Contingent Payment Mechanism for Resource Utilization

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10^{th} Aug 2019

Appeared in
18th International Conference on Autonomous Agents and Multi-agent Systems (AAMAS 2019), Montreal, Canada

1 Problem Addressed

Considering the problem of assigning resources to improve their utilization, for settings where agents have uncertainty about their values for using a resource, and where it is in the interest of the society or the planner that resources be used and not wasted, and designing mechanisms, presenting a simulation study of the welfare properties of these mechanisms.

2 Previous Work

- Previously arisen contingent payments are conditional on observable world states rather than agent's downstream actions.
- In past applications, the principal role of contingent payment is to improve revenue and to limit risk.
- Atakan and Ekmecki studied auctions where the value of taking each action depends on the collective actions by others, but the timing of information is quite different than in our model.
- Courty and Li studied the problem of selling airline tickets. However, they consider distributions that satisfy either mean-preserving spread or stochastic dominance and reduce the type space to one-dimensional.
- A mechanism was designed to incentivize reliability in demand-side response in electric power systems where any number of agents can be selected. In our model, only one agent can be assigned to a resource.

3 Basic Assumptions

- All agents are risk-neutral, expected utility maximizers with quasi-linear utility functions.
- The cumulative distribution function (CDF) F_i of V_i of agent $i's$ private information at period 0, corresponds to her *type*. The following are the assumptions about F_i for each $i \in N$:
  - $(A1) : \mathrm{E}[V_i^+] > 0$, which means that V_i takes the positive value with non-zero probability, thus the option to use the resource as one wishes has a positive value.
  - $(A2) : \mathrm{E}[V_i^+] < \infty$, which means that agents do not get infinite expected utility from the option to use the resource.

4 Contingent Payment Mechanism

Definition: The contingent payment mechanism with maximum penalty Z collects two-part bids $b = (b_1 ... b_n)$. For each $i \in N$, $b_i = (b_i^{(0)}, b_i^{(1)}) \in R$, where $R = \{(z, y) \in R^2 | 0 \leq z \leq Z, y = 0\} \cup \{(z,y) \in R^2 | z = Z, y \geq 0\}$

- *Allocation rule*: $x_{i^*}(b) = 1$ for $i^* \in argmax_{i \in N}\{b_i^{(0)} + b_i^{(1)}\}$ (breaking ties at random); $x_i(b) = 0$ for all $i \neq i^*$
- *Payment rule*: let $i' \in argmax_{i \neq i^*}\{b_i^{(0)} + b_i^{(1)}\}$. $t_{i^*}^{(0)}(b) = b_{i'}^{(0)}$; $t_{i^*}^{(1)}(b) = b_{i'}^{(1)}$; $t_i^{(0)}(b) = t_i^{(1)}(b) = 0$. for all $i \neq i^*$

Theorem (Dominant Strategy in CP):
Given $(A1) - (A2)$, under the contingent payment mechanism with maximum penalty Z, it is a dominant strategy for each agent $i \in N$ to bid $b_{i^*,CP} = (Z, u_i(Z))$ if $u_i(Z) \geq 0$. Otherwise, it is a dominant strategy to bid $b_{i^*,CP} = (z_i^0, 0)$, where z_i^0 is the unique zero-crossing of $u_i(z)$.

Theorem:
For any set of agent types satisfying $(A1) - (A2)$, under the dominant strategy equilibria, the $CP(W)$ mechanism Pareto-dominates the second price auction in the utilization and social welfare.

Characterization and Optimality:

- $P1$. Dominant-strategy equilibrium
- $P2$. Individually rational

- $P3$. No deficit
- $P4$. Anonymous
- $P5$. Deterministic
- $P6$. No subsidy

5 Uniqueness & Optimality of CSP

Theorem: Assume the type space is the set of all value distributions satisfying $(A1) - (A3)$, assume generic input, and consider two-period mechanisms that satisfy $(P1) - (P6)$:

i. the CSP mechanism is the unique mechanism that always allocates the resource, and does not charge the allocated agent if the resource is utilized.

ii. for the (w_i, p_i) type space, the CSP mechanism is optimal for utilization, type profile by type profile.

iii. the CSP mechanism is not dominated for utilization.

iv. the CSP mechanism is utilization optimal type profile by type profile, among all mechanisms that always allocate the resource and use an ordered payment space.

6 Conclusion

The $CP(W)$ mechanism which was given in the paper optimizes social welfare for assigning a single resource and can be generalized to multiple heterogeneous resources. Simulations also demonstrate the effectiveness and robustness of the mechanism.

7 Future Work

- Generalizing the model to allow more than two periods
- Repeated assignments of resources using points.
- Folding in considerations of behavioral economics, understanding the impact of present bias on resource utilization and designing commitment devices through the CP mechanism.