A LOGICAL FORMULATION FOR NEGOTIATION AMONG DISHONEST AGENTS

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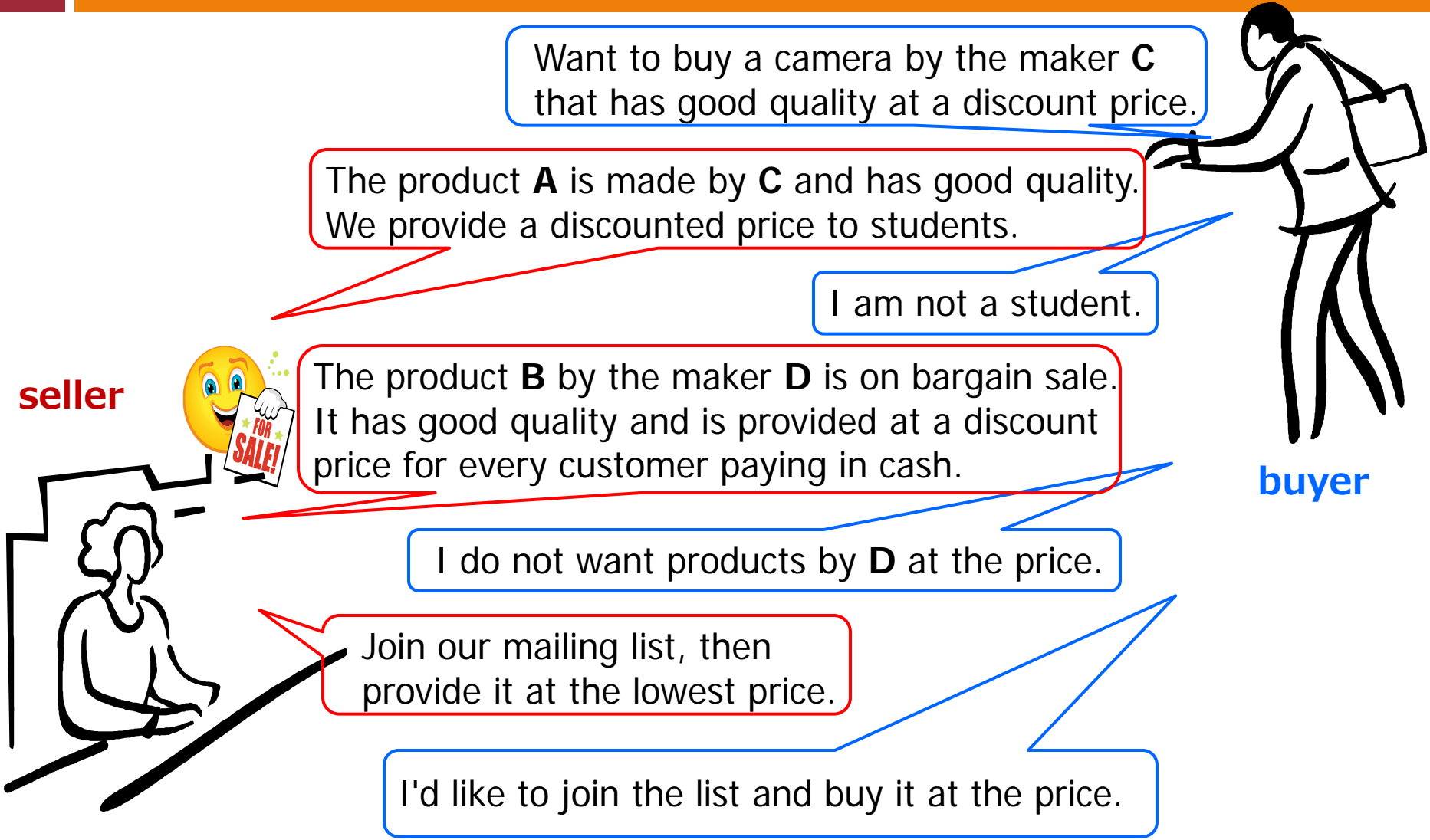
Background and Motivation

- The need of modeling **negotiating agents** for automated negotiation

- Most of the existing formalisms assume negotiation between **honest** agents

- This is **NOT** realistic because people often behave **dishonestly** in real-life negotiation
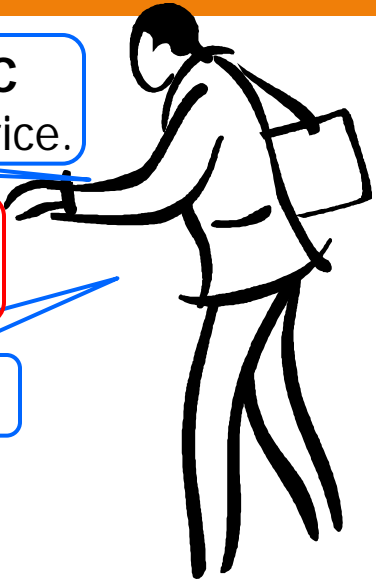
Contribution

- Providing a method for representing and reasoning with **disinformation**

- Formulating negotiation between **dishonest agents**

- Exploring various **negotiation strategies** that agents can employ

Example

seller

buyer

Want to buy a camera by the maker **C** that has good quality at a discount price.

The product **A** is made by **C** and has good quality. We provide a discounted price to students.

I am not a student.

The product **B** by the maker **D** is on bargain sale. It has good quality and is provided at a discount price for every customer paying in cash.

I do not want products by **D** at the price.

Join our mailing list, then provide it at the lowest price.

I'd like to join the list and buy it at the price.

Example

I do **not** know the quality of **A**, but know that **B** is **not** of good quality.

Want to buy a camera by the maker **C** that has good quality at a discount price.

The product **A** is made by **C** and has good quality. We provide a discounted price to students.

Misleading

I am not a student.

seller

The product **B** by the maker **D** is on bargain sale. It has good quality and is provided at a discount price for every customer paying in cash.

Lying

buyer

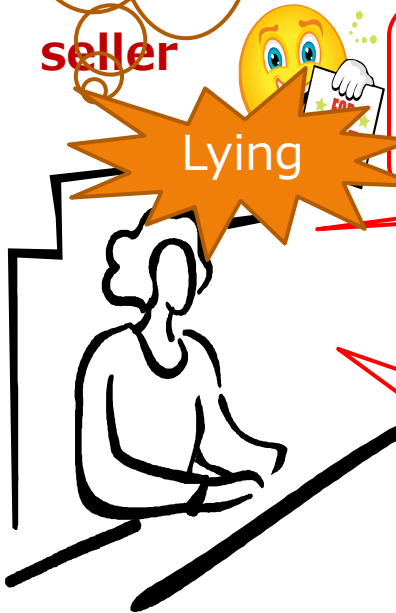I do not want products by **D** at the price.

Join our mailing list, then provide it at the lowest price.

Lying

I do **not** want to join the mailing list.

I'd like to join the list and buy it at the price.

Need to Manage

- **Preference**
  - Seller: higher price, cash payment, etc
  - Buyer: lower price, certain specification, etc
- **Incomplete information**
  - Seller does not know about the types of customers (status, preference, payment, etc)
  - Buyer does not know about the details of products (availability, price, quality, etc)
- **Disinformation**
  - Seller/Buyer may provide false or inaccurate information to get a good deal
- **Goal change**
  - Seller/Buyer may change his/her original goal to reach an agreement

Representing and Reasoning with Disinformation

- Representation Language
  - **abductive program with preferences**
    - background knowledge, goals and preferences are encoded in a logic program
    - assumptions for incomplete information are encoded as **abducibles** （**literals or rules**）
  - **extending to deal with disinformation**
    - **bullshit or BS**: stating a fact is true while its truth value is unknown
    - **lie**: stating a fact is true while it is believed to be false
- Reasoning with Disinformation
  - Computing **(most preferred) belief sets** of an **abductive program with disinformation** (or **ALD-program**)

Abductive Program with Preference

<P , A>: **abductive program** for a seller

P: **logic program**

```
makerC ← productA.
makerD ← productB.
bargain ← productB.
¬ qualityB ← productB.
sale ← productA, high.
sale ← productA, low.
sale ← productB, high.
sale ← productB, low.
sale ← productB, lowest.
productA ←.      productB ←.
← high, low.
← high, lowest.
← low, lowest.
← not sale.

n2 < n1.   n3 < n1.   n4 < n1.
n4 < n2.   n4 < n3.
```

A: **abducibles**

```
n1: high.
n2: low ← student.
n3: low ← bargain, cash.
n4: lowest ← mailing, cash.

n5: student.   n6: cash.  n7: mailing.
```

n1,...,n7 are names attached to abducibles

background knowledge

goal

preference between abducibles

Abductive Program + Disinformation

<P , A>: **abductive program** for a seller

P: **logic program**

$makerC \leftarrow productA.$
$makerD \leftarrow productB.$
$bargain \leftarrow productB.$
$\neg\, qualityB \leftarrow productB.$
$sale \leftarrow productA, high.$
$sale \leftarrow productA, low.$
$sale \leftarrow productB, high.$
$sale \leftarrow productB, low.$
$sale \leftarrow productB, lowest.$
$productA \leftarrow. \qquad productB \leftarrow.$
$\leftarrow high, low.$
$\leftarrow high, lowest.$
$\leftarrow low, lowest.$
$\leftarrow not\ sale.$

$n2 < n1. \quad n3 < n1. \quad n4 < n1.$
$n4 < n2. \quad n4 < n3.$

A: **abducibles**

n1: high.
n2: low ← student.
n3: low ← bargain, cash.
n4: lowest ← mailing, cash.

n5: student.   n6: cash. n7: mailing.

D: **disinformation**

qualityA.   (BS)
qualityB.   (lie)

*If **qualityB** is used, conflicting rules from **P** must be removed*

Abductive Program with Disinformation

$<P_D, A_D>$: **ALD program** wrt $<P, A>$ and **D**

P_D : logic program

makerC $\leftarrow$ productA.
makerD $\leftarrow$ productB.
bargain $\leftarrow$ productB.
sale $\leftarrow$ productA, high.
¬ qualityB $\leftarrow$ productB.
....
$\leftarrow$ not sale.
n2 < n1.   n3 < n1.   n4 < n1.
n4 < n2.   n4 < n3.

A_D : abducibles

n1. n2. n3. n4. n5. n6. n7.

+

n8: ¬ qualityB $\leftarrow$ productB.
n9:   qualityA.   (BS)
n10: qualityB.   (lie)

+

ni < n8. (i=1,…,7)

n9 < nk.   n10 < nk. (k=1,…,8)

n9 < n10.

Rules from **P** is preferred to abducibles **A**

Rules from **P ∪ A** are preferred to disinformation

BS is preferred to lies

Negotiation Among Dishonest Agents

- Each agent has its own **negotiation knowledge base** representing:
  - an agent's **belief** and **goals**
  - **negotiation conditions** with his/her **preference**
  - possible **assumptions** about the other agent
  - possible attitude of **dishonesty**

- Each agent builds **proposals** and judges whether a proposal made by the other agent is acceptable or not
  - a proposal contains an agent's **goal**, **assumptions** about the receiver, and **conditions** on the feasibility of the proposal
  - an agent decides whether a proposal is **acceptable**, **rejectable**, or **negotiable**, based on his/her state of belief

Negotiation Knowledge Base (NKB)

K=(Π, H, N$^<$): Negotiation Knowledge Base

Π=$<$P$_D$, A$_D>$: ALD program

P$_D$: logic program

> *makerC ← productA.*
> *makerD ← productB.*
> *bargain ← productB.*
> *sale ← productA, high.*
>   *........*
> *productA ←.   productB ←.*
> *← not sale.*
>
> *n2 < n1. n3 < n1. n4 < n1.*
> *n4 < n2. n4 < n3.*
>
> *ni < n8.* (i=1,...,7)
>
> *n9 < nk. n10 < nk.* (k=1,...,8)
>
> *n9 < n10.*

A$_D$: abducibles

> *n1. n2. n3. n4. n5. n6. n7.*
> *n8: ¬ qualityB ← productB.*
> *n9: qualityA.   (BS)*
> *n10: qualityB.   (lie)*

H : assumptions

> *student. cash. mailing.*

N$^<$: negotiation conditions

> *lowest < low < high*

Proposals

K=(Π, H, N<): Negotiation Knowledge Base with **Π=<P_D, A_D>**

P_D: logic program

> *makerC ← productA.*
> *makerD ← productB.*
> *sale ← productA, high.*
> *sale ← productB, low.*
>   *........*
> *productA ←.   productB ←.*
> *← not sale.*
> *n2 < n1. ...   n9 < n10.*

A_D : abducibles

> *n1: high.*
> *n2: low ← student.*
> *n3. n4. n5. n6. n7.*
> *n8: ¬ qualityB ← productB.*
> *n9:   qualityA.   (BS)*
> *n10: qualityB.   (lie)*

H : assumptions

> *student.   cash.   mailing.*

N< : negotiation conditions

> *lowest < low < high*

Building proposal by a seller:
<Goal, Assumption, Condition>

> *<{high}, ∅, {productA}>*
> Sell a product **A** for a high price   **honest**

> *<{low},{student},{productB, qualityB }>*
> Sell a product **B** with quality for a low price
> if student   **deceptive!**

Acceptability of Proposals

K=(Π, H, N$^<$): Negotiation Knowledge Base with **Π=<P$_D$, A$_D$>**

P$_D$: logic program

> *makerC ← productA.*
> *makerD ← productB.*
> *bargain ← productB.*
> *sale ← productA, high.*
> *sale ← productB, low.*
>   **........**
> *productA ←.   productB ←.*
> *← not sale.*
> *n2 < n1. ... n9 < n10.*

A$_D$: abducibles

> *n1: high.*
> *n2: low ← student.*
> *n3: low ← bargain, cash.*
> *n4. n5. n6. n7.*
> *n8: ¬ qualityB ← productB.*
> *n9: qualityA.   (BS)*
> *n10: qualityB.   (lie)*

Evaluating proposals by a buyer:

<Goal, Assumption, Condition>

> *<{high}, {productA, qualityA }, ∅ >*
> Buy **A** with quality at a high price

acceptable with BS

> *<{low},{productB, makerD },∅>*
> Buy **B** by maker **D** at a low price

negotiable if student or cash

> *<{low},{productB , makerD },*
>   *{¬ student, ¬ cash }>*
> Buy **B** by maker **D** at a low price under
> the condition of ¬student and ¬cash

rejectable

Formulating Negotiation Dialogue

buyer

Want to buy a camera by the maker C that has good quality at a discount price.

seller

$<${*low*}, {*productA, qualityA, makerC* }, $\varnothing >$

The product A is made by C and has good quality. We provide a discounted price to students.

$<${*low*}, {*student*}, {*productA, qualityA, makerC* } $>$

Bullshit

I am not a student.

$<${*low*}, {*productA, qualityA, makerC*}, {*¬student* } $>$

The product B by the maker D is on bargain sale. It has good quality and is provided at a discount price for every customer paying in cash.

$<${*low*}, {*cash*}, {*productB, qualityB, makerD* } $>$

Lie

I do not want products by D at the price.

Goal Change

$<${*lowest*}, {*productB, qualityB, makerD*}, {*cash* } $>$

Goal Change

Join our mailing list, then provide it at the lowest price.

$<${*lowest*}, {*cash, mailing*}, {*productB, qualityB, makerD* } $>$

I'd like to join the list and buy it at the price.

Lie

$<$T, $\varnothing$, $\varnothing >$

Negotiation Strategies

- **Observant Strategy**
  - An agent does not repeat the same response to the same proposal in a negotiation
  - Negotiation terminates if one of the agents uses the strategy
- **Deliberate Strategy**
  - An agent builds a proposal only if it is supported by a most preferred belief set
  - An agent lies or BS only if he/she has no alternative
- **Best Practice Strategy**
  - A deliberate strategy which is also observant
  - An agent may accept a less preferred outcome even though he/she might obtain a more preferred one had he/she used disinformation

Final Remark

- A formal semantics of the negotiation framework is given by the **belief sets** of abductive programs (or **answer set semantics** of logic programs)

- **Complexities** of computing proposals follow from those of abductive programs

- The framework is implemented on top of the **ASP-Prolog** platform (Nguyen, Son, Pontelli and Sakama: "**ASP-Prolog for negotiation among dishonest agents**", Proc. LPNMR, LNAI 6645, 2011)