RUTGERS

Utility Fit Lookahead Agent – Sequential Multi-deal Negotiation

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Sequential Multi-Deal Negotiation

- Center agent encounters multiple edge agents in sequence
- Subnegotiation (center <-> edge): Bilateral, Alternating Offers Protocol



- Rewarded for combination of all agreements
- Aware of own utility function
  - Opponent's utility function unknown

Baarslag, T. (2024). *Multi-deal Negotiation.* ANL 2025 Call for Participation.

A Look into Subnegotiations

- Let Ω denote the outcome space
  - Let Ω_i denote the i-th subnegotiation
  - $\Omega = \Omega_1 \times \cdots \times \Omega_n$
- Given utility function
  - $u : \Omega \to \mathbb{R}$
- What's the utility of realizing some suboutcome $\omega_i \in \Omega_i$?
  - At each subnegotation, what is best agreement?

- Naively,
  - We can underestimate the utility of ω_i
  - Let h be the history of previous suboutcomes
  - $u(\omega = (h, \omega_i, None, \dots, None))$
- **Can we do better?**

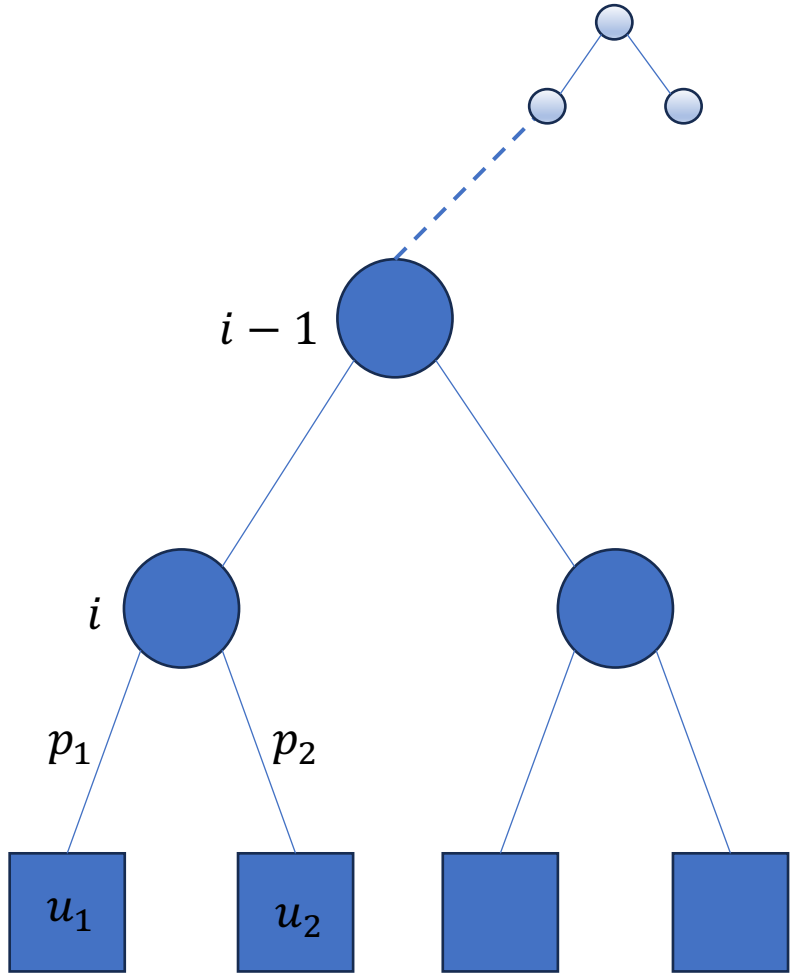
Our Approach

Divide center strategy in two parts:

1. Lookahead planning
   - Utility estimation
   - Early termination
2. Conceding Strategy
   - Utility Fit
     - Opponent bids -> our estimated utility

Tree Representation To Solve Estimated Utilities

- Calculate estimated utilities of suboutcomes
- A node at depth i
  - Beginning of subnegotiation i
  - Contains suboutcomes from previous subnegotiations $0, \dots, i-1$
- Children represents all suboutcomes Ω_i
- Recursively,
  - Calculate expected utility of all children
  - Assign probabilities to children
    - Cooperative vs. adversarial
  - Propagate expected utility of parent upwards



Early Termination

- What if the number of outcomes becomes intractable?
  - M suboutcomes, N subnegotiations → M^N outcomes
- Perform early termination
  - Do at each subnegotiation
- Stop at some depth k and propagate some terminal utility
  - Need heuristic
  - Use the naive underestimation
  - $u(\omega = (h, \omega_i, None, \dots, None))$

Concession Strategy – Time-Based

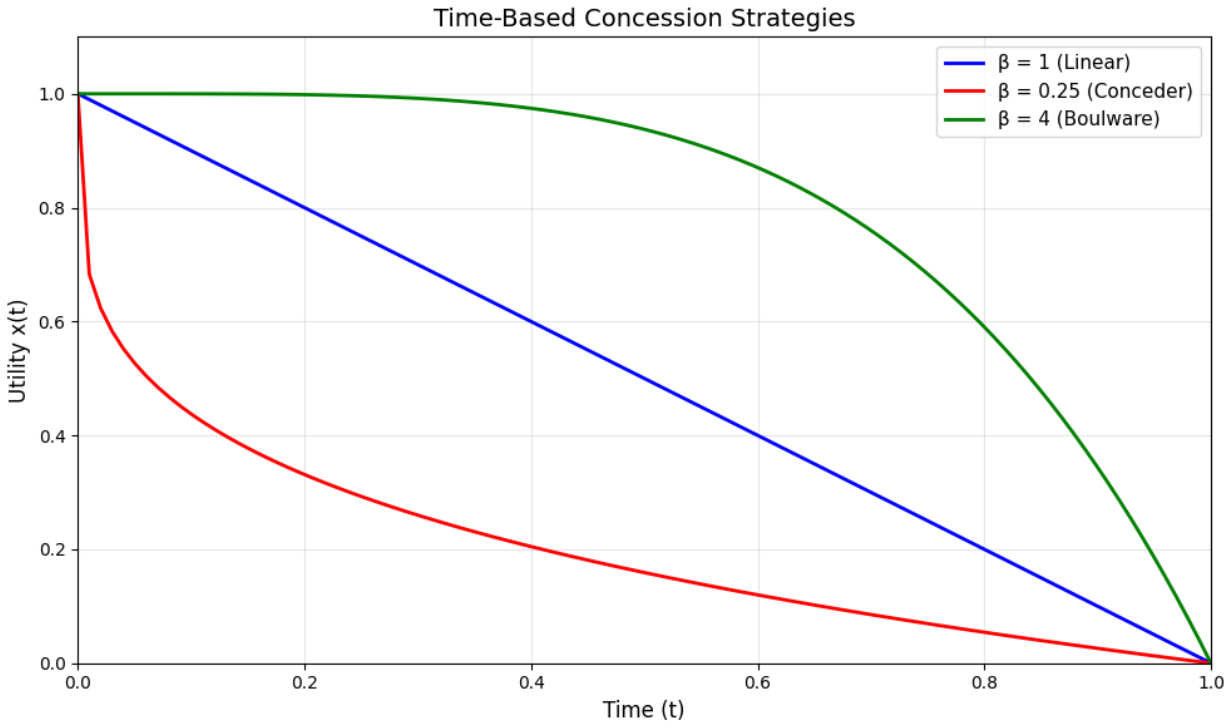
Assumption

- Opponents follow time-based strategy
- Faratin et al. (1998)

General Form

$$x(t) = u_{min} + (u_{max} - u_{min}) * (1 - t^{\mathrm{B}})$$

- $x(t)$: **opponent's** utility of bid offered at time t
- u_{min} : minimum utility
- u_{max} : maximum utility
- B : concession degree



Our Concession Strategy

Idea:

- No discount
- Delay negotiation as long as possible
  - Reject all offers
  - Bid suboutcomes with large utility
- Make most informed bid at last timestep
  - From their offers

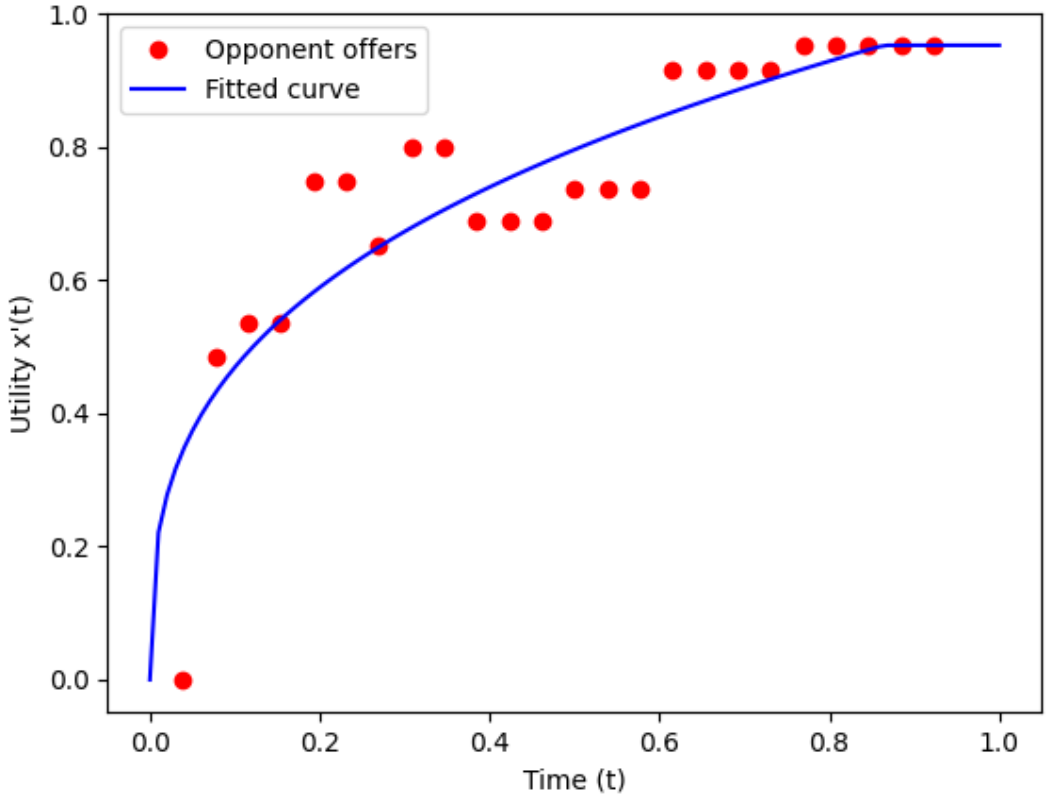
How To Use Information?

- As opponent concedes over time (adversarial)
  - Opponent utility decreases
  - Our utility increases
- Map opponent offers to our estimated utilities from lookahead
  - Estimated utilities increase w/ time
- Use opponent offers → our utility to fit utility curve

Utility Fit

$x'(t;\, \boldsymbol{u_{max}}, \mathbf{B})$

- x′ : **our estimated utility** from opponent's offers
- $\boldsymbol{u_{max}}$: our maximum utility, opponent willing to concede to
- $\mathbf{B}$: opponent's concessive degree



- Find parameters $\boldsymbol{u_{max}}$ and $\mathbf{B}$ that best fit according to their offers
- Final timestep:
  - Propose outcome w/ estimated utility: $x'(t = 1)$