Formalizing Negotiations

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TU Delft

Outline

- Recap last week
- Domain model
- Preferences
- Utility functions
- Negotiation Analysis
- Prepare for Tutorial and Test

Recap

- Why negotiate: joint decision needed, hidden information, cannot be decided otherwise (power, deliberation)
- Principles for human negotiators
- Phases of negotiation
- Definitions
- Styles: negotiation & conflict handling

Domain

- Validity and Added value: The added value of using artificial intelligence techniques highly depends on the quality/validity of the model:
  - Weak model $\rightarrow$ weak support by the technique
  - Faulty model $\rightarrow$ faulty advice
- Transparency: Model should be transparent for the user of technique
  - Trust
  - Understanding the advice

Domain model

- For the negotiations we do we need
- A set of issues X, and for each issue $x \in X$ a set of values for each of those issue: V(x)
- Another word for issues is attributes.
- For each stakeholder we need a preference profile for this domain

Domain Modelling

- Domain modelling is difficult for humans:
  - Constructive process: humans become aware of them when working with the material/problem. For negotiation this implies that they might realise that something is an issue they would like to negotiate about when the other party makes a remark about it.
  - Lack of experience in structuring problems
  - Lack of formal techniques (math/logic, data structures)
- Can the stakeholder understand your model?
- An exam question might be: construct and explain a domain model for the following domain. <followed by an informal description of the domain>

Preferences

- Given a finite set of issues X, and i and j $\in$ X and sets of values for each of those issues: V(i), V(j)
- Stakeholders have preferences over the values per issue and over combinations (bids) of values for a range of issues, expressed by a preference relation $<_p$
- Suppose a, b $\in$ V(i), for some issue i, then a $<_p$ b expresses that the stakeholder prefers b over a.
- Furthermore, suppose that, c, d $\in$ V(j), for some j $\neq$ i,
- Then similarly (a, c) $<_p$ (b, d), expresses that the combination (b,d) is preferred over (a,c).

Preferences

- **Preference Independence**: A set of attributes $Y \subset X$ is preferentially independent of its complement X-Y when the preference order over outcomes with varying values of attributes in Y does not change when the attributes of X-Y are fixed to any value.
- **Mutual Preferential Independence**: The attributes of set X are mutually independent if every subset Y of X is preferentially independent of its complementary set.
- **Value function of an attribute**: for every attribute $x \in X$, v_x: $V(x) \rightarrow [0, 1]$, is a value function for x.

Preferences

Theorem of Additive Value Function: Given a set of attributes X,

- an additive value function $v_X = \Sigma_{x \in X} (\lambda_x v_x)$, where $\Sigma_{x \in X} \lambda_x = 1$, and for all $x \in X$: $\lambda_x \in [0,1]$
- exists if and only if the attributes are mutually preferentially independence.

Preference elicitation

- Preferences are constructive in nature: humans become aware of them when working with the material/problem. For negotiation this implies that they might realise they have a preference for an issue when the other party makes a remark about it.
- Study Chen's survey paper to pick a good elicitation technique for the practical assignment (D1), see Brightspace.
- Exam question might be: what elicitation technique is applicable for the following domain? (followed by a domain description)

Utility functions

- The value function reflects the stakeholder's preferences on a particular outcome. In case of uncertain decision scenarios, where the outcomes are characterized by probabilities, a more complex function, **utility function**, is need to evaluate the "utility" of a decision.
- The utility function represents the user's attitudes about risk as well as the value of outcomes, so it induces a preference ordering on the probability distributions over the outcome space.
- If risk is not a factor in the domain, then, the utility function coincides with the value function.

Utility: Determine the Value of a Bid

- **Utility** is like a **grade**, determined as a weighted sum of the evaluation values of each issue.

$$U(X_1, X_2, ..., X_n) = \sum_{i=1}^{n} w_i * U_i(X_i)$$

- The utility of <Sea, Summer, One-week> =

$0.5 * U_{1}(\text{Sea}) + 0.3 * U_{2}(\text{Summer}) + 0.2 * U_{3}(\text{One-Week})$

$= 0.5*0.9 + 0.3*0.7 + 0.2*0.5 = 0.76$

where w_{1} (Location) $= 0.5$, w_{2} (Season) $= 0.3$, w_{3}(Duration) $= 0.2$

U_{1}(Sea) $= 0.9$, U_{2} (Summer) $= 0.7$, U_{3}(One-Week) $= 0.5$

Utility

- n issues:
  - b = (v1, …, vn)
  - v1 ∈ D1, …, vn ∈ Dn
  - D = D1 x … x Dn
- For every bid b ∈ D
  - Utility of A: $U_A(b)$
  - Utility of B: $U_B(b)$
- $U_X : D \rightarrow [0, 1]$
- $U_X(b) = \sum_j w_{X,j} E_{X,j}(b)$
- $w_{X,j}$: weight issue j
- $E_{X,j}(b)$: evaluation of value of issue j in bid b

- 2 issue example
  - G: g1, g2
  - H: h1, h2
- Agent A
  - $E_{A,1}(g1) = 1$
  - $E_{A,1}(g2) = 0.5$
  - $E_{A,2}(h1) = 0.3$
  - $E_{A,2}(h2) = 1$
  - $w_{A,1} = 0.7$
  - $w_{A,2} = 0.3$
  - $U_A((g1, h1)) = 0.7*1 + 0.3*0.3 = 0.7 + 0.09 = 0.79$

Utility (2)

- 2 issue example
  - G: g1, g2
  - H: h1, h2
- Agent A
  - $E_{A,1}(g1) = 1$
  - $E_{A,1}(g2) = 0.5$
  - $E_{A,2}(h1) = 0.3$
  - $E_{A,2}(h2) = 1$
  - $w_{A,1} = 0.7$
  - $w_{A,2} = 0.3$
  - $U_A((g1, h1)) = 0.79$
  - $U_A((g2, h1)) = 0.44$
  - $U_A((g1, h2)) = 1$
  - $U_A((g2, h2)) = 0.65$

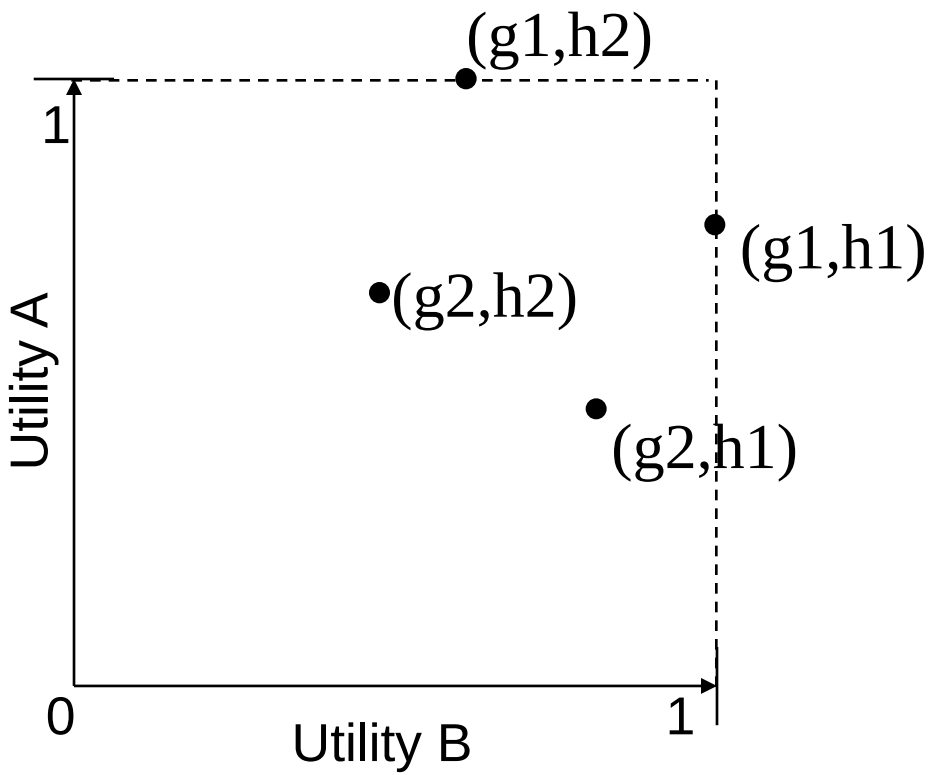
- 2 issue example
  - G: g1, g2
  - H: h1, h2
- Agent B
  - $E_{B,1}(g1) = 1$
  - $E_{B,1}(g2) = 0.6$
  - $E_{B,2}(h1) = 1$
  - $E_{B,2}(h2) = 0.4$
  - $w_{B,1} = 0.4$
  - $w_{B,2} = 0.6$
  - $U_B((g1, h1)) = 1$
  - $U_B((g2, h1)) = 0.84$
  - $U_B((g1, h2)) = 0.64$
  - $U_B((g2, h2)) = 0.48$

Analysis of Negotiation Results

- How do you rate a bid?
  - Balance between what you give and take
  - Utility: grade between 0 and 1
- Comparing results

give *take*

Outcome space



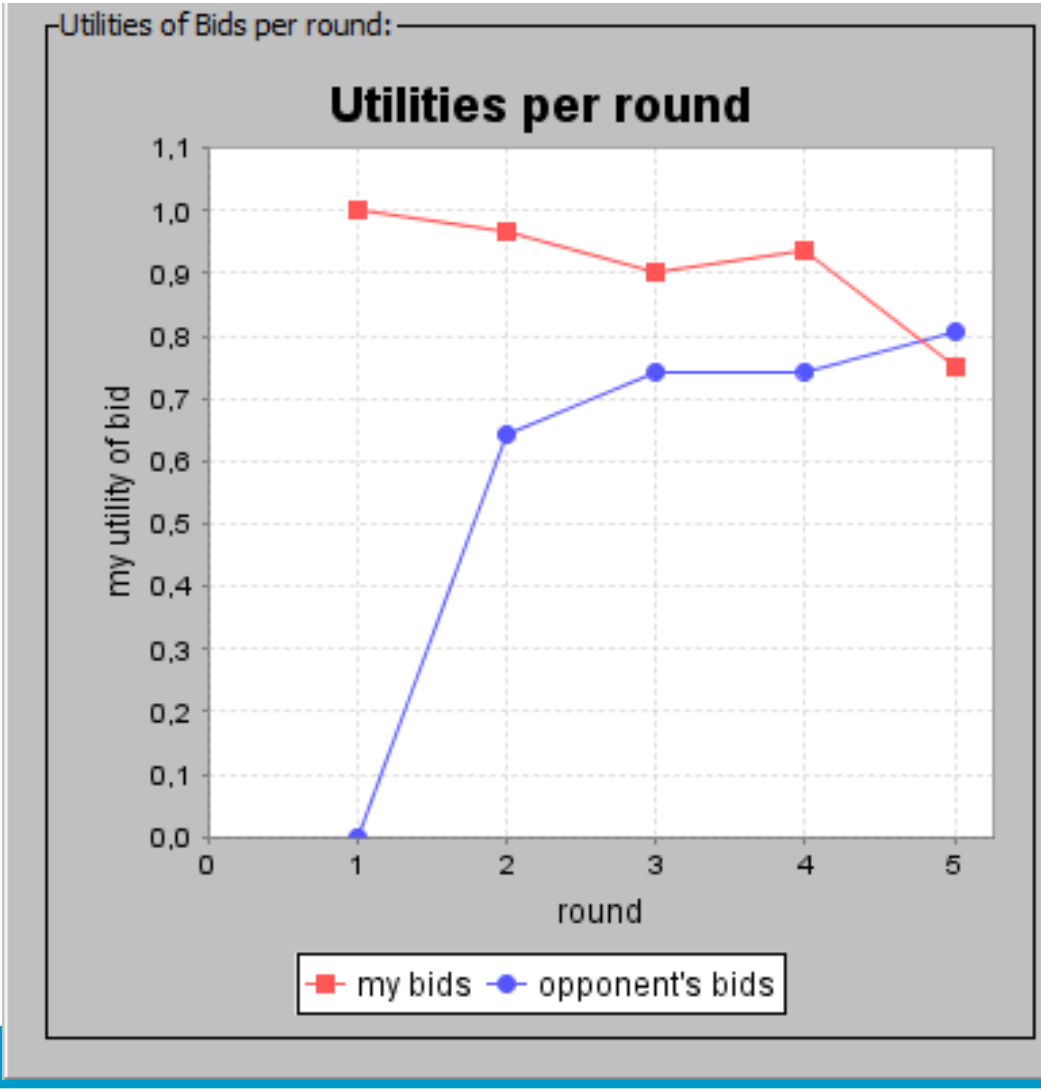
- Result of a bid:
  - $R : D \rightarrow ([0, 1], [0, 1])$
  - $R(b) = (U_A(b), U_B(b))$
- 2 issue example

  G: g1, g2

  H: h1, h2
- Bid

Bid	UA	UB
(g1,h1)	0.79	1
(g2,h1)	0.44	0.84
(g1,h2)	1	0.64
(g2,h2)	0.65	0.48

The bidding from your own perspective

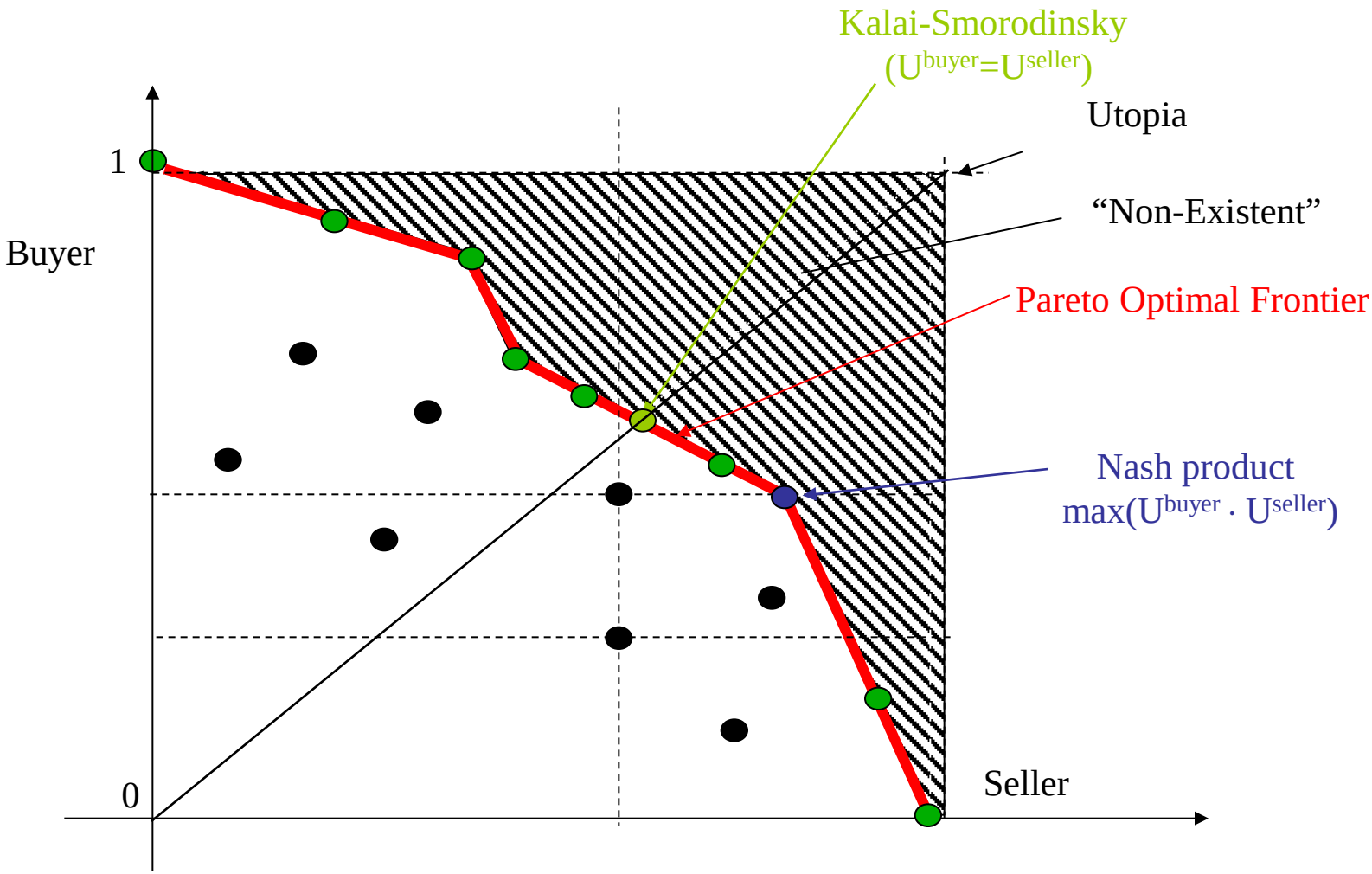


Comparing results

You think

The other partner thinks

How Well Did You Do?



Definitions

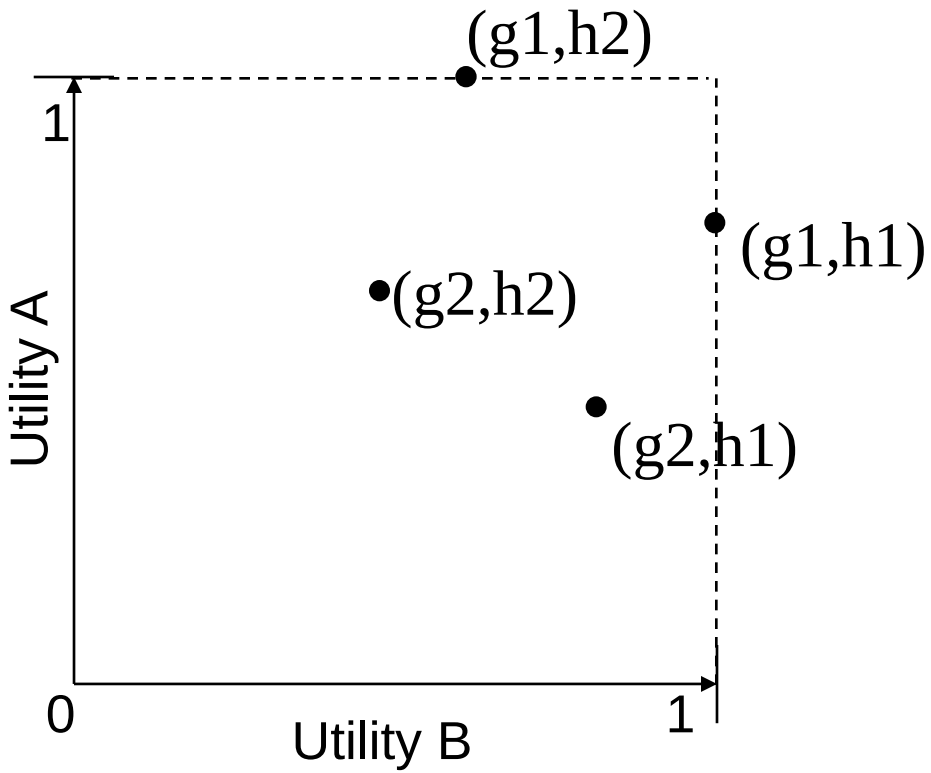
- Let U_A and U_B be the **utility functions** of party A and party B. Both functions are defined on the domain D of all possible bids that the agents can make, mapping D to the range [0, 1]. Thus,
  $U_A : D \rightarrow [0, 1]$ and $U_B : D \rightarrow [0, 1]$.
- The **Pareto Optimal Frontier** is the set of bids, such that there is no other bid that is better for at least one party, without making things worse for the other parties. Thus, if two agents A and B are involved,
  $POF = \{ b \in D \mid \forall b' \in D : b \neq b' \rightarrow (U_A(b') < U_A(b) \vee U_B(b') < U_B(b)) \}$

Definitions (2)

- **Nash Product**: the bid (or bids) that maximizes the product of utilities of the parties, under the assumption that all utility values are positive. If that is not the case, you have to transpose the utility space to positive values.
- The **equal proportion of potential line** (EPP) is the line from (0,0) to (1,1).*
- **Kalai-Smorodinsky**: maximizes the minimum of the utilities of the parties. To be found at the intersection of POF and EPP, i.e., the bid(s) closest to that intersection.

*It is a bit more technical than this if the domain is not continuous

Result space



- Result of a bid:
  - $R : D \rightarrow ([0, 1], [0, 1])$
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- 2 issue example

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- Bid

Bid	UA	UB
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Relation to Artificial Intelligence

Negotiation Has Entered the Digital World:

- e-mail, e-commerce, ...

Artificial Intelligence:

- Intelligent decision making
- Engineering Heuristic Approaches for Machines
- Engineering Cognitive Skills used in Negotiation

Russell & Norvig: 2 – 6, 10, 13 - 22

The Future:

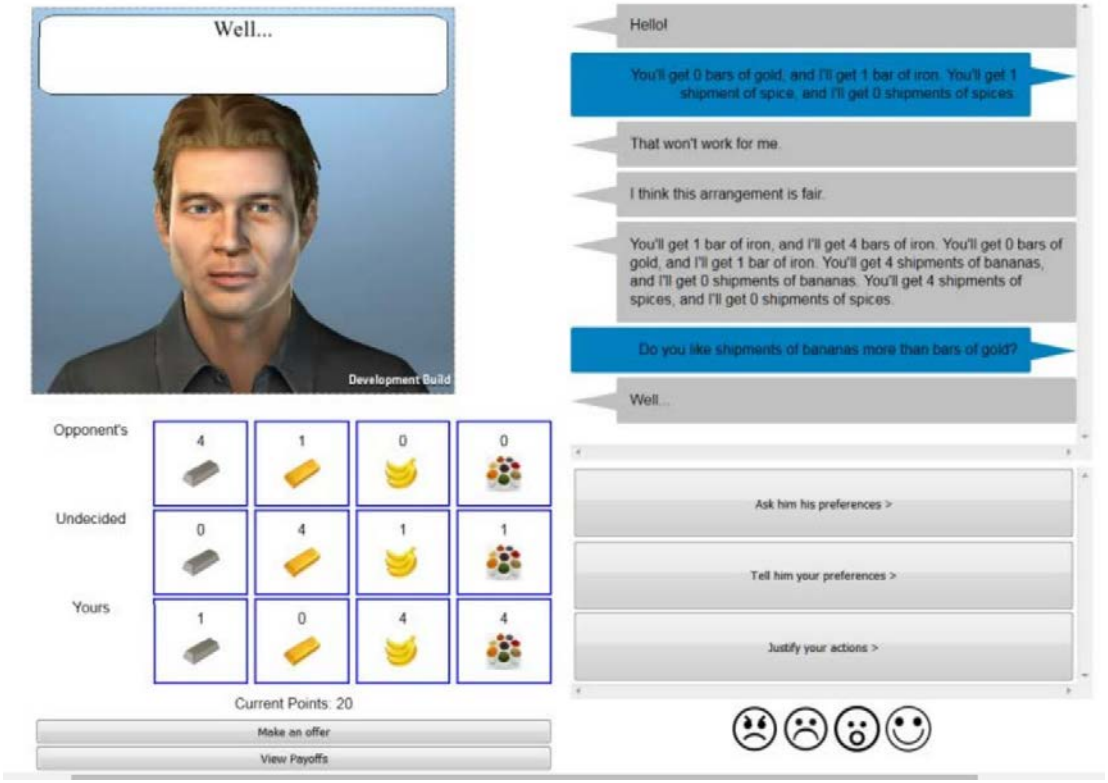
- Enhanced negotiations by using the Negotiation Support Systems

The Pocket Negotiator

http://ii.tudelft.nl/negotiation/index.php/Pocket_Negotiator

- Domain specification
- Preference elicitation
  - Underlying interests
  - Weights of issues
  - Evaluation functions of issues
- Bidding support
  - What to bid
  - When to stop

IAGO platform – Group Jon Gratch



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Additional literature

- Preference elicitation

Chen, L., & Pu, P. (2004). *Survey of preference elicitation methods* (No. EPFL-REPORT-52659).

Classics on the way to automated negotiation

- Rosenschein, J.S., and Zlotkin, G., (1994). Rules of Encounter: Designing Conventions for Automated Negotiation Among Computers. MIT Press.
- Raiffa, H., Richardson, J., and Metcalfe, D., (2002). Negotiation Analysis: The Science and Art of Collaborative Decision Making, Cambridge, MA: Belknap Press of Harvard University Press.

Supporting humans

- Michele Joy Gelfand and Ya'akov Gal. The brave new negotiating world: Challenges and opportunities. In B. Goldman & D. Shapiro (Eds.) The psychology of negotiations in the21st Century Workplace. SIOP Frontiers Book, Routledge, 2013.http://www.routledge.com/books/details/9780415871150/
- Ya'akov Gal, Sarit Kraus, Michele Gelfand, Hilal Khashan, Elizabeth Salmon. Negotiating with People across Cultures using an Adaptive Agent. ACM Transactions on Intelligent Systems and Technology 3(1), Article 8, 2011. http://www.eecs.harvard.edu/~gal/Papers/culture10.pdf
- http://ii.tudelft.nl/negotiation/index.php/Pocket_Negotiator
- Jonker C.M., Aydogan R, Baarslag T, Broekens J, Detweiler C, Hindriks K.V., Huldtgren A, Pasman W, (2017). An Introduction to the Pocket Negotiator: A General Purpose Negotiation Support System. In: *Multi-Agent Systems and Agreement Technologies, Multi-Agent Systems and Agreement Technologies* – Proceedings of the 14th European Conference, (EUMAS 2016), LNAI 10207, Springer International Publishing, pp:13—27.
- The InterNeg Research Centre: http://interneg.concordia.caa