Contracts with Information Acquisition, via Scoring Rules

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This paper considers a principal-agent problem of delegation that features two types of information asymmetry. A principal delegates a task to the agent; the agent can first choose to acquire a costly signal, then takes an action. The signal is relevant to the final outcome and the best course of action. Both of these decisions are hidden from the principal, who only observes a final outcome – a noisy function of both information and action. We call this problem Contracts with Information Acquisition.

To incent the agent, the principal offers a menu of contracts, each a function mapping the observed outcome to the agent’s payment. The agent selects a contract after the information acquisition phase. The principal designs the menu in order to incentivize this hidden acquisition as well as to incentivize the desired choice of hidden action conditioned on the information acquired. We impose the important assumption of limited liability from economics literature, which states that the agent must never be required to make a payment to the principal under any state of the world. Limited liability plays the role of risk aversion, without which the problem becomes trivial. A plan consists of 1) a decision to acquire information or not and 2) a mapping that specifies, for each signal realization, the action that the principal wants the agent to choose. Given that after the information acquisition phase, the agent has better understanding of the outcome, the principal potentially wants a different action performed for each signal realization. This can be encapsulated by the plan that the principal specifies. Hence we consider the minimum payment problem, which asks what the minimal expected payment is to incent the agent to follow a specific plan.

As a motivating example, consider a company (principal) designing a contract for a marketing firm (agent). The marketing firm can choose to conduct a costly survey to gain more information regarding customer preferences. Then, regardless of whether they acquired survey information or not, it will run a marketing campaign. The choice of campaign design and effort level may be influenced by the survey results. The principal cannot directly observe whether the agent acquired survey information nor how much effort they expended, but can observe the final outcome, e.g. sales numbers.

We show that our general problem reduces without loss of generality to the design of a proper scoring rule: a function $s(p, \omega)$ that assigns a score to prediction $p$ when the true outcome turns out to be $\omega$. It is interesting that although proper scoring rules are designed for settings in which agents acquire no new information and take no action, they are “complete” for a problem that involves both. Similar observations have been previously noted, especially in the information acquisition literature (see below). We use this observation to frame our approach in the following results.

We first consider two subcases of our general setting before we move on to the results in the general combined case. For the first subcase of just Information Acquisition (IA), the agent only acquires information and does not take actions. The principal’s goal reduces to incenting the agent to acquire the signal and select a contract that reveals its’ realization. It is very similar the models in [Chen and Yu, 2021, Li et al., 2020], but the constraints differ. We show that an optimal scoring rule takes the form of a polyhedral pointed cone in the
general multidimensional setting, and give a closed-form solution. Qualitatively similar results are obtained by Chen and Yu [2021], Li et al. [2020] under their constraints.

The second subcase, the classic contracts with hidden action or moral hazard problem where agents have no signal to acquire but just actions, is well studied [Mas-Colell et al., 1995]. However, we use the scoring-rule perspective to provide some geometric characterizations of feasible and optimal solutions that may be of interest. In particular, while it is classical that some menu consisting of a single contract is always optimal, we show that this optimal contract must be a shifted subtangent of the convexified cost curve, and we geometrically characterize the set of contracts that can be added to the menu without compromising optimality. While these results are not necessarily contributions to the hidden action literature, they are helpful in understanding, solving, and simplifying the general problem studied next.

Finally, we return to the general problem. While it appears impossible to obtain a closed-form solution – even in the hidden action setting, the solution involves a linear program (LP) – we give an efficient polynomial time algorithm for solving it via an LP. We provide further simplification of this LP and some necessary conditions for elicitability of certain plans. These could be crucial observations for the future work of geometric characterization of all feasible plans for the general case and the characterization of optimal scoring rules for it.

For full version of the paper, see https://arxiv.org/abs/2204.01773.

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