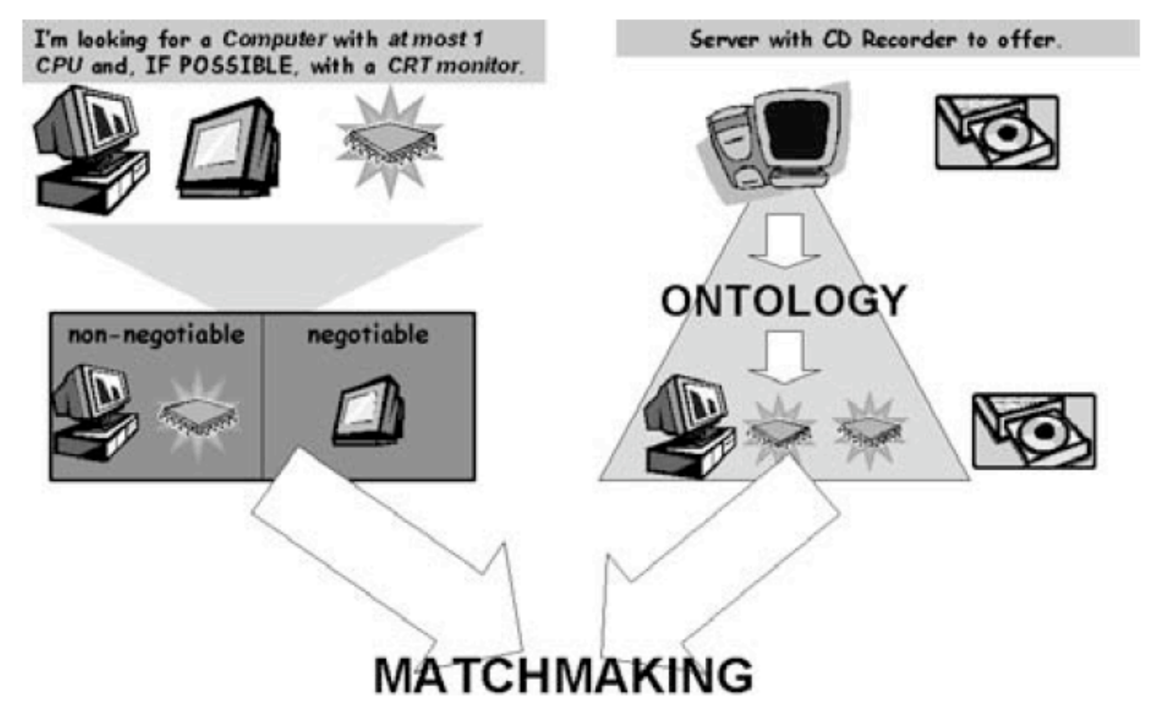
Comparison

- Satisfiability might be too weak
  - Very „strong" Tbox required
- Entailment of non-disjointness seems promising
  - Could be combined with contraction
  - Instead of satisfiability (one model) check for non-disjointness (in all models)
- Subsumption might be too strong
  - Abduction can help to add missing requirements

We note that Concept Contraction extends satisfiability — in particular, by providing new concepts G and K when a conjunction $S \sqcap D$ is unsatisfiable — while Concept Abduction extends subsumption — in particular, by providing a new concept H when S is not subsumed by D.

Contract everything?

- Some aspect might be non-negotiable
- Separate strict and negotiable aspects of a service/demand



Example

$\mathrm{unix} \sqsubseteq \neg \mathrm{winX}$

$\mathrm{linux} \sqsubseteq \mathrm{unix}$

$\mathrm{CRTmonitor} \sqsubseteq \neg \mathrm{LCDmonitor}$

$\mathrm{USBpen} \sqsubseteq \mathrm{removableDevice}$

$\mathrm{AMD} \sqsubseteq \neg \mathrm{Intel}$

$\mathrm{computer} \sqsubseteq (\geq\ 1\ \mathrm{hasStorageDevice}) \sqcap (\geq\ 1\ \mathrm{hasComponent})$

$\mathrm{server} \equiv \mathrm{computer} \sqcap (\geq\ 2\ \mathrm{hasCPU})$

$\mathrm{personalComputer} \sqsubseteq \mathrm{computer}$

$\mathrm{personalComputer} \sqsubseteq \neg \mathrm{PDA}$

$\mathrm{homePC} \sqsubseteq \mathrm{personalComputer} \sqcap (=\ 1\ \mathrm{hasOS})$

Strict and Negotiable Aspects

In an e-marketplace setting, a concept describing a Demand, can be read as a set of constraints on the user request. For example, the simple demand $D = \texttt{server} \sqcap (= 4\texttt{hasCPU})$ can be represented by the set $\{\texttt{server}, (= 4\texttt{hasCPU})\}$ in which each element represents a constraint imposed by the user. We model a user description, representing a Demand/Supply in an e-marketplace, as two sets of constraints, accounting for negotiable and non-negotiable elements of the request description. In DL terms, we model the non-negotiable and the negotiable constraints as a conjunction of concepts: negotiable constraints, from now on $\mathcal{NG}$ and non-negotiable – strict – constraints, from now on $\mathcal{ST}$.

Interaction between *ST* and *NG*

Obviously, if an element belongs to $\mathcal{NG}$ it cannot belong to $\mathcal{ST}$ *i.e.*, if $(= \ 4$ `hasCPU`$)$ is a negotiable constraint, then it cannot be also a non-negotiable one, otherwise an inconsistency ensues within the user specification. Such an inconsistency may be caused by the interaction between the ontology and the user's specifications about negotiable/non-negotiable constraints.

Problematic Example

For example, consider the axiom $\mathtt{server} \equiv \mathtt{computer} \sqcap (\geq 2\ \mathtt{hasCPU})$ in the reference ontology, and a user request $D = \mathtt{server} \sqcap (\geq 2\ \mathtt{hasCPU}) \sqcap (\geq 1\ \mathtt{hasOS})$, with $\mathcal{ST} \equiv (\geq 2\ \mathtt{hasCPU})$ and $\mathcal{NG} \equiv \mathtt{server} \sqcap (\geq 1\ \mathtt{hasOS})$.

- *ST* and *NG* overlap (w.r.t. Tbox)
- Use contraction to compute how dissimilar *ST* and *NG* are?

Example

With reference to the ontology in Figure 2, let us consider a user demand $D = \texttt{homePC} \sqcap \forall\texttt{hasComponent.LCDmonitor}$, with $\mathcal{NG} = \forall\texttt{hasComponent.LCDmonitor}$ and $\mathcal{ST} = \texttt{homePC}$, and a supply $S = \texttt{homePC} \sqcap \forall\texttt{hasComponent.CRTmonitor}$. It is possible to verify that $D \sqcap S$ is unsatisfiable, hence a *partial match* ensues.

Solving a ***CCP*** we obtain $\langle G, K \rangle$ where $G = \forall\texttt{hasComponent.LCDmonitor}$ and $K = \texttt{homePC}$.

Example - Discussion

By definition $K \sqcap S$ is satisfiable, hence, K potentially matches S. We also know that the demand D is a conjunction of $\mathcal{NG}$and $\mathcal{ST}$. Let us point out that, having $D \sqcap S$ unsatisfiable, if $\mathcal{ST} \sqcap S$ is satisfiable, then the unsatisfiability is due to $\mathcal{NG}$ (or to the conjunction of elements $\mathcal{ST}$ and other elements in $\mathcal{NG}$), *i.e.*, the part of the Demand the user is less interested in and may be willing to negotiate on, and –in case– retract.