NEGOTIATION AND BARGAINING

Negotiation is a form of interaction in which a group of agents with conflicting interests try to come to a mutually acceptable agreement over some outcome. The outcome is typically represented in terms of allocation of resources (commodities, services, time, money, CPU, etc.).

Agents' interests are conflicting in the sense that they cannot be simultaneously satisfied, either partially or fully. Since there are many different possible outcomes, negotiation can be seen as a ―distributed search through a space of potential agreements‖. Different aspects of Negotiation are (i) the set of possible outcomes;

(ii) the agents conducting the negotiation;

(iii) the protocol for a specific agreement in this space; and

(iv) the individual strategies that determine the agents' behavior.

The set of possible outcomes may be represented as a number representing who gets whatamount of resource. It is worth noting that agents may already have a particular allocation of resources before they begin negotiation. *Negotiation becomes an attempt to reallocate the resources in order to reach a new allocation that is more preferable to both.*

The **conflict deal** (also known as the no negotiation alternative) refers to the situation in which agents do not reach an agreement in negotiation. The approaches to defining the space of possible outcomes of negotiation are :

1. Task-oriented domains: domains involving the division of tasks to execute.
2. State oriented domains: domains involving joint decision about what state agents willachieve;
3. Worth-oriented domains: domains involving a joint decision about what goals to achieve.

1.Game-Theoretic Approaches for Single-Issue Negotiation

Let us considering the scenario, where there is a **single resource and there are two agents competing for the resource, called Single-issue Negotiation.** Each agent wants to get aslarge share of the resource as possible, so there is a conflict between the agents that how the resource must be divided between them. To resolve this conflict, the agents must negotiate or bargain and decide upon a division that will be acceptable to both parties. So

each party can onlyobtain what the other is prepared to allow it.

1. The negotiation will either end successfully, whereby the parties reach an agreement on amutually acceptable split,
2. Or else negotiation will end in a failure to reach an agreement.

In the event of the failure, both agents get nothing. Hence, each agent will prefer to get a non-zero share and allow the negotiation to break down.

There are two ways to model such bilateral negotiations: using cooperative game theory and using non-cooperative game theory.

1. In **cooperative games,** agreements are binding or enforceable, possibly by law. When agreements are binding, it is possible for the players to negotiate outcomes that are mutually beneficial.
2. In **non-cooperative games,** agreements are not binding. Here, the players are self-interested and their focus is on individually beneficial outcomes. So a player need incentive to deviate from an agreement in order to improve its utility.

	B: Quiet/cooperate	B: Defect/testify against partner
A: Quiet/Cooperate	Both serve 1 month	A: serves 1 year, B: goes free
A: Defect/testify against partner	A: goes free, B: serves 1 year	Both serve three months

Table 4.1: Prisoner's Dilemma game

Consider Prisoner's Dilemma game given in Table 4.1. Assume that this game is non - cooperative. Then the dominant strategy for both players will be to confess. The outcome is not Pareto optimal. In contrast, if the same game was played as a cooperative game, and the players agreed not to confess, then both players would benefit. The agreement (deny, deny) would be binding and the resulting outcome would be Pareto optimal.

BARGAINING

Situations such as trading between a buyer and a seller, or an employer and a labor may be regarded as **bargaining problems.** There will be more than one way of collaborating, and how much an individual benefits depends on the actions taken by both agents. **Nash** analyzed the bargaining problem and defined a solution/outcome, by

determining how much each individual should expect to benefit from the situation, using an **axiomatic approach.**

1. **Cooperative Models of Single-Issue Negotiation**

There are two players (say a and b) who want to come to an agreement over the alternatives in an arbitrary set A. Failure to reach an agreement, i.e., disagreement, is represented by a designated outcome denoted{D}. Agent i ∈ {a,b}. The set of all utility pairs that result from an agreement is called the bargaining set (S).

Definition: A **bargaining problem** is defined as a pair (S,d). A bargaining solution is a functionf that maps every bargaining problem (S,d) to an outcome in S, i.e., f : (S,d)→ S

The pay off allocations that the two players ultimately get depend on two factors:

1. The set of payoff allocations that are jointly feasible for the two players in the processof negotiation or arbitration, and

2. The payoffs they would expect if negotiation were to fail to reach a settlement.

Axioms

The bargaining problem is solved by stating general properties (or axioms) that a reasonable solution should possess.

Axiom 1 (Individual Rationality) - The bargaining solution should give neither player less thanwhat it would get from disagreement, i.e., f(S,d)≥d.

Axiom 2 (Symmetry) - When the players' utility functions and their disagreement utilities arethe same, they receive equal shares.

Axiom 3 (Strong Efficiency) - The bargaining solution should be feasible and Pareto optimal.

Axiom 4 (Invariance) - The solution should not change as a result of linear changes to the utilityof either player.

Axiom 5 (Independence of Irrelevant Alternatives) - Eliminating feasible alternatives that would not have been chosen should not affect the solution.

2. **Non-Cooperative Models of Single-Issue Negotiation**

A key difference between the cooperative and non-cooperative models is that the former does not specify a procedure, whereas the latter has a procedure. There are two players and a unitof good, an apple, to be split between them. If player a gets a share of x_a

$\in [0,1]$, then player b gets $x_b = 1 - x_a$. Neither player receives anything unless the two players come to an agreement. Here, the apple, can be split between the players. So the issue is said to be divisible.

Player b can accept or reject the offer. If player b accepts, the game ends successfully with the pie being split as per player a's proposal. Otherwise, the game continues to the next timeperiod in which player b proposes a counteroffer to player a. This process of making offers and counteroffers continues until one of the players accepts the other's offer. Since the players take turns in making offers, this is known as **alternating offers protocol.**

2.Game-Theoretic Approaches for Multi-Issue Negotiation

The four key procedures for bargaining over multiple issues are:

3. **Global bargaining:** Here, the bargaining agents directly tackle the global problem in which all the issues are addressed at once.
4. **Independent/separate bargaining:** Here negotiations over the individual issues aretotally separate and independent, with each having no effect on the other.
5. **Sequential bargaining with independent implementation**: Here the two parties consider one issue at a time. There are several forms of the sequential procedure, defined in terms of the *agenda* and the *implementation rule*. For sequential bargaining, the **agenda** specifies the order in which the issues will be bargained. The **implementation rule** specifies when an agreement on an individual issue goes into effect. There are two implementation rules that have been studied in the literature:
    a. The rule of *independent implementation* - an agreement on an issue goes into effect immediately
    b. The rule of *simultaneous implementation* - an agreement is implemented on both.
6. **Sequential bargaining with simultaneous implementation:** An issue does not takeeffect until an agreement is reached on all the subsequent issues.

1. Cooperative Models of Multi-Issue Negotiation

Cooperative Models of Multi-Issue Negotiation includes efficiency,

invariance,symmetry axioms, and the following:

1. **Simultaneous implementation agenda independence:** Global bargaining and sequentialbargaining with simultaneous implementation yield the same agreement.
2. **Independent implementation agenda independence**: Global bargaining and sequentialbargaining with independent implementation yield the same agreement.
3. **Separate/global equivalence:** Global and separate bargaining yield the same agreement.

2. Non-Cooperative Models of Multi-Issue Negotiation

Theorem 4.1 *For the package deal procedure, the following strategies form a subgame perfect equilibrium. The equilibrium strategy for $t = n$ is:*

$$\text{STRATA}(n) = \begin{cases} \textit{OFFER } (\delta^{n-1}, \mathbf{0}) & \textit{If a's turn to offer} \\ \textit{ACCEPT} & \textit{If b's turn to offer} \end{cases}$$

$$\text{STRATB}(n) = \begin{cases} \textit{OFFER } (\mathbf{0}, \delta^{n-1}) & \textit{If b's turn to offer} \\ \textit{ACCEPT} & \textit{If a's turn to offer} \end{cases}$$

where $\mathbf{0}$ *is a vector of m zeroes. For all preceding time periods $t < n$, the strategies are defined as follows:*

$$\text{STRATA}(t) = \begin{cases} \textit{OFFER } \text{SA}(\text{TA}(t)) & \textit{If a's turn to offer} \\ \textit{If } (U^a(x^a, t) \geq \text{UA}(t+1)) & \textit{If a receives an offer } (x^a, x^b) \\ \textit{ACCEPT} & \\ \textit{else REJECT} & \end{cases}$$

$$\text{STRATB}(t) = \begin{cases} \textit{OFFER } \text{SB}(\text{TB}(t)) & \textit{If b's turn to offer} \\ \textit{If } (U^b(x^b, t) \geq \text{UB}(t+1)) & \textit{If b receives an offer } (x^a, x^b) \\ \textit{ACCEPT} & \\ \textit{else REJECT} & \end{cases}$$

where $\text{UA}(t)$ *(*$\text{UB}(t)$*) denotes a's (b's) equilibrium utility for time t. An agreement takes place at* $t = 1$.

The package deal procedure is similar to the alternating offers protocol in that the parties take turns in making offers. However, here, an offer must include a share for each issue under negotiation. An agent must now make trade-offs across the issues in order to maximize its cumulative utility.

3. Heuristic Approaches for Multi-Issue Negotiation

Heuristic approach will be useful for solving the problem of finding optimal agendas which may be computationally hard. Heuristics can also be used to predict the opponent's preferences for the issues. This prediction is relevant to situations where the

negotiators have limited information about their opponents. Here, any information gained from the opponent's offers in the past rounds is used to heuristically form a prediction of the future.

An agent's preferences will be revealed when it makes offers to the mediator, because an agent will only propose those offers that are optimal from its individual perspective. In order to generate a counteroffer for an issue under negotiation, there are three types of strategies:

1. **Time dependent strategy** - takes ―time‖ as an input and returns an offer such that concessions are small at the beginning of negotiation but increase as the deadline approaches.
2. **Resource dependent strategies** - takes ―domain of the function‖ as the quantity of resources available instead of the remaining time.
3. **Imitative strategies** - Behavior dependent strategy simply imitates its opponent's strategy in order to protect itself from being exploited by the opponent.

Negotiating with Humans

When agents negotiate with humans, a completely new challenge arises. This is because, humans make systematic deviations from the optimal behavior prescribed by normative theory. For example, people often change their valuations based on how the choices are framed and are willing to engage in irrational behavior such as costly punishment.

One of the earliest agents capable of negotiating with humans was designed by Kraus andLehmann to play the game *Diplomacy* using a variety of heuristics. Surprisingly, humans were unable to find whether they were playing with a human or an agent. More recently introduced agents use reinforcement learning to participate in single-shot auctions or games, and have been shown to achieve higher payoffs than humans.

Argumentation-Based Negotiation (ABN)

In *proposal-based* approaches, agents exchange proposed agreements in the form of bids or offers and when proposed deals are not accepted, the possible response is either a counterproposal or withdrawal.

Argumentation-based negotiation **(ABN)** approaches, on the other hand, enable agents to exchange additional *meta*-information (i.e., arguments) during negotiation. Consider the case in which an agent may not be aware of some alternative plans of achieving some goal. Exchanging this information may enable agents to reach agreements not previously possible. This was shown through the well known painting/mirror hanging example. The example concerns two home-improvement agents – agent *i* trying to hang a painting, and agent *j* trying to hang a mirror.

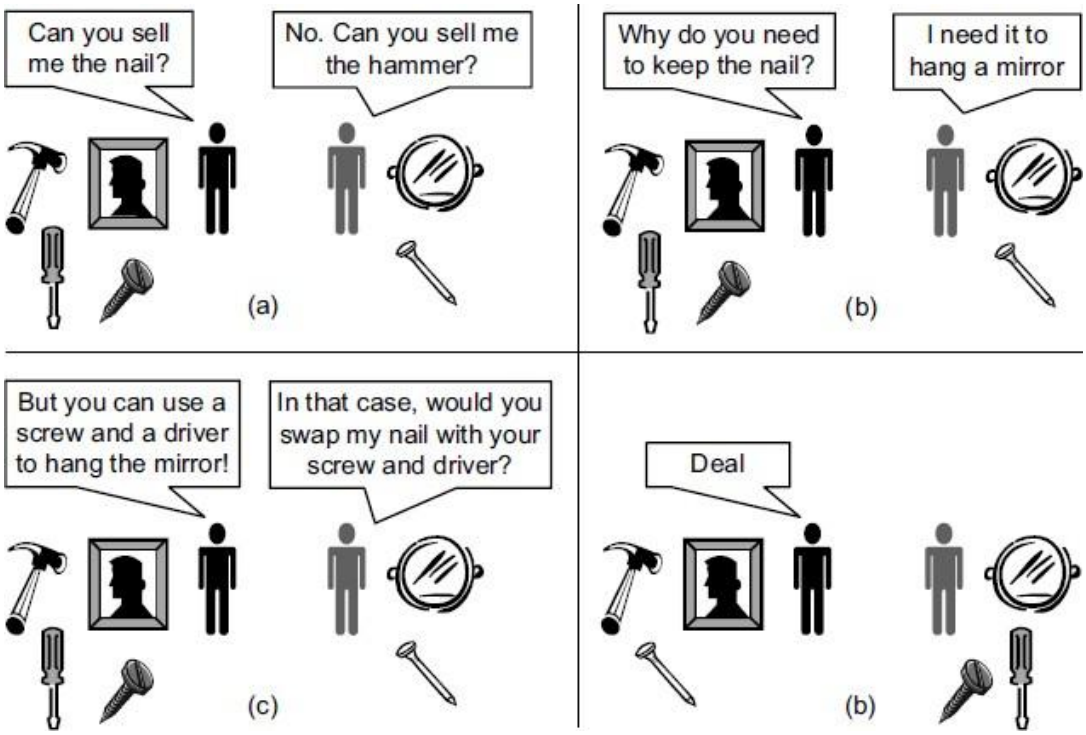

Figure 4.3: Dialogue between agents i (black) and j (gray).

There is only one way to hang a painting, using a nail and a hammer. But there are two ways of hanging a mirror, using a nail and a hammer or using a screw and a driver, but *j* is only aware of the former. Agent *i* possesses a screw, a screw driver, and a hammer, but needs a nail inaddition to the hammer to hang the painting. On the other hand, *j* possesses a nail, and believes that to hang the mirror, it needs a hammer in addition to the nail. Now, consider the dialogue depicted in Figure 4.3 between the two agents.

Drawback is that agents may withhold or misreport arguments in order to influence the negotiation outcome to their own advantage.