Strategies and reputation - a microeconomic description of the Golem marketplace

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1 Introduction

1.1 Reader notes

Every important statement is labelled as a Conclusion - consider skimming through them if you're not interested in the reasoning.

This document is quite formal, but please don't expect clean, bulletproof implications only. The purpose of this document is to present the topic and conclusions while maintaining resonable level of brievity.

1.2 Abstract

This document provides a simple microeconomic model of the Golem marketplace. Following questions are answered within the model:

- What do we exactly mean by the "reputation"?
- What is the exact problem we hope to solve with the reputation mechanism?
- What are the other, non-reputation approaches to the main problem?
- How to measure the quality of our solutions? I.e. how to know if we succeeded?

The problem is approached from the highest point of view - no specific solutions are proposed, only general classes of solutions are discussed. With an exception of a few details/examples this document describes just a "general" marketplace (replace "provider/requestor" with "seller/buyer").

1.3 Definitions

Agent - A decision-making entity (person, company, etc.).
Utility - The total happiness of an agent.
Utility function U - A function $U : StateOfTheWorld- > \mathbb{R}$, defined for a particular agent, that represents their utility in a given situation.
Expected utility - For every possible decision an agent can make (D) and every possible state of the world w, there is some probability $P : (D, w) \to [0, 1]$ that given decision will lead to the given state of the world. Agents don't have the full knowledge about P, they know only some information I and an estimation of P based on this information: $P_I : (D, w) \to [0, 1]$. The expected utility $E : (I, U, D)- > \mathbb{R}$ is defined as follows:

$$E(I, U, D) = \sum_{w \in all\_possible\_world\_states} U(w) * P_I(D, w) \quad (1)$$

We'll be also using a shorter notation, $E(I, U, D) = E_A(D)$ to describe "expected utility of the decision D, for agent A, who has information I and utility function U".

In other words, for agent A and decision D, $E_A(D)$ is "how happy agent A expects to be if they do D".

Golem - The observable result of all the work done by the Golem Factory - the Golem protocol, available software, state of the market etc.

1.4 Additional assumptions

1. The Expected Utility Hypothesis[1]: every agent tries to maximize their expected utility.

2. Every agent can costlessy access and analyze all of the publicly available information about Golem. Thanks to this assumption we can remove I from the equations - we no longer care about "what agent knows", but only about "what really is". This is a major simplification that might not be a good approximation of the "real world" Golem market, but we accept it for the sake of the brevity of this document. Also "truth about Golem is known" is an ideal world we would like to live in.

3. The expected utility and money are interchangeable, that is - for every agent A and a pair of decisions $(D_1, D_2) : E_A(D_1) < E_A(D_2)$, there is an amount of money X that can be given to the agent so that $E_A(D_1) + U_A(X) = E_A(D_2)$. This way we can treat utilities as if they were money, and thus compare them between different agents.

4. Lets define the Golem Value as:

[1] https://en.wikipedia.org/wiki/Expected_utility_hypothesis

$$V_G = \sum_{A \in all\_agents\_using\_Golem} E_A(USE\_GOLEM) \quad (2)$$

(Note that - because of assumption 1 - $E_A(USE\_GOLEM)$ is always positive, decision "use Golem" is only made by agents who expect to profit from it).

We assume that maximization of V_G is one of the goals of the Golem Factory - and from the point of view of this document, the only goal.

2 The "reputation" and its purpose

2.1 Notation

We'll be using a bunch of different symbols, but they follow a clear common pattern, so please don't be frightened.

- $V_A(a)$ is the total value of the agreement a from the POV of agent A. As per assumption 3, this is "utility expressed as money".[2]
- $V_P(a)/V_R(a)$ are agreement values from the POV of (respectively) provider/requestor.
- $V_{PN}(a)/V_{RN}(a)$ are nominal (i.e. negotiated) values of the agreement. They equal $V_P(a)/V_R(a)$ if neither side breached the agreement a.
- $V_{AL}(a)$ is the value lost by agent A because of the other side breaching the agreement a.
- $V_{AG}(a)$ is the value gained by agent A when they break the agreement a.
- V_{PL}, V_{RL}, V_{PG}, V_{RG} are V_{AL}/V_{AG} from the POV of provider/requestor.
- C_A is the cost of the participation in the Golem market for agent A that is not related to any particular agreement (e.g. the opportunity cost[3] of the hardware offered on the market, or the cost of writing the requestor agent).

2.2 Dissolving the Golem Value

Utilizing the above notation, we can rewrite the V_G equation as:

$$V_G = \sum_{a \in all\_agreements} (V_P(a) + V_R(a)) - \sum_{A \in all\_agents\_using\_Golem} C_A \quad (3)$$

[2] I.e. $V_A(a) = X$ means "when agent A takes part in the agreement a, their hapiness changes as if they were given X money".

[3] https://en.wikipedia.org/wiki/Opportunity_cost

The following equation and it's counterpart from the requestor POV are true by definition:

$$V_P(a) = V_{PN}(a) + V_{PG}(a) - V_{PL}(a) \tag{4}$$

By placing them in the previous equation, we get:

$$V_G = \sum_{a \in all\_agreements} (V_{PN}(a) + V_{PG}(a) - V_{PL}(a) + V_{RN}(a) + V_{RG}(a) - V_{RL}(a)) - \sum_{A \in all\_agents\_using\_Golem} C_A \tag{5}$$

$$\begin{aligned} V_G = &\sum_{a \in all\_agreements} (V_{PN}(a) + V_{PG}(a)) \\ &- \sum_{a \in all\_agreements} (V_{PL}(a) - V_{RG}(a)) \\ &- \sum_{a \in all\_agreements} (V_{RL}(a) - V_{PG}(a)) \\ &- \sum_{A \in all\_agents\_using\_Golem} C_A \end{aligned} \tag{6}$$

Important note here is that both $\sum_{a \in all\_agreements}(V_{PL}(a) - V_{RG}(a))$ and $\sum_{a \in all\_agreements}(V_{RL}(a) - V_{PG}(a))$ are positive: when someone breaks the agreement, the harm done to the victim is usually greater then the offenders gain[4]. Let's thus define one more symbol:

- $V_L(a) = (V_{PL}(a) - V_{RG}(a)) + (V_{RL}(a) - V_{PG}(a))$ - the total value lost because of agents breaking the terms of agreement a.

and use it to rewrite the main equation one last time:

$$\begin{aligned} V_G = &\sum_{a \in all\_agreements} (V_{PN}(a) + V_{RN}(a) - V_L(a)) \\ &- \sum_{A \in all\_agents\_using\_Golem} C_A \end{aligned} \tag{7}$$

This equation defines few general ways to increase the V_G:

1. Increase the number of agreements
2. Increase the average nominal value of the agreement (e.g. by providing additional capabilities, like internet connectivity or GPU access)

[4]TODO: examples/proof/justification?

3. Decrease the average value lost because of breaches of the agreements ($V_L(a)$)
4. Decrease the cost of the participation in the Golem market (e.g. by creating better SDKs)

Note that these ways interact with each other: e.g. if we improve 2 by implementing some features that will be hard to use, we'll also worsen 4. Or: the better is the average nominal value of the agreement, the more agreements we'll expect to have. Or - what is important from the POV of this document - if we implement complex safeguards against cheating, they might have negative impact on all the other points.

Keeping that in mind, the rest of the document is aimed at the third direction from the above list.

2.3 Honest strategy

Fo an agreement a between agents A_1 and A_2 let's define the "dishonesty index" of agent A_2 as:

$$D_{A_2}(a) = \frac{V_{A_1 L}(a)}{V_{A_1 N}(a)} \tag{8}$$

That is: if A_1 received everything that was agreed, $D_{A_2}(a) = 0$. If all agreement-related costs of A_1 are covered, but they got nothing more, $D_{A_2}(a) = 1$. If A_1 lost on the agreement, $D_{A_2} > 1$.[5]

The value of $V_{A_1 L}(a)$ (so also the dishonesty index) depends on the decision made by agent A_1. In an usual case the "visible decision" will by caused by the algorithm implemented in the provider/requestor agent, but this is just an effect of the agent's "real decision" about the implementation.[6]

The agent's core decision-making process is called a "strategy". The better agent fulfills their part of the agreements, the more "honest" is the strategy. So, in other words: when agent A signs an agreement a with an agent using a dishonest strategy, the expected value of $V_{AL}(a)$ is high. When the other side is fully honest, $V_{AL}(a) = 0$. Note that agent's intentions don't matter here - there's no difference if an agent breaks an agreement on purpose or accidentally.

Agent always tries to maximize their own utility (the "expected utility maximization" assumption), in other words: agent always selects the most profitable strategy. Let's now paraphrase the third goal from the previous section as:

Conclusion 2.1 *The final purpose of the reputation system on Golem is to make honest strategies more profitable than dishonest strategies.*

[5] Values below 0 are also possible, e.g. paying more than agreed is also "against the agreement".

[6] In an extreme case we can imagine a human operator who directly interacts with the Golem protocol. Or just imagine someone who turns off the currently rented hardware.

2.4 Non-reputation solutions

Let's consider few directions towards the goal defined in the previous section:

- Make dishonest strategies not available at all, e.g. ensure that debit note acceptance forces payment.
- Make dishonest strategies hard to implement, e.g. hide/obfuscate some important components of Golem.
- Add some mechanics that directly penalize dishonesty, e.g. require deposits and confiscate them when dishonesty is proven.

It's important to note that - while they have the same purpose as the reputation - they have nothing else to do with anything we call the "reputation".

Conclusion 2.2 *Golem Factory works on the reputation system because we believe it's the best way to achieve goal defined in Conclusion 2.1.*

2.5 Defining reputation

$V_{whatever}$ is a determined, known value. When trading on the Golem market, some values are known from the start (e.g. $V_{AN}(a)$), and other only post factum (e.g. $V_{AL}(a)$, so also $V_A(a)$). When making decisions under uncertainity, we're using expected values - they will be written as $E(...)$, e.g. $E(V_A(a))$.

Imagine an honest agent A_1 who considers signing an agreement a with agent A_2. The decision algorithm can be rougly summarized as

1. Calculate the expected value of the decision **not** to sign the agreement, $E_{A_1}(\neg a)$
2. Calculate the expected value of the decision to sign the agreement $E_{A_1}(a)$. Using the eq. 8 we can express this value as a function of the nominal value of the agreement and the estimated dishonesty index: $E_{A_1}(a) = V_{A_1N}(a) - V_{A_1N}(a) * E(D_{A_2}(a))$
3. Sign the agreement if $E_{A_1}(a) > E_{A_1}(\neg a)$

This leads us to a simple observation: the higher dishonesty we expect, the better E_N we need to sign the agreement, and thus to:

Conclusion 2.3 *"Reputation system" is an attempt to solve the problem defined in the conclusion 2.1 in the following way:*

- *Make some additional information available to the market participants*
- *This information can be used to estimate the "dishonesty index" of an agent, and thus improves the accuracy of the total agreement value estimation*

- *The more accurate is the total agreement value estimation, the less profitable it is to trade with dishonest agents*
- *The less profitable it is to trade with dishonest agents, the fewer/worse agreements they have*
- *The fewer/worse agreements dishonest agents have, the less profitable are dishonest strategies*

3 Final notes

1. "How good is reputation" == "estimate honesty factor" 2. "How useful is reputation" is "utilization of the honesty factor estimation" −¿ Two separate topics: provide the information and ensure the information is used.

E.g. what if there is only a single requestor? Or there are less providers the necessary? −¿ We must take care about the market.

"Fulfillment levels" could be different for providers /requestors (and compensated by V_N). Possible balance: super-honest providers and equally dishonest requestors.