FINANCIAL CRYPTOGRAPHY: ALGORITHMIC MECHANISMS for A HEDONIC GAME

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Abstract: A (or a group of) selling agent wants to allocate and sell a (or a set of) parcel of land optimally and fairly to a buying agent within the capacity constraint of the selling agent and budget constraint of the buying agent. This problem has been solved by combining the concept of algorithmic cooperative game theory and financial cryptography. This is an approach for a group of decision-making agents to reach a mutually beneficial agreement through compromise and stable matching of preference. The work presents a cooperative game and a set of algorithmic coordination mechanisms: SBSS, SBMS (for collective and non-collective bargaining in holdout problem) and MBSS. The game is characterized by a set of agents, inputs, strategic moves, revelation principle, payment function and outputs. The coordination mechanisms are designed based on domain planning, rational fair data exchange and compensation negotiation. These mechanisms preserve the privacy of strategic data through secure multi-party computation (SMC), more specifically solving Yao's millionaire problem. The mechanisms are analyzed from the perspectives of revelation principle, computational intelligence and communication complexity. The communication complexity depends on the time constraint of the negotiating agents, their information state and the number of negotiation issues. The computational complexity depends on the valuation of pricing plan, compensation estimation and private comparison. It is a mixed strategy game; both sequential and simultaneous moves can be applied intelligently to search a neighborhood space of core solutions.

Categories and Subject Descriptors Cooperative game
General Terms Algorithmic mechanism
Keywords: Financial cryptography, Private comparison, Yao's Millionaire problem, Cooperative game, Hedonic pricing, Coordination mechanisms, Computational intelligence, Compensation,.

1. INTRODUCTION

Cryptographic techniques can be used to solve game theoretic problems. The cross fertilization of the two disciplines has been used to understand privacy, fairness and correctness against various types of malicious attacks in multi-party negotiation [1]. The other objective of such research is to understand the behavior of rational, honest, semi-honest and malicious agents in coordination mechanisms, to analyze the cryptographic concerns within game theoretic formalisms such as rational fair exchange of secrets, Nash equilibrium and pareto optimality [2]. Most of the recent works have analyzed non-cooperative game through SMC. In this paper, we study a cooperative game with the basic concept of SMC and rational fair exchange of secrets. We have adopted a specific case of multi-party negotiation in land trading to understand the computational and communication complexities and information revelation principle of intelligent algorithmic mechanisms. A case based reasoning approach has been adopted. These mechanisms are the basic building blocks of the computational intelligence of a smart market.

Traditionally, hedonic games have been studied for land trading [11,19,25,27]. We have reviewed the related works to know the basic concept of hedonic pricing. What are the computational challenges of hedonic games? Can it be used to estimate the reference optimal pricing plan in coordination mechanisms? What is hedonic price index? How land is priced in developed countries? What are the gaps of existing practice? The computational challenges of hedonic pricing have been discussed in details in section 4.1.1. We find that the direct application of hedonic pricing strategy may not result an efficient solution in land trading. The hedonic pricing method may not be relatively straightforward and uncontroversial since it is based on approximately estimated market intelligence and measured data. Reliable data on sales transactions and characteristics of land may not be readily available through authenticated sources. The method is relatively complex to implement and requires a high degree of statistical skill.

The precision of pricing depends on model specification, quality, availability and accessibility of appropriate data. The valuation will be incorrect if the trading agents are not aware of the interrelationships between the price and characteristics of land. The cost of data collection may be high if the data are not readily available. The hedonic pricing method does not consider any scope of intelligent multi-party negotiation and speculation of the trading agents. Apparently, a complete and complex quantitative model should yield better valuation, but it is not necessarily so since such a model requires many inputs which may introduce potential input errors. A good valuation provides a precise estimate of value but it is unrealistic to expect absolute certainty in valuation since the cash flows and discount rates are estimated with approximation and error. A quantitative model of valuation use inputs based on subjective judgments. There is risk of undervaluation or overvaluation of an asset due to the bias of the analysts.

Auction may lead to corruption and growth of black money in land trading through false bids of the corrupted bidders [12,17]. There are various types of auction protocols used in land trading such as English auction and two-stage auction. English auction is a standard ascending auction; the participation may require cash deposit and may be bounded by reserved price. The two-stage auction may have high chance to face corruption due to the side deals between potential bidders and the auctioneer. It would most likely maximize revenue for the assets which are likely to have relatively few bidders or are cold. The stability of pricing having high growth or overestimation in land and property market has become a critical issue globally.

A cooperative game and algorithmic mechanisms were studied in the context of supply chain coordination in [4,5,6]. This work had its root in [13] which looked at various scenarios of collaborative supply chain planning. In this work, a cooperative game is studied and a set of coordination mechanisms are proposed based on domain planning, fair and rational data exchange, compensation negotiation and secure multi-party computation and the concept is applied in the context of land trading. The mechanisms are based on the concept of rational exchange of data among the trading agents, fairness and correctness. These concepts of SMC can be used intelligently in financial cryptography.

The work is organized as follows. Section 2 defines a cooperative game and a set of algorithmic coordination mechanisms (SBSS, SBMS and MBSS) for the game. Section 3 analyzes the cooperative game and the coordination mechanisms. An automated information system should give necessary support to the proposed mechanisms through its computing, security, data, communication and application schema; section 4 presents these schema in brief. Section 5 concludes the work.

2. COOPERATIVE GAME

Game theory is concerned with a complex decision making process in which two or more players interact. Each of these players tries to optimize its own objective function. A game can be classified as a *cooperative game* or a *non-cooperative game*. In a cooperative game, the players make agreements in order to minimize their common cost or to maximize their utilities. This is not possible in a non-cooperative game. Let us first define the cooperative game and explain the critical issues of this game in the context of algorithmic mechanism [7,8,21].

A *cooperative game* is a common approach for a group of decision-making agents to reach mutually beneficial agreements. This is an important conflict management and group decision making technique for making a joint decision. The agents exchange information in the form of offers, counter-offers and arguments and search for a fair consensus. This concept has been used effectively in various applications such as auction, task allocation, strategic sourcing, compensation negotiation for human resources management, strategic alliance, land acquisition, foreign trade and global supply chain management [3,8,19]. This is a game where a group of players enforce a cooperative behavior. The game is defined by (N,u) where N denotes a group of agents and u is a real valued characteristic function. A subset $S \subseteq N$ is called a *coalition*, where N is called the *grand coalition*.

An algorithmic *coordination mechanism* is characterized by a group of agents, a finite set of inputs of each agent, a finite set of outcomes as defined by output function, a set of objective functions and constraints, payments, an optimal set of strategic moves, a dominant strategy which maximizes the utility of an agent for all possible strategies of other agents involved in the mechanism and revelation principle [23]. Absolute privacy or confidentiality may result an inefficient game. Therefore, the agents preserve the privacy of strategic data but share critical information. A mechanism is truthful if the agents report their strategic moves correctly. It should be a dominant strategy. A mechanism is strongly truthful if truth telling is the only dominant strategy.

The basic objective of a cooperative game is to find *imputation* i.e. an acceptable distribution of value among the agents. Imputations are efficient and individually rational distribution. An imputation $\boldsymbol{y} = (y_1,\ldots,y_N)$ is a vector such that value y_i is allocated to player and $y(N) = \sum_{i=1}^{N} y_i$. A *solution concept* of a cooperative game must satisfy a number of properties. The values allocated to the players must be equal to the total value of the game, y(N) = v(N). The value allocated to a player should not be higher than the cost the player would have to incur if he acts individually without joining others. This property is known as *individual rationality*. The allocation of value should be symmetric. The solution should satisfy the property of monotonocity. If the overall value of the game increases, the allocation of the agent should also increase synchronously. The *nucleolus* indicates those imputations that minimize the maximum discontent of any player of a cooperative game. The *kernel* of a game indicates the imputations for which no player outweighs another player.

The *core* is the most significant fair solution concept of a cooperative game. In a core solution, there is no incentive for any player to leave the grand coalition; the core solutions are stable. In a game (N,c), the *core* is defined as those imputations y that satisfy $y(S) \le v(S)$, $S \subseteq N$ and y(N) = v(N). The total value allocated to the players in a game should not exceed the value of a system dedicated to the coalition and should satisfy group and individual rationality constraints. The efficiency constraint implies that the total value of the game is to be equitably distributed among the players. The *bargaining set* is a set of objections and counter objections. An imputation y belongs to a bargaining set M(v) of the game if for any objection of a player against another with respect to y there exists a counter objection. The agents start negotiation with a set of initial plans, negotiate and settle a set of final plans.

In a finite state space, a *plan* consists of a finite set of states, finite set of actions, a state transition function and an utility function. The state space has an initial state and goal state. The basic objective of a search process is to explore a good plan satisfying single or multiple objectives subject to a set of constraints of the decision making agents. *Aspiration point* is the value of an objective function which is desirable or satisfactory to the decision maker. *Reservation point* is the value of an objective function that the decision maker wants to avoid. The *nondominated set* generate pareto optimal frontier. A decision vector $\mathbf{x}^* \in S$ is pareto optimal if there does not exist another decision vector $\mathbf{x} \in S$ such that $f_i(\mathbf{x}) \le f_i(\mathbf{x}^*)$ for all i =1,…,k and $f_j(\mathbf{x}) < f_j(\mathbf{x}^*)$ for at least one index j; f_i is objective function and S is feasible space. An objective vector $z^* \in Z$ is pareto optimal if there does not exist another objective vector $\mathbf{z} \in Z$ such that $z_i \le z_i^*$ for all i =1,…,k and $z_j < z_j^*$ for at least one index j.

Various types of *preference thresholds* are used to compare alternatives and to define outranking relations during interactive search or negotiation between the mediator and decision making agent [22]. There is an interval of preference wherein it is not possible for the DMA to distinguish between different alternatives due to imprecision and uncertainty of measurements; it is *indifference threshold*. *Preference threshold* can be of two types. *Strict preference threshold* is minimal increase or decrease of any objective that makes the new alternative strictly preferred with respect to this objective. There exists an intermediate region between indifference and strict preference threshold where the DMA hesitates to compare alternatives. It corresponds to *weak preference* threshold. *Veto threshold* indicates what is the minimal increase or decrease of any objective that makes the new alternative unacceptable regardless of the value of other objectives. In each round of interactive search, a finite sample of non-dominated points is generated by S. The sample is composed of a *middle point* and a set of points within its neighborhood. The starting middle point is obtained by projecting the aspiration point on the non-dominated set in the direction of reservation point.

2.1 Coordination Mechanisms

This section presents *local planning domain based coordination mechanisms* (LPDCM). There may be different settings in multi-party negotiation. The most simple setting is Single Buyer Single Seller (SBSS) where a selling agent negotiates with a buying agent. There may be different types of complex scenarios such as Single Buyer Multiple Seller (SBMS) and Multiple Buyer Single Seller (MBSS). In SBMS setting, a buying agent negotiates with many selling agents simultaneously or sequentially. In MBSS setting, a selling agent negotiates with many buying agents. In this section, several coordination mechanisms have been proposed based on domain planning, data exchange and compensation negotiation. Sections 2.1.1, 2.1.2 and 2.1.3 present SBSS, SBMS and MBSS coordination mechanisms respectively.

2.1.1 SBSS Coordination Mechanism

Agents: B, S, M;

Constraints: ceiling; consent clause; Negotiation issues: single or multiple;

1. B bids its optimal plan P_0 to S. Set i = 0. Reference plan = P_0.
2. Repeat until the stopping criteria is satisfied:

a. Set i = i + 1;

b. B counter bids P_i^B to S, or S counter bids P_i^S to B.

c. B and S compute local utility effects $\Delta u^B(P_i)$ and $\Delta u^S(P_i)$ respectively.

d. B and S compare $\Delta u^B(P_i)$ and $\Delta u^S(P_i)$ privately and sets the reference plan to P_i if $\Delta u^S(P_i) > \Delta u^B(P_i)$.

3. If both agents agree through a stable matching of preferences, output plan $P_f = P_i$.
4. B and S jointly settle the incentive or compensation plan (P_c) to be given to the losing party through negotiation, based on relative utility effects for the final plan P_f subject to the constraints.
5. B and S disclose (P_f,P_c) to M. M checks the authenticity of the identities of the agents and constraints; verifies fairness and correctness of (P_f,P_c) and announces penalty clauses against malafide behavior.
6. M computes payment based on disclosed data and authenticates the registered transaction through a signcrypted contract in the data warehouse.

Let us explain SBSS coordination mechanism in details.

Agents: Three different classes of agents are involved in the cooperative game: B,S and M. B and S have well-defined objective function and a set of constraints that represent their preferences over the possible outputs of the game. These agents act rationally to optimize their objective functions and follow the coordination mechanisms correctly. B and S disclose their negotiated data to M (e.g. authenticated land reforms authority). The primary responsibility of M is to ensure fairness and correctness of computation in land transactions.

Planning domains (Local and Global)**:** In case of land trading, it is hard to define a planning domain based on single or multi-objective optimization; it may be based on a valuation model (reference: section 4.1.1). Here, B and S hold individual planning domains which are derived from their revenue optimization models; B has a budget constraint and S has a capacity constraint. The agents try to minimize the cost of transaction. The *local planning domain* of B is defined through the constrained optimization problem: max $(o^B)^T\mathbf{x}^B$, s.t. $M^B\mathbf{x}^B \leq b^B$ where $\mathbf{x}^B$, o^B, b^B and M^B are the vector of decision variables, the cost vector, the constraint lower bound vector and the constraint matrix for B, respectively (T: matrix transpose operation). Similarly, the lpd of S is: max $(o^S)^T\mathbf{x}^S$, s.t. $M^S\mathbf{x}^S \leq b^S$. Combining these two one can obtain the joint optimization problem: max $o^T\mathbf{x}$, s.t. $M\mathbf{x} \leq b$ where $\mathbf{x} = \mathbf{x}^B \oplus \mathbf{x}^S$, $o = o^B \oplus o^S$, $M=M^B \oplus M^S$ and $b = b^B \oplus b^S$ for the entire system referred as the *global planning domain.* Here, $\mathbf{x}$, o, M and b represent the set of decision variables, the cost or objective function vector, the constraint matrix and constraint upper bound vector for the global plan.

Plan: The plan in land trading is basically a pricing plan for a parcel of land i.e. (p,s,a) where p is the land price, s is the land schedule and a is the characteristic of land (e.g. pattern, geometric shape, size, topography etc.). It is a multi-issue negotiation; the trading agents negotiate p, s and a simultaneously during each round of negotiation. The bi-party negotiation starts with B bidding a plan P to S. S evaluates P and counter bids an alternative plan P'. B in turn evaluates P' and counter proposes yet another P" and so on. Finally, if the negotiation ends successfully, B and S accept the commonly accepted agreed plan. The negotiation for a plan consists of successive bidding cycles. In each bidding round, a plan P is bid by either B or S. A successful negotiation process consists of an initial plan followed by a series of compromise plans which culminates in a finally accepted plan.

Plan utility: For any plan P, the utility components of B and S are denoted by $u^B(P)$ and $u^S(P)$ respectively. These are private to the agents and will not be disclosed to the opponent, i.e. what is revealed in the negotiation process is the proposal for B and the proposal for S without any utility implications. The total utility for a plan P, $u(P) = u^B(P) + u^S(P)$, is also not revealed to either agent. The concept of utility is also used as plan cost or revenue in artificial intelligence and operations research literature.

Local and global utility effects: Since P_0 is optimal for B, $u^S(P_0) < u^S(P_i)$ for all i ≥ 1, i.e. the *utility effect* for B(S) for P_i, $\Delta u^B(P_i) = u^B(P_0) - u^B(P_i)$. $\Delta u^S(P_i) = u^S(P_i) - u^S(P_0)$. Utility effect of B or S is also referred as *local utility effect*, whereas the *global utility effect* or total utility effect for P_i is sum of the local utility effects of all the agents. This is because the objective of the coordination process is to increase the total utility, not the individual utility. However, B is entitled to ask for suitable compensation from S to compensate for the reduced utility it has to incur in P_i. Individual utility effects are treated as private information.

Compensation and utility sharing: The losing party will always ask for a compensation amount, which is at least the utility effect. The compensation negotiation has basically two purposes: i) to determine whether the current plan P_i is a feasible one, i.e. whether total utility of P_i has increased over the previous plan P_{i-1} (or any other past plan P_j, j<i-1); and ii) to determine how the increased utility to be shared between B and S. This is known as *utility sharing*.

Utility implication: *Utility Implication* of B for a plan P denoted $u'^B(P)$ is the utility component of P, $u^B(P)$ plus the compensation settled $u_m(P)$. Similarly, the utility implication for S agent $u'^S(P)$ is determined. The total of utility implications for B and S is same as the total utility for the plan, u(P). Thus, $u'^B(P) = u^B(P) + u_m(P)$; $u'^S(P) = u^S(P) - u_m(P)$; $u(P) = u^B(P) + u^S(P) = u'^B(P) + u'^S(P)$.

Compensation negotiation, rational behaviors of the agents and privacy preservation: Incentive or compensation negotiations are realistic. The agents behave rationally. If the total utility increases, compensation will always be settled such that no agent loses compared to the previous round. In other words, the utility implications for both parties improve. Further, if the compensation negotiation fails, it only means that the total utility for the current bid is less than that for the previous bid. When the negotiation ends successfully in the final plan P_f, the total utility achieved is nothing but $u(P_f)$. The total improvement of utility through the negotiation will be $u(P_f) - u(P_0) > 0$, which is apportioned as $u_m(P_f)$ for B and $u(P_f) - u(P_0) - u_m(P_f)$ for S. Both B and S are assumed to be rational in exchange of truthful communication and are interested in reducing total plan utility. If none of parties respond then there will be a deadlock. That means that neither B nor S is interested in utility improvement, which violates our assumption. Privacy preservation of individual agents is an important concern for this cooperative game. For this purpose, the utility effects are compared privately. Because the utility effects are kept secret from the respective opponents, the compensation negotiation becomes relevant and the parties feel encouraged to participate in this negotiation. It may be a single or multi-issue negotiation.

Payment: The buying and selling agents disclose the pricing, compensation and delivery plans to the mediator in step 4 of the coordination mechanism. The mediator checks the authenticity of the identities of the agents and regulatory constraints such as ceiling, consent and sustainability clauses; verifies fairness and correctness of asset valuation and announces penalty clauses against malafide behavior. The mediator computes payment (e.g. tax, stamp duty, registration / legal / security protection charge etc.) based on disclosed data; collects payment and authenticates the registered transaction through a signcrypted contract in the computerized land bank. S collects payment from B.

Stopping criteria: Stopping the game is possible on various counts such as stable preference matching, total negotiation time deadline, total number of plan bidding rounds and number of successive failed biddings. If any agent withdraws prematurely the game ends unsuccessfully.

2.1.2 SBMS Coordination Mechanism

Collective bargaining or group selling: In this case, a buying agent negotiates with many selling agents concurrently. Basically, the negotiation process has two phases. In the first phase, the agents settle a pricing plan with the consent of the buying agent and k% of the selling agents collectively. One of the selling agents acts as the leader and negotiates with the buying agent. In second phase, each selling agent negotiates with the buying agent independently and settles the compensation plan. A simple case assumes that each selling agent holds same pattern of land. A complex deal may assume that different selling agents hold different patterns of land.

Agents: B, $S_{j,j=1,\ldots,m}$, M;

Constraints: ceiling, consent clause (k:1); Negotiation issues: single or multiple;

Negotiation phase 1:

1. B bids its optimal plan P_0 with reference to a standard price ladder. $P_0 = P_{01} \oplus \ldots \oplus P_{0m}$. Set i = 0. Set, Reference plan = P_0.

2. Repeat until the stopping criteria is satisfied:

a. Set i = i + 1;

b. B agent's round: For each j, j=1,…,m, B counter bids $P_{ij}{}^B$ to S_j in parallel. S agents' round: For each j, j=1,…,m, S_j counter bids $P_{ij}{}^{Sj}$ to B. Thus, the combined plan P_i received from m number of S-agents is $P_i = P_{i1}{}^{S1} \oplus \ldots\ldots \oplus P_{im}{}^{Sm}$.

c. B and S agents (S_j,j=1,…,m) compute local utility effects $\Delta u^B(P_i)$ and $\Delta u^{Sj}(P_i)$ respectively.

d. The leader of the selling agents (S_l) and B privately compare $\sum_{j=1}^{m} \Delta u^{Sj}(P_i)$ and $\Delta u^B(P_i)$ and sets the reference plan to P_i if $\sum_{j=1}^{m} \Delta u^{Sj}(P_i) > \Delta u^B(P_i)$. [Reference: Section 4.1.3]

3. If the agents agree through a stable matching of their preferences as per consent clause, the output is the final plan $P_f = P_i$.

Negotiation phase 2 :

4. Optionally, B and S jointly settle the compensation plan (P_c) or incentive to be given to the losing party by referring to a standard compensation table.

5. The agents disclose (P_f,P_c) to M. M checks the authenticity of identities of the agents and constraints; verifies fairness and correctness of (P_f,P_c) and announces penalty clauses against malafide behavior.

6. M computes payment based on disclosed data and approves the registered transaction legally through a signcrypted contract in the data warehouse.

SBMS mechanism is constrained by various regulatory constraints such as ceiling, consent clause (i.e. the ratio of willing and unwilling selling agents in land acquisition) and sustainability clauses. Random heuristics should be avoided in land trading; the regulatory constraints should be enforced based on fair and rational computational logic. For example, a land reforms organization should have to secure the nod of k% of selling agents to acquire a patch of land for a project while acquisition in tribal areas should be possible only with the approval of local panchayat. The willingness of the land owners to sell a patch of land forms a crucial part of land acquisition. A fair land acquisition also requires social impact and environmental assessment. The upper bound or *ceiling* of land acquisition should not be a simple random heuristic; it depends on multiple factors such as future development plan, type of plant layout, business objective and future vision for diversification, expansion and strategic growth. It may be different for different types of projects.

Non-collective bargaining & holdout problem*:* A buying agent may face *holdout problem* if it tries to procure multiple separately owned parcels of land for a mega project. The problem may be caused by monopoly power of the land owners, high transaction costs of land acquisition, imperfect information, excessive bargaining power of the selling agents once they recognize the scope of the project and value of the land, the need for contiguous parcels to complete a given project, strategic behavior of the selling agents or some combination of these factors [20]. There are some other reasons of holdout problem. A buying agent negotiates with many selling agents sequentially; partial procurement is inefficient and there is a commitment during the negotiation process. The holdout problem indicates that the prices of land will increase as the negotiation progresses and the last selling agent will receive the highest price. It further implies that the cost of the project of the buying agent may increase significantly and the land acquisition process may be delayed. The buying agent requires the support of land reforms group in mediation.

In case of non-collective bargaining, the trading agents should follow a two phase negotiation process on the basis of a standard price ladder and compensation table to avoid hold out problem : phase 1 settles the price of land and phase 2 settles the compensation. Land reforms organization should generate a comprehensive rational price ladder and compensation scheme adaptively for different patterns of land by using an efficient valuation technique. In phase 1, the trading agents start negotiation referring to the price ladder. B should negotiate with many selling agents in parallel and settle the land price. B also collects the conditional data of the selling agents for compensation. In phase 2 of the negotiation, B should refer to a standard compensation scheme as defined by LRO and conditional data and publish compensation plan for all or some of the selling agents simultaneously within a strict deadline. No selling agent should be treated with partiality, discriminately or unfairly by B to avoid holdout problem. The trading agents can follow an interactive search (refer : section 4.1.2). In the context of holdout problem, it may not be practically feasible to generate a pareto optimal frontier through solving a multi-objective optimization problem since the complexity of the problem will be very high and it may be hard to design a MOLP model. It is hard to satisfy the preference of all the selling agents concurrently; some have to compromise. A fast negotiation process requires a standardized price ladder, efficient valuation technique and compensation scheme.

SBMS is a hard problem as compared to SBSS mechanism. The problem should be solved through *social choice*. Land is often selected randomly and emotionally for a project or development rather than evaluating the issues of supply chain network optimization, sustainability and strategic importance logically. The decision making agents take perception based, nonfactual and readymade decisions instead of rational analytics and that creates disputes and conflicts in multi-party negotiation. The investors often try to acquire fertile land with good facilities though a huge area of surplus barren land remain unutilized or covered with dead assets in our society. Land reforms organization should be able to identify, utilize and sell such surplus and barren land to ease fiscal crunch.

Traditionally, a market is viewed as simply the confluence of supply and demand; an efficient market design also depends on game theory and experimental economics. A primary motive for market design is the need to address market failures. *Stable matching* is the fundamental concept of a market; inefficient matching occurs because the market has too few participants or suffers congestion as a result of having too many trading agents or true preferences of the trading agents can not be revealed fairly and rationally [26]. To function properly, an efficient land market should provide thickness; a large number of rational trading agents should be able to produce satisfactory outcome in the form of correct land valuation. The market may offer incentives to the trading agents for disclosing their preferences appropriately. The trading agents should not face any congestion problem if the number of trading agents is high; they should be able to compare multiple offers effectively and make the right choice in time. A buying agent may negotiate with many selling agents in parallel and selects the best bid based on proper comparison. A simple stable matching algorithm ensures that no buying agent would be matched to an unacceptable selling agent and no agent not matched to each other would both prefer to be known as a blocking pair. The selling agents offer bids to the buying agent; the buying agent ranks the bids, rejects the least preferred bids and selects the best bid. A matching is *blocked* by an individual agent or a pair of agents based on their preference. A matching is *stable* if it is not blocked by any individual or pair of agents. A stable matching is pareto-efficient and in the core of the cooperative game. A stable matching ensures that right type of land should be chosen for right objective.

The concept of SBSS and SBMS mechanisms can be extended to MBSS coordination mechanism. A selling agent may negotiate with many buying agents either sequentially or simultaneously. S be involved in negotiation with m number of B agents. There can be two types of MBSS mechanisms. If each buying agent communicates its plan to the selling agent individually and independently, MBSS mechanism will be similar to SBMS. For a particular bidding round, S may treat the plans of B agents simultaneously, or according to different priorities. The second scenario will be a multi-stage mechanism. One of the buying agents plays the role of the leader and interacts with S. If the leader of the buying agents conducts a negotiation among B agents and generates a combined plan and interacts with S on the basis of this combined plan, MBSS mechanism will converge into SBSS mechanism.

3. MECHANISMS' INTELLIGENCE

Theorem 1: *The coordination mechanisms try to search the neighborhood space of a core solution in the cooperative game; it is basically an approximation algorithm.*

In the proposed coordination mechanisms, a group of agents try to maximize their utility through rational secret sharing. They have specific preferences over the outcome of the game and they follow the mechanism correctly if and only if doing so increases their expected utility [14,16]. Accordingly, they should define their aspiration and reservation points and preferential thresholds. For instance, if S tries to maximize its own utility; the utility of B may be reduced and this conflict should be compensated through suitable compensation. If they try to optimize their utility irrationally, the coordination mechanisms may face the problem of stable matching and the negotiation may end unsuccessfully.

The core solution of the cooperative game is directly linked with the fairness and correctness of plan computation and compensation options. The outcome of the cooperative game is driven by the information states and time constraints of the decision making agents and the number of negotiation issues. In case of multi-issue negotiation, the agents may negotiate multiple issues sequentially or simultaneously. The agents may bundle all the issues and negotiate them simultaneously as a complete package. Alternatively, they may negotiate the issues sequentially according to a predefined order. The sequential approach is less complex than the simultaneous approach from computational perspectives. Each agent defines its information state in terms of negotiation strategies, business objectives, aspiration and reservation levels. It may adopt different types of time-dependent strategic moves such as linear, boulware or conceder. An agent may go to its reservation level from initial level linearly. It may maintain its initial offer till the timeline is almost exhausted and then offers its reservation value. Alternatively, it may offer its reservation value very fast and maintains the same offer till the deadline. Each agent's information state is a private knowledge; it has both complete and incomplete information. An agent does not disclose its negotiation strategy to the other players; it has only probabilistic information about the strategic moves of the other players. But, the agents have complete information about the rule of the cooperative game, negotiation protocol, negotiation issues and time constraints.

The agents alternately propose offers and counteroffers. The negotiation starts when an agent makes its offer to the other agent. The other agent receives the offer; evaluates the offer using its utility function; either accepts the offer or makes counteroffer. Thus, the agents are trying to reach an agreement by searching a stable matching of their preferences. The coordination mechanisms try to explore a set of stable matching solutions so that the strategic moves of the agents constitute equilibrium. A set of strategic moves are in Nash equilibrium if each agent's strategic move is a best response to its opponent's move. An outcome is pareto-efficient if there is no other outcome that improves the payment of an agent without making another agent worse off.

The basic objective of the proposed cooperative game is to explore the imputation that minimizes maximum discontent of the agents. This is only possible if the players of the game act rationally and share correct information cooperatively maintaining privacy at desired level. Each move tries to reduce the discontent of the players through a bargaining set i.e. a set of objections and counter-objections. But, the critical issue is the allocation of the payment among those players. A player can decide to leave if it is not satisfied with the allocation of the payment. The coordination mechanisms try to achieve social choice which is simply an aggregation of the preferences of different agents towards a single joint decision assuming that the agents act rationally in the cooperative game.

In case of collective bargaining of SBMS mechanism, a group of selling agents form a coalition. The core is the most significant fair solution concept of the cooperative game. In a core solution, there is no incentive for any player to leave the grand coalition. The core solutions are stable. A utility vector is in the core if the total utility of every possible coalition is at least as large as the coalition's value. There does not exist a coalition of players that could make all of its members at least as well off and one member strictly better off. It is hard to compute the core solution in the game. The existence of a core is an important issue because with an empty core, it is difficult to predict the formation of a coalition and the payment of each agent. There exists a core solution in the proposed cooperative game. The ultimate objective of various coordination mechanisms is to explore the neighborhood space of the core solution through social choice. It is basically an approximation algorithm.

Theorem 2: *SBSS, SBMS and MBSS coordination mechanisms converge to a plan P_f which is only locally optimum w.r.t. total utility.*

For the issue of convergence, for example, in step 2(d) of SBSS, if $\Delta u^S(P_i) > \Delta u^B(P_i)$, the plan P_i becomes the reference plan for next iteration (i.e. P_i has improved in the total utility over P_{i-1}). Thus to show, $u(P_i) > u(P_{i-1})$ i.e. $u^B(P_i) + u^S(P_i) > u^B(P_{i-1}) + u^S(P_{i-1})$, i.e. $u^S(P_i) - u^S(P_{i-1}) > u^B(P_{i-1}) - u^B(P_i)$, i.e. $\Delta u^S(P_i) > \Delta u^B(P_i)$, which is given. Thus, the algorithm accepts a new or counter proposal only when the corresponding plan is better than the previous plan. Thus, the algorithm basically ensures a sequence of plans having monotonically increasing utility by ignoring the less utility plans which are generated and then not considered further. The finally accepted plan has the maximum utility among the plans generated by both B and S.

There is however no guarantee of achieving the globally maximum utility plan, as the negotiation process does not necessarily converge to the global optimum solution. The negotiation, which is being done based on the local information of an agent or a subset of B or S agents cannot guarantee the global optimum which will require total information. Only repeated application based on progressive computation can achieve a mutually acceptable solution which hopefully is one of the better local optima. Finding the global optimum would as such be a combinatorially explosive problem, even in the presence of total information. A fair and correct valuation may resolve this problem.

In these coordination mechanisms, the agents select their dominant strategies to optimize individual utilities. The agents act rationally and reveal their strategies truthfully. These mechanisms are strongly truthful since truth telling is the dominant strategy. B and S go through a series of plans. If the stopping criteria is satisfied, B starts negotiation with S on the basis of the plan resulting in maximum utility and settles the claim for compensation. The proposed coordination mechanism requires only one round of negotiation for settling the compensation claim and this corresponds to the plan of maximum utility. The stopping criteria is used to decide whether or not to continue the iterative negotiation process based on the current and previous best outcome detected so far. The improvement in the total utility is an important criterion in this connection. Another stopping criterion can be time, i.e. deadline of planning. Both the buying and selling agents get the information regarding relative utility-effectiveness of various plans. This leads to the following result.

Theorem 3: *SBSS, SBMS and MBSS coordination mechanisms preserve the privacy of utility and utility effects of B and S under the assumptions of relevant secure multi-party computation protocols. M ensures fairness and correctness of the computation.*

In the setting of secure two-party computation of SBSS mechanism, two mutually distrusting parties wish to compute a function based on their inputs while preserving privacy and correctness. *Fairness* guarantees that if either party receives its output, then the other party also receives the same [15]. *Correctness* ensures that a protocol computes a deterministic function correctly if the agents share correct inputs and follow the protocol correctly. They should get high payment if they behave fairly and correctly but, pay penalty for any malafide behavior. In steps 5 and 6 of SBSS and SBMS mechanisms, the mediator (M) ensures correctness and fairness of computation by verifying the accuracy of valuation and constraints (e.g. ceiling, consent and sustainability clause). For instance, the buying and selling agents may disclose incorrect plan to M in order to avoid duty. M alerts the agents by informing penalty clauses if it detects any malafide behavior in the mechanism.

B does not disclose its utility or utility effect to S The converse is also true for S. B and S evaluate the relative utility effectiveness of any two successive plans. This is done through secure summation and private comparison. The trading agents do not share any information regarding their revenue optimization models and constraints. But, they share critical information regarding land schedule, topography and constraints. This is the core revelation principle of the trading agents.

Preserving privacy and confidentiality, information sharing is important for an intelligent negotiation process. If the agents disclose their critical private data during negotiation, the market may not attain stability and efficiency. But without confidentiality, efficient information sharing is not possible. The agents should get proper incentives to be involved in information sharing. When, the agents share their strategic information truthfully preserving privacy, the efficiency of the market is expected to improve. But, confidentiality in information sharing may create a situation of information asymmetry in the game.

Theorem 4: *SBSS, SBMS and MBSS are efficient mechanisms in terms of fair utility allocaton.*

The communication complexity of the coordination mechanisms' depends on the time constraint of the negotiating agents, their information state and the number of negotiation issues. The computational complexity depends on the valuation of pricing plan, compensation estimation and private comparison. These issues have been discussed in details in section 4.1. The computation and communication costs depend on the number of plans generated. Each plan generation requires computation for estimation of local utility effects of B and S and private comparison of the utility effects. Local utility effect is estimated by solving an optimization problem. For each plan generated, B and S solve Yao's millionaire problem in order to compare local utility effects.

4. INFORMATION SYSTEM SCHEMA

An intelligent decision support system (e.g. GIS) should be associated with the aforesaid coordination mechanisms. Geographical Information System (GIS) is a combination of hardware, software, data, people, procedures and institutional arrangements for collecting, storing, analyzing and displaying information about spatially distributed land to perform efficient transaction processing, decision making, business analysis, urban, rural and regional planning, programming and implementation, community growth and sustainability management [24]. This section presents the basic elements of an effective land information system in terms of computing, data, networking, application and security schema.

4.1 COMPUTATIONAL INTELLIGENCE

A smart market needs computational intelligence. Real-time intelligence is used primarily by a set of entities in a dynamic market such as combinatorial auction. Collective intelligence develops an understanding of complex relationships in any multi-echelon codependent and coevolving ecosystem such as supply chain coordination and land trading. The computational complexity of the proposed coordination mechanisms depends on three issues: (i) Pricing plan computation which depends on land valuation technique and the complexity of price ladder, (ii) Compensation estimation and (iii) Secure multi-party computation i.e. private comparison. The communication complexity depends on the deadline of negotiation, information state of the agents and the number of negotiation issues.

4.1.1 Pricing Plan Computation: A smart land market needs *computational intelligence*. The basic objective is to define a simple discriminatory price ladder as shown in table 1, appendix. The trading agents should refer to this price ladder to start negotiation. Price discrimination is an interesting move in land trading. The price ladder defines the price settings of a set of land patterns for a valid period and particular location specifying standard compensation options and various constraints like ceiling, consent, sustainability and penalty clauses, discount scheme and payment terms. Price is adjusted to match supply with demand. If there is excess demand; the price will rise. If there is excess supply, the price will fall. It is really a complex task to match supply with demand. Excess supply means lost resources; excess demand means over booking and lost revenue.

Land and financial assets share several common characteristics: their value is determined by the cash flows they generate, the uncertainty and expected growth associated with these cash flows. Other parameters remaining same, the higher the level and growth and the lower the risk associated with the cash flows, the greater is the value of the asset. There are three basic approaches to valuation of an asset [9,30]. The first is *discounted cashflow valuation* which relates the value of an asset to the present value of expected future cashflows that the asset generates discounted at a risk-adjusted discount rate. The second is *relative valuation*, where the value of an asset is based upon the pricing of comparable assets relative to a common variable such as cashflows, book value or sales. The third is contingent claim valuation where an asset with the characteristics of an option is valued using a stochastic option pricing model. In the proposed coordination mechanisms, the trading agents start negotiation with a reference plan which may be estimated based on following approaches.

Discounted Cash flow Valuation: $v = \sum_{t=1}^{n} C_t / (1+r)^t$ where n = life of an asset, C_t = cashflow in period t, r = discount rate reflecting the riskiness of the estimated cashflows. This approach is based upon expected future cashflows and discount rates. The value of any cash-flow producing asset is the present value of the expected cash flows on it. To apply DCF technique, it is necessary to measure the riskiness of real estate investments, to estimate a discount rate based on the riskiness and to estimate expected cash flows on the land investment during the asset life-cycle.

Relative Valuation: Most valuations are relative valuations where the value of an asset is based upon how similar assets are priced in the market place. The value of an asset is derived from the pricing of comparable assets. This approach is much more reliant on the market intelligence and the errors are corrected over time. In case of land trading, typical adjustment factors are time of sale, location, shape, size, and topography. For example, there are two similar types of land L_1 and L_2; the value of L_1 is v_1; the adjustment factor based on time of sale, location land shape, size and topography is k; the value of land L_2 is $v_2 = (k.v_1)$. Let us consider another example; land L_3 represents about z% of the total property value v; land value $v_3 = (z.v/100)$. This method is simple, fast and easy to work when there are a large number comparable lands being traded in the market. But, this method may not result precise value due to the errors in identification of comparable assets, comparison method and evaluation parameters and bias of the analysts.

Hedonic Pricing: A class of differentiated products is valued by a vector of objectively measured *characteristics* and a set of implicit or *hedonic prices*. Let, a parcel of land is described by n objectively measured characteristics $\mathbf{z = (z_1, z_2, .., z_n)}$, with z_i measuring the amount of the i-th characteristic contained in land profile. The hedonic price function can be specified as $\mathbf{p(z) = p(z_1, z_2, \ldots, z_n)}$. Land price can be computed by Hedonic pricing method [25, 27]. The price of a marketed good is related to its characteristics or the services it provides. For example, the price of a parcel of land in a region for a specific time period depends on asset characteristics (e.g. quality of land), neighborhood characteristics (e.g. tax, crime rates and quality of education), accessibility characteristics (e.g. distances to workplace and shopping centers or market and availability of public transportation, energy and utilities) and environmental characteristics (e.g. proximity to open space, air , water and sound pollution, environmental amenities like aesthetic views or proximity to recreational sites). Statistical regression analysis can estimate a function that relates asset values to the asset characteristics.

Hedonic pricing is basically a regression model. The key concept behind regression analysis is the statistical dependence of dependent variables on independent variables. A simple statistical regression model is expressed as $Y= \beta_1+\beta_2.X+u$ where Y is dependent variable, X is dependent variable and u is disturbance or error. The values of β_1 and β_2 are estimated from a set of data through regression analysis. It is basically time series data, a set of observations on the values that a variable takes at different times with regular time interval. It is mainly quantitative data and may also include qualitative data.

The regression analysis involving time series data includes not only current but also past lagged values of the dependent variables. It is often known as auto-regressive or distributed lag model. For example, a simple autoregressive model can be expressed as $Y_t = \alpha + \beta_0.X_t + \beta_1.X_{t-1}+ \beta_2.X_{t-2} + u_t = \alpha + \beta.X_t + \gamma.Y_{t-1} + u_t$. The problem can be solved by different approaches such as single equation regression model, simultaneous equation regression model, autoregressive integrated moving average (ARIMA) model and vector auto-regression (VAR) model. AR process can be modeled as $Y_t - \delta = \alpha_1.(Y_{t-1} - \delta)+ \alpha_2.(Y_{t-2} - \delta)+\ldots+\alpha_p.(Y_{t-p} - \delta) + u_t$ where Y_t is p-th order autoregressive term; δ is mean of Y and u_t is uncorrelated random error term with zero mean and constant variance. Moving average model can be expressed as $Y_t = \mu + \beta_0.u_t + \beta_1.u_{t-1}+\ldots+ \beta_q.u_{t-q}$ where μ is constant; so MA is a linear combination of noise error terms. ARMA (p,q) model can be expressed as a linear combination of auto-regressive and moving average terms as $Y_t = \theta + \alpha.Y_{t-1} + \beta_0.u_t + \beta_1 u_{t-1}$.

It is difficult to know whether land pricing is a purely AR or MA or ARMA process looking at time series data. This approach is not simple. It is computationally hard to identify p,d and q and to estimate parameters of auto-regressive and moving average terms. It is required to do diagnostic checking to test whether the chosen model fits the collected data reasonably well. It is also required to verify the accuracy. There are other debatable issues: whether to adopt a linear or nonlinear model; a single or simultaneous equation model? Are the collected data appropriate? The availability of appropriate data and the selection of right regression model are the critical success factors in this computation approach.

For instance, hedonic price function for land trading can be estimated as an auto-regressive model $P = f(S,N,L;\alpha,\beta,\gamma)$ where the price of a parcel of land be a function of the various attributes; P is land price; S indicates structural characteristics; N is neighborhood characteristics; L is locational or spatial characteristics and α, β and γ are respective co-efficient parameters [19]. This can be represented by the spatial-lag or spatial autoregressive model: $P = \lambda\ W_1P+\alpha.S+\beta.N+\gamma.L+\epsilon$ where λ is the spatial autocorrelation coefficient, W_1 is spatial weight capturing a definition of neighborhood and ϵ is error term. Recurrent artificial neural network with Back-Propagation learning algorithm may be used to estimate a regressive function but it is computationally hard to extract knowledge from ANN model as the trading agents may be interested in knowing the exact price function.

Analytic Pricing: From the above discussions, a simple analytic pricing mechanism is proposed here. Let, the price of a parcel of land L is computed by two different valuation methods; the price computed by discounted cash flow method is P_d and relative valuation method is P_r. $P_{c'} = \max(P_d, P_r)$. The crux of this method is the determination of relative weights for different criteria which can be done through pair wise comparison method. Let the weights at level 1 are time index (w_t), geometric index (w_g), asset index (w_a), neighborhood index (w_n), accessibility index (w_x), environmental index (w_e) and macroeconomic index based on demand-supply gap (w_m) where $w = (w_t+w_g+w_a+w_n+w_x+w_m) = 1$. Let the score of L for time, geometric, asset, neighborhood, accessibility, environmental and macro-economic criteria be (x_t, x_g, x_a, x_n, x_x, x_m) respectively; each score can be given from (1-10) or (1-5) rating scale. Let, the composite score be $s = (w_t.x_t + w_g.x_g + w_a.x_a + w_n.x_n + w_x.x_x + w_m.x_m)$; a composite weight i.e. hedonic land index w_c should be estimated from a set of bands at level 2 : for $s_1 \le s \le s_2$, $w_c = w_1$; for $s_3 \le s \le s_4$, $w_c = w_2$; for $s_5 \le s \le s_6$, $w_c = w_3$; for $s > s_7$, $w_c = w_4$. The base price for multi-party negotiation, $P_b = (w_c.P_{c'})$. The buying and selling agents start negotiation with reference to P_b and settle final price P_f with compensation.

4.1.2 Compensation Computation: A fast negotiation process requires a standard compensation table as shown in table 1 (appendix). The logic of compensation computation is not transparent in [28]. The estimation of compensation is a social choice as a part of corporate social responsibilities. An efficient negotiation promotes trade which promotes economic progress. The strategies and heuristics of incentive sharing are essential components of a coordination mechanism in a cooperative game;

the trading agents should settle the same through intelligent negotiation.

Interactive Search for Optimal Compensation: Generally, a simple planner searches for a single solution assuming that the preferences of the DMA are completely specified objective functions. In many planning scenarios, the preferences of the DMA on desired plans are either unknown or at best partially specified. In such situations, the planner has to present not only one but a set of plans to the DMA so that the planner can generate desired plan. In the proposed coordination mechanisms, the trading agents can settle the compensation plan through an interactive search. B or M acts as a mediator agent and computes an initial feasible solution. B interacts with S acting as DMA. B obtains a (or a set of) new solution. If the new solution or one of the previous solutions is acceptable to S, stop. Otherwise, go to the previous step. Let us discuss the computational aspects of compensation negotiation in details [4,22].

Here, B holds compensation optimization model and S holds its aspiration point (P_A), reservation point (P_R), indifferent threshold (I_{th}), strong (S_{th}) and weak preference threshold (W_{th}) and veto threshold (V_{th}). B calls standard compensation table. If S is satisfied with the standard compensation option, the negotiation ends. Else, B requests S to specify its preferential parameters (P_A, P_R, I_{th}, P_{th}, S_{th}, W_{th}, V_{th}). S informs the same to B. Repeat until S is satisfied with a solution or concludes that no compromise point exists for the present constraints: B computes a middle point along with characteristic neighbors for each set of preferential parameters; S gets back the results of middle points along with characteristic neighbors; S scans the inner area of the current neighborhood and stores its preferred solutions in a list. S may want to define a new aspiration and/or reservation point and/or updates preferential thresholds. Or, S wants a point from the current neighborhood to be the new middle point. B projects the new aspiration point onto the non-dominated set and generates neighborhood of the middle points. S gets back the results. B and S jointly settle the final compensation plan.

The idea of interactive search is analogous to projecting a search light from the aspiration point onto the non-dominated frontier. The lighted part of the frontier changes if the *aspiration point* or the point of interest in the non-dominated set is changed. The interactive search occurs between B and S. B asks S to specify its preference in the form of aspiration and reservation point and various types of preferential thresholds. At each iteration of the search, B generates a sample of non-dominated points using this preferential information. The sample is composed of a middle point and a set of non-dominated points from its neighborhood. B shows these points to S. Each point is basically a compensation plan. Different types of preferential parameters and thresholds are used to evaluate the quality of different compensation plans. B can negotiate with many selling agents sequentially or simultaneously.

4.1.3 Private Comparison: The concept of secure multiparty computation is used to ensure fairness, correctness and rational data exchange among the planning domains of the trading agents and to do private comparison in SBSS and SBMS coordination mechanisms. In secure multiparty computation, two or more agents want to conduct a computation based on their private inputs but neither of them wants to share its proprietary data set to other. A SMC protocol preserves privacy if no agent learns anything more than its output; the only information that should be disclosed about other agent's inputs is what can be derived from the output itself. The mechanisms assume that the agents are semi-honest; they follow the protocol properly with correct inputs. But after the execution of the protocol, an agent is free to use all its intermediate computations to compromise privacy.

Agents : Bob and m number of DMAs;
Inputs : Bob holds a value v_b and each DMA_i holds v_i ;
Output : True if $v_b < (v_1+\ldots+v_m)$; False otherwise;

Private Comparison Protocol:
1. One of the DMAs (DMA_k) shares a common random number r_c with Bob. Bob computes $(v_b + r_c) = v'_b$.
2. For all i except k, DMA_i sends $(v_i + r_i)$ to the leader of the DMAs (DMA_l) where r_i is a random number. DMA_k sends $(v_k + r_k + r_c)$ to DMA_l.
3. Let $R_j = \sum_{i=1}^{j} r_i$. DMA_1 sends R_1 to DMA_2 who computes R_2 and sends it to DMA_3 and so on. Thus, m-th DMA informs DMA_l about R_m. DMA_l computes the sum of values of all m DMAs i.e. $V = [\, r_c + \sum_{i=1}^{m} (r_i+v_i) - R_m]$.
4. Bob and DMA_l privately compare v'_b and V respectively.

The above section presents a private comparison protocol which is useful to preserve the privacy of data in the proposed coordination mechanisms [4]. The objective is to compare the value of Bob with the sum of values of m number of DMAs. The protocol preserves the privacy of the values of each DMA. The leader of the DMAs cannot know the exact value of the sum of the values of m DMAs since a random number r_c is added. Otherwise, if m=2, it would be possible for the leader to know the value of other DMA. The computation and communication cost depends on the number of DMAs. The protocol solves Yao's millionaire problem in step 4 [31,32]. *Yao's millionaire problem* is to find out who is richer between two parties such that no information about one agent's value is revealed to the other agent. The concept of private comparison is used in step (2d) of SBSS and SBMS coordination mechanisms to evaluate the quality of different bidding plans.

4.2 SECURITY SCHEMA

The proposed coordination mechanisms require proper support of a well-defined security schema in order to avoid disputes and to ensure authentication, authorization, correct identification, privacy and audit of each land transaction. An effective security schema assumes a set of probable *adversaries models*. It is really challenging to protect our society against the malicious attacks of the land sharks through fair corporate governance, law and order and security policy.

The public expect a good e-governance through a trusted computing, networking, data, application and security schema. A flawed land bank may be created through incorrect data structure, wrong land registration, misallocation of land, missing record and false injection of data. For instance, the land of agent A is registered as land of agent B. A is forced to take legal actions against B to get back its own land. The trading agents may disclose incorrect data to the mediator to avoid stamp duty or tax. An efficient coordination mechanism should be able to verify this malafide behavior intelligently.

The buying agents may try to deceive the selling agents through false promise (halafnama) in land acquisition. For example, A acquires the land of B with a promise of public healthcare project; later B sells the same land to agent C for industrial project. Huge chunks of rural land may be traded through unauthorized transfer of ownership with false promise. A buying agent may be forced to pay bribe (tola) to a malicious party against threats. It may be possible to restrict fraudulent *benami* land deals by a transparent registration process using UID or social security number of the trading agents. There are many cases of fraudulent land transactions where a selling agent may sell same land multiple times by recycling black money to evade the clutches of law.

It is a common recent trend in our society that a buying agent often gets delayed in acquiring the possession of a parcel of land from the selling agent. The selling agent takes advanced payment but delays the project in various ways intentionally. The buying agent takes loan from the bank; pays interest and is forced to sell the land to the selling agent at a lower price; the selling agent again sells the same land to a different buying agent at higher price. The buying agents should be protected from adversaries through tough regulation act; malicious business practice such as misleading advertisements of real estate assets and land without proper registration and clearances should be banned. Let us consider another problem. Agent X buys a large parcel of land from the poor peasants at low price and sells the same to a real estate firm Y; Y sells the same land to agent Z at grossly undervalued rate in exchange of some favors. It may not be possible to take any legal action against X, Y and Z involved in unfair land transactions. Unless there is a specific allegation of quid pro quo or corruption, private transactions may not be allowed to be questioned.

The trading agents often face non-cooperative work culture such as administrative delay, workflow and slow legal process in case of land disputes. An efficient mediator can resolve a complicated dispute through effective communication and try to diffuse the ego of the litigating parties. It is difficult to resolve most of the disputes due to miscommunication or high ego of the agents involved in the negotiation. In SBMS / MBSS mechanisms, the mediator should show high sensitivity to the concerns of the losing parties and try to convince the distressed parties with a human touch.

Most of the aforesaid examples are basically social problems which cannot be solved simply by a robust information and communication technology schema. Rather, the problems should be solved through intelligent security and communication strategy, organized labor economy, HR planning, education, poverty control and periodic change in corporate governance. A fair and rational legal system should monitor the negotiation process among the trading agents for the protection of their rights. The agents should have bargaining power to preserve the value of their land.

4.3 DATA, COMMUNICATION AND APPLICATION SCHEMA

Data Schema: Conceptual, physical and logical data modeling is a fundamental concern of GIS data schema. In the proposed coordination mechanisms, the trading agents can search land bank for critical data and the data of each valid transaction are stored in the data bank by the mediator. The basic building block of the data schema is a normalized land bank having a simple data structure: land identification code, land owner's name, UID or social security number, photo image, PAN number, address, contact, land schedule, land map (e.g. base map, coordination reference system), land area, land value, valuation method, asset, neighborhood, accessibility, infrastructure and environmental characteristics, land designations or zoning, administration and ownership boundaries. The data schema requires data warehouse and analytics to process simple and complex queries and to generate intelligent reports. Land data management may face various critical issues like accuracy of map and boundaries, verification of data entry error, language, duplication of data and disputes.

Communication Networking Schema: The system requires efficient communication protocol and proper communication infrastructure which includes mobile helpline number and e-mail of different groups of workforce. Mobile devices and wireless internet can integrate the network of urban and rural land reforms organizations, municipal corporations / gram panchayat / block development offices, revenue, security and legal systems so that the work force of different groups are able to work collaboratively. The trading agents can negotiate and offer bids and counter bids using an web enabled negotiation support system.

Application Schema: An efficient land reforms system requires web enabled enterprise solution for different business functions such as asset and revenue management, workflow control and compensation estimation. A typical GIS application should have geocoding, data management, map visualization, feature, grid and network analysis tools. A GIS analyst can use the applications for intelligent decision making, process analysis, spatial data mining and scenario planning. Enterprise application integration plays a significant role in proper coordination and fast transaction processing. The buying agents should use the application schema to explore lands in upcoming or present hubs, lands close to infrastructure or nature, land within affordable budget, new land development projects and to see land index and agent directory.

5. CONCLUSION

In this work, a cooperative game is presented with decision making in strategic settings where the preferences and rational choices of a group of agents are considered collectively into a decision to make the best choice. The fundamental issues are: who will cooperate with whom? How do the players allocate the value fairly among themselves? How to represent the game in a compact way? How to compute core solution of the game? What should be the compensation heuristics? What should be the heuristics for consent clause? What should be the relief and rehabilitation protocols? What should be the norms of land acquisition and SEZs? There are various open problems in the context of the present work.

Firstly, the proposed coordination mechanisms try to ensure fairness and correctness with the support of a trusted mediator. It is interesting to explore how to design self-enforcing coordination mechanisms. A self-enforcing mechanism itself guarantees fairness and does not require any arbitrator to complete the mechanism or any adjudicator to resolve the disputes. If one party tries to deceive the other, the other party immediately detects the problem and the mechanism stops. But, there may not be a self-enforcing mechanism for every situation. The agents may be assumed to behave maliciously. Secondly, it is required to improve the cost of computation and communication of the mechanisms. The basic objective is to explore a set of simple mechanisms which can direct the trading agents to do multi-party negotiation effectively for economically viable and ecologically sound land trading.

Thirdly, it is interesting how to compute the *Shapely value* of the cooperative game. It is the unique payoff vector that is symmetric, additive and efficient. This also satisfies anonymity and assigns zero payoffs to dummy players. The order of the players does not affect the costs allocated to the players. Finally, it is required to investigate and compare the efficiency of different techniques such as hedonic pricing, DCF and relative valuation by analyzing actual land transaction data. Our society needs a rational, fair and efficient valuation technique for land pricing. The trading agents often compute price using common sense or random heuristics. The intervention of malicious agents adds fuel to the fire and may make the computation highly corruptive. The pricing mechanisms require the support of financial economics and computer science for necessary computational intelligence. The proposed mechanisms are expected to build a suitable platform of hedonic games in future.

An efficient land reforms system should trade off strategic business intelligence and corporate social responsibilities rationally. It requires the computational intelligence of a standardized price ladder and compensation scheme based on fair and rational valuation technique for avoiding deadlock and delay in the search process. Actually, it is a cooperative game from the perspective of common sense economics. A set of intelligent coordination mechanisms are essential for efficient multi-party negotiation but not necessarily enough for fair land allocation. The proposed coordination mechanism should work effectively if the land allocation problem is solved through a fundamental rethinking and radical redesign of land reforms policy. Otherwise, the mechanisms may fail and the negotiation may stop without any result.

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APPENDIX:

S L N o.	Land types	Constraint	Valuation valid for $T_1<T\leq T_2$	Compensation Option 1	Compensation Option 2	Compensation Option 3	Compensation Option 4
1	Fertile agriculture land	Ceiling : c_1; Consent clause : k:1.	$P_{1 \text{ for option } 1}$ $P_{1' \text{ for option } 2}$ $P_{1'' \text{ for option } 3}$	100% cash payment	75%cash payment + a job as per skill	50% cash payment + a retail outlet	Accomodation
2	Industrial land	Ceiling : c_2 for large project; c_3 for small project; sustainability clause.	P_2	100% cash payment	75%cash payment + provide a job as per skill.	50% cash payment + a retail outlet	Accommodation
3	Residential land (Urban)	Ceiling : c_4; Environmental clause.	P_3	100% cash payment	50% cash payment + a retail shop;	25% cash payment + accommodation	10% cash + a retail shop + accomodation
4	Residential land (Rural)	Ceiling : c_5	P_4	100% cash payment	15% cash + a job	50% cash + a retail shop	25% cash + accommodation
5	Solid land	Ceiling : c_6	P_5	100% cash payment	25% cash + a job as per skill	50% cash + a retail shop	10% cash + accommodation
6	Semi-solid land	Ceiling : c_7	P_6	100% cash payment	25% cash + a job as per skill	50% cash + a retail shop	10% cash + accommodation
7	Water	Environmental clause: Penalty *p* for filling lake.	P_7	100% cash payment	25% cash + share 25% revenue on fisheries	50% cash + Revenue sharing on swimming pool.	Not applicable
8	Hilly / Rocky	Discount : d_1	P_8	100% cash payment	Rehabilitation through migration	Not applicable	Not applicable
9	Infrastructure land	Ceiling : c_8	P_9	Provide accommodation	Provide a job	Rehabilitation of accommodation / retail shop	Not applicable
10	Forest / Jungle	Discount : d_2	P_{10}	Rehabilitation through migration	Provide a job in an ecological park.	Not applicable	Not applicable
11	Desert land	Discount : d_3	P_{11}	Not applicable	Not applicable	Not applicable	Not applicable

Table 1 : A Simple Price Ladder

Plan	Utility of B (1)	Utility of S (2)	Compensation to B settled (3)	Utility Implication for B (1+3)	Utility Implication for S (2-3)	Total Utility (1+2)	Plan Status
P_0^B	105,451	106,228	-	105,451	106,228	211,679	S counterbids.
P_1^S	103,400	117,350	7,000	110,400	110,350	220,750	S counter bids again.
P_2^S	100,679	120,459	4,000	96,679	124,459	221,138	B counterbids.
P_3^B	102,727	120,122	5,000	107,727	115,122	222,849	B counterbids again.
P_4^B	105,550	120,124	5,000	1,10,550	115,524	225,674	S didn't counter bid.
P_5^B	109,972	117,234	-	-	-	227,206	S didn't respond.
P_6^B	115,212	115,121	Negotiation failed			230,333	Aborted
P_7^S	98,667	129,574	3000	101,667	126,574	228,241	Agreed

Table 2 : Example of negotiation scenario in SBSS mechanism

Bidding round	Utility effect of B (1)	Utility effect of S_1 (2)	Utility effect of S_2 (3)	Utility effect of S_3 (4)	Net utility effect (1) + {(2)+ (3) + (4)}
1st ($B \rightarrow \{S\}$)	+3000 for S_1 +2000 for S_2 +4000 for S_3	-3000	-6000	-4000	-4000
2nd ($\{S\} \rightarrow B$)	+3200 for S_1 + 800 for S_2 +5000 for S_3	-2000	-6000	-4000	-3000
3rd ($B \rightarrow \{S\}$) (The plans are accepted)	+4000 for S_1 - 4000 for S_2 +6000 for S_3	+1000	-6000	-3000	-2000

Table 3 : Example of negotiation scenario in SBMS mechanism