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Human Computation and Economics

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This article is devoted to economical aspects of Human Computation (HC) and to perspectives of HC in economics. As of economical aspects of HC, it is first observed that much of what makes HC systems effective is economical in nature suggesting that complexity being reconsidered as a “HC complexity” and the conception of efficient HC systems as a “HC economics”. This article also points to the relevance of HC in the development of standard software and to the importance of competition in HC systems. As of HC in economics, it is first argued that markets can be seen as HC systems avant la lettre. Looking more closely at financial markets, the article then points to a speed differential between transactions and credit risk awareness that compromises the efficiency of financial markets. Finally, a HC-based credit risk rating is proposed that, overcoming the afore mentioned speed differential, holds promise for better functioning financial markets.

Human Computation Economics

In working at ensuring the success of the gaming platform MetropolItalia[1], the aim of which is to collect data for a linguistic study on the divergence of italian vernaculars and dialects, we investigated the following issues:

- **Incentives:** What are the factors motivating both the potential users of the HC system to try it and its actual users to behave as it is needed?[2]

- **Self-sufficiency.** Does the HC system as a whole, or a part of it (like a single game), generate all data it needs for its proper working or does it require to regularly acquire new data from external systems (like other games)?

  A self-sufficient HC system is necessary if a first success is not to end up in a failure. Indeed, an increase in the number of users of a HC system in general calls for an increase of the data it relies upon. If a HC system is not self-sufficient, then the more popular it

[1] http://beta.metropolitalia.org

[2] MetropolItalia must makes its users produce vernacular or dialectal sentences in a context where they might use standard Italian.

becomes, the more human work does its proper working require. At some point, more human work might be necessary than can be provided with. The HC system then fails to satisfy its users and looses its audience.

- **Efficiency:** Are the users participating in the HC system doing so as (among other with the intensity and at the speed) the HC system needs?

  A HC system might provide the right incentives for its users to contribute as needed and be self-sufficient but none the less be inefficient if it does not attract enough human work for performing its task in the desired time.

- **Expandability:** Is the HC system capable of growing in the sense of attracting more human participation?

  Expandability of HC systems involves traditional algorithmic complexity as well as as psychology, especially work organisation and social psychology, a mix we propose to call "Human Computation Complexity".

Incentives, self-sufficiency, efficiency and expendability are economical properties usually considered in investigating macro-systems such as countries and markets and micro-systems such as businesses. The amount of human computation a HC system makes possible can be seen as the wealth it generates. The field concerned with the conception of HC systems can be called "Human Computation Economics". Indeed, economics is the field concerned with the production, consumption, and transfer of wealth [13].

Competitiveness of Human Computation

HC has become popular with aesthetic selection (or interactive evolutionary computation) [6], serious games [31], games with a purpose (GWAP) [27], and reCAPTCHA [29] because it provides with practical solutions to problems that cannot not be solved without involving humans. We argue that HC also has a potential for problems that can be solved with no human aid, provided it gives rise to systems simpler, and consequently cheaper, to develop and to maintain.

The potential of HC where computing solutions without involving humans are possible is illustrated on two examples. The first example is that of a navigation system. Reporting and predicting traffic congestions require no HC. However, provided a navigation system has enough users, data as reliable as sensor data can be collected from the users' positions. This way, the costs of deploying and maintaining a sensor infrastructure are partly or completely avoided. The price to pay for the approach is the disclosure by its users of their positions to the system. The incentives for users to do so is the traffic information they are provided with.

The second example is a Germany-wide university application and registration system. Since German universities do not detect early enough students who do not take a place they have been offered, a significant number of university places remain unoccupied for as long as a year. In order to reduce the number of lost places, a central registration system is under development that will immediately inform all German universities a student applied at when that student takes a place she has been offered by one of them. A rather simple HC approach would make the complex information interchange between a central system and all German universities unnecessary:

Requiring high enough a deposit with each application and refunding this deposit on the application's withdrawal would incite students to provide the universities with the information they need for immediately re-assigning free places.

Both examples describe self-sufficient, efficient and expandable solutions that critically depend on incentives, that is, HC economical solutions. The HC systems have a lower algorithmic, or traditional, complexity than their HC-free counterparts because they shift some tasks to humans.

Admittedly, examples are no evidences. We argue, however, that considering HC as an option and think in terms of HC Economics and HC Complexity often would, like in the two examples given above, make software simpler, and therefore cheaper to develop and to maintain.

Competition in Human Computation

Markets are very successful at the regulation of economical systems because they make it the concern of each economical agent: In a well-functioning market economy, the striving of each agent for its own wealth maximises the collective wealth. Will competition, an essential feature of market economies, become a characteristic of successful HC systems? There are good reasons to think so.

First, competition between users for the reward (real or play money, badges, status, etc.) resulting from success in using a HC system is often an important incentive to use the system. User competition is also often convenient a means towards an HC system's efficiency because good performances in a competition for rewards often are an incentive in themselves. Exploiting competition as an inventive for a GWAP suggests devising adaptive [12], collective scoring schemes, that is, scoring schemes such that the reward of a player for her contribution depends as well on other players' contributions. Collective scoring schemes usually contribute to the attractiveness of a GWAP. Indeed, collective scoring give a social dimension to a game or strengthen its social dimension, if it already has one.

Adaptive scoring schemes, and more generally adaptive HC systems, that is, scoring schemes and HC systems that adapt to a single player's behaviour, or to the behaviour of a players' community, so as to better achieve the HC system's objectives, are promising research issues. In investigating adaptive HC systems, a key issue is the interplay between incentive and efficiency. This issue reaches to psychology. It is an issue of the afore mentioned HC complexity.

Competition between HC systems, in particular between adaptable HC systems, might contribute to the efficiency of HC systems. Often, the sub-systems of an HC system, like the different GWAPs of a gaming platform, compete with each other for the users' attention. It happens sometimes that a sub-system attracts too many users, reducing the efficiency of the overall HC system.

We are faced with this problem with our GWAP platform ARTigo[3] the aims of which are the development of a semantic search engine for art works and art work perception analysis. The games Sentiment and TagATag[4] we specifically designed to generate semantically rich data (like

[3]http://artigo.org

[4]At the time of writing this article, Sentiment and TagATag are on a beta version of ARTigo accessible by selected users.

“sad smile” and “ambiguously inviting”) tend to be less visited than ARTigo’s ESP game [28] and Karido [23] that both generate useful but more trivial data (like “woman” and “hut”). So as to gain more semantically rich tags, we are investigating making ARTigo’s games adaptable. We consider making games played too often to the detriment of others to select images more difficult to tag, for example images that in the past have been less tagged than average, or images that have been tagged with rarer, or more sophisticated, tags than average.

User competition for gaming performances and game competition for users’ attention are useful means for the efficiency of GWAP platforms. We argue that they are more generally important issues of HC Economics. Indeed, games are always related to real life, serious, activities.[5]

Adaptive scoring schemes and adaptive HC systems probably can be achieved by markets – like the market-based HC system for decision making described in [15]– where the competitors (users, HC (sub-)systems, software agents acting for users or for HC (sub-)systems) offer and purchase some fictive goods. The challenge of such a market-based approach to adaptation is to appropriately design markets, that is, to select the goods traded with, to specify the behaviour of the robot traders, the start capital of the (human and robot) traders, the market-making mechanism, and most importantly what information is available to the (human and robot) traders. Especially appealing would be to rely on HC in realising a market for adaptation, that is, to conceive a first HC system as a market making a second HC system adapt as desired. Such a market in turn could be offered as a GWAP on a gaming platform. Indeed, speculation has a gaming side that cannot be denied!

The Invisible Hand as Human Computation

Markets can be seen as HC system avant la lettre because on markets traders perform the following “computations”, even though they did so in the past without computer support and they do so today partly without market-related computer support:

1. Interpreting information on the goods traded with
2. Adjusting the trading prices

On a market there might also be one or several (human oder computerised, institutional or non-institutional) market-makers [11] ensuring the market liquidity by selling (purchasing, resp.) at prices lower (higher, resp.) than the current sale (purchase, resp.) prices and possibly speculating on the prices’ evolution for making a profit. The tasks human market-makers perform can be sen as HC.[6]

The Efficient Market Hypothesis [7] according to which market prices well reflect informations on the goods traded with makes sense because of a rarely perceived HC, namely the human activity necessary for the timely wide-spreading of the information the traders rely on for

[5]Biology teaches that role games in which real life activities are simulated are the premier form of learning among mammals.

[6]An HC-based market-maker would be worth considering.

their price adjustments. In other words, Adam Smith's "invisible hand" ensuring markets' self-regulation [22, 19] is an invisible HC avant la lettre![7] This unperceived HC can be seen as a further component of markets even though it traditionally takes place not on the markets themselves but in their surrounding social contexts.

Intransparency Compromises Markets

There are no reasons for markets to remain self-regulated and efficient if the afore mentioned human activity becomes deficient. Today, it is sometimes deficient on many markets for a couple of reasons:

Variety of goods traded with. While in the 18th century, as Adam Smith reflected on the surprising ability of markets to self-regulate, it was possible for a trader to timely acquire both the expertise and the information necessary for relatively accurate predictions on what he[8] was trading with, say, the next wheat harvest or the cattle's health in his region, it is today hardly possible even for credit experts to accurately compare the credit risks of home mortgages in, say, Alabama, U.S.A., Bavaria, Germany, and Attica, Greece.

One of the reasons why the subprime mortgage crisis of 2008–2009 so strongly hit Europe is first that few in Europe were aware to which extent consumer protection in the credit industry was less developed in the U.S. than in Europe, second that almost nobody in Europe was –and still is– aware that in some US states home mortgages need not be backed with more than the real estate for the purchase of which they have been taken. In Europe a home mortgage is always backed with the whole properties and all future income of the debtor. Also, up till the Greek sovereign debt crisis of 2011–2012 almost no European and surely even less U.S. investors buying securities backed with real estate in Greece were aware that this member country of the European Union still has no cadastre (central land register).

Complexity of the goods traded with. Most goods traded with today are much more complex than were the goods traded with only a century ago. This holds of technological goods, of finance products and also of agricultural products.

Which traders do for example fully understand the perspectives of a nano-tech or IT start-up? Also an insufficient understanding of derivatives by many investors, including some of the bankers who traded with these financial products, and by the regulation agencies is among the acknowledged causes of the current financial crisis [4, 10, 18].

Global markets. Today's markets attract goods and traders from everywhere in the world adding a cultural dimension to the variety and complexity of the goods traded with.

While the markets are global, the information on the goods traded with is largely local and, as two of the examples given above illustrate, can be missing or be misunderstood in other world regions than those where it originates from: Some U.S. home mortgages are more risky than

[7]"Unperceived HC" would be more to the point but we could not resist paraphrasing the celebrated expression.
[8]In 18th century England traders were male.

European home mortgage, real estate is more risky in Greece than elsewhere in the developed world.

Speed differential between transactions and information. On most markets, transactions can be conducted today at a very high speed. In contrast, the information on the goods traded with is widespread among the traders at a considerably lower speed.

This differential is dramatic on financial markets where algorithmic trading [14, 9] makes it possible to react to index variations in fractions of seconds, credit risk estimates still are computed by humans working mostly in committees delivering their updates at best weekly (for example for the home mortgages of a region), at worst every quarter of a year (for example for government bonds) [26, 1, 17, 2].

Financial Markets and Credit Risk Rating

On financial markets the information of relevance is the risk induced by financial instruments. This risk is the likeliness that a debtor might fail to serve and reimburse her debt weighted by the loss this failure would entail. On financial markets not only credit contracts of various kinds (loans, mortgages, bills, and bonds) are traded with but also derivative contracts of many kinds (futures, forwards, options, warrants, swaps among others credit default swaps (CDS) and contingent credit default swaps (CCDS)) [5]. Technically, with a derivative there are no creditors and no debtors because, when the derivative contract is entered, it is open in which direction money will flow between the two contract parties. The payments specified in a derivatives can, like with credits, fail to be honoured. Thus, while with a credit only the creditor assumes a risk, with a derivative both parties in the derivative assume a risk. The risk induced by both, derivatives and credits, is called "credit risk". Abusing the terminology we shall call "debtor" ("creditor", resp.) a party in a derivative contract which has to perform (receive, resp.) a payment.

Assessing credit risk is an essential activity on financial markets called "credit risk rating". Creditor and parties in derivatives use sophisticated stochastic models, statistical methods and complex procedures for credit risk rating [26, 1, 3, 17, 2] some of which are codified in national and international regulations such as Basel II and III. In spite of a large corpus of models, mathematical methods, procedures and regulations, credit risk rating remains awkward.

Today's credit risk rating has been criticised for practical and methodological reasons. As of practical criticisms, it is acknowledged that inaccurate risk assessment has been instrumental in the subprime mortgage and the late–2000s financial crises [18] and that the widespread disregard of the counterparty risk of derivatives has been one of the major causes of the late–2000s financial crisis [18, 10].

As of methodological criticisms of credit risk rating, some –prominently Benoit Mandelbrot [16] and Nassim Nicholas Taleb [24]– argue that, as it is currently based on stochastics, it is not sufficiently scientifically founded. Furthermore, a folklore criticism is that, being performed mostly by banks to display evidence of their financial health and by rating agencies on behalf, and often at the expenses of, debtors that need good ratings for getting credits at good conditions, current credit risk rating is not free from moral hazard. A further folklore observation is that credit risk rating is largely ineffective during bubbles. As a bubble booms, that is, some prices keep raising more and over longer a period of time than usual, more and more traders get seduced by the perspective of unexpected gains, loose their sense of risk and join in the frenzy contributing to keep the price raising up till enough traders come to reason, what causes the bust. Credit risk rating, as it is performed today, cannot keep with the pace of price raising during bubbles' booms.[9] Another folklore observation, is that any market analysis including credit risk rating has unexpected effects because of a reflexivity typical of economics: Market analyses provide traders with additional information that often lead them to re-consider their actions.

Human Computation for Credit Risk Rating

The reflexivity mentioned at the end of the last section is where HC comes in.

We propose to collect risk estimates related to credits and derivatives from traders on financial market, to aggregate and publish these estimates as follows where (H) denote tasks to be performed by human and (C) computerised tasks:

1. **(H) Risk Estimation:** Each debtor (including each party in a derivative) estimates the risks she induces to her counterparties.
2. **(C) Risk Consolidation:** For each creditor or party in a derivative A the risk estimates of its counterparties are consolidated, that is, aggregated, yielding a risk estimate for A.
3. **(C) Risk Publication:** Anonymised through meaningful aggregations, the risk estimates computed at Step 2 are published.

Note the collecting of risk estimates from the "risk producers" or "debtors", not from the "risk takers" or "creditors" as with current credit risk rating. This unusual approach being free of moral hazard aims at an earlier and more accurate risk assessment.

Recall the abuse of terminology in calling "debtor" ("creditor", resp.) a party in a derivative contract which has to perform (receive, resp.) a payment.

The HC scheme given above raises many questions. Why should debtors provide with their own estimates of the risks they induce? This question is addressed below under "Incentive: Grace Period Insurance". Can risk estimates be aggregated in a meaningful manner? This is discussed below under "Consolidated risk as eigenvector". How can risk estimates provide financial markets with information contributing to their self-regulation without compromising the markets' liquidity? This issue is addressed below under "Contributing to financial markets' transparency". The proposed scheme would be a significant interference in financial markets. Could it be accepted? This question is discussed below under "Pragmatics".

Incentive: Grace Period Insurance. The incentive we propose for debtors to disclose the risks they induce to their counterparties is a Grace Period Insurance (GPI) functioning like a

[9] No methodological criticism of current credit risk rating can be derived from this since, being based on stochastic, its outcomes do not apply to exceptional situations like bubbles. This is intellectually satisfying but does not help for, in practice, bubbles happen.

credit default insurance but, most importantly, only for a short period of time like three months. The GPI can be activated by debtors at any time and for any coverage, that is, percentage, of their outstanding payments. The GPI can also be deactivated at any time by debtors.

An activated GPI comes at a cost for debtors, what incites them only to activate it when they see a need. The costs of an activated GPI are proportional to both the payment's percentage covered and its activation duration, making it reliable an estimate of the credit risk a debtor perceives. The costs of an activated GPI are covered from a compulsory GPI deposit to be made by debtors when entering a credit or derivative contract. The GPI deposit is lost by the debtor if she defaults while the GPI is not activated and otherwise refunded up to the costs incurred from activating the GPI. This deposit is set to be significantly higher than the costs of an activated GPI. The possible loss of the GPI deposit and the value of this deposit both incite debtors to activate the GPI accordingly to the risk of defaulting they perceive.

Finally, whether a given debtor activates the GPI or not is kept confidential. As discussed below, only aggregated data on GPI activations are disclosed. This confidentiality ensures that no moral hazard impairs the risk assessments deduced from GPI activations.

The GPI requires tuning: The GPI costs must be set according to insurances' good practices and the grace period must be defined possibly depending on businesses, types of credits, and types of derivatives.

Note that risk assessment by means of the GPI does not conflict with standard credit risk rating. Indeed, in deciding whether or not to activate the GPI, any financial risk and derivative pricing method can be used.

Consolidated risks as eigenvector. Let i denote an economical agent involved in credit or derivative contracts. Let c_i^τ be the proportion of the total (notional) credit on the financial market agent i is taking at time τ, $D^\tau(i)$ be the set of debtors and $C^\tau(i)$ the set of creditors of i at time τ, "debtor" and "creditor" understood as recalled at the beginning of this section. Let $w_{ji}^\tau \in [0,1]$ express the likeliness as revealed by the GPI that agent j defaults to agent i at time τ. Set w_{ii}^τ to a same arbitrary value in $]0,1]$ for all i and τ.

The consolidated credit risk $CCR^\tau(i)$ incurred by i at time τ is the following linear combination of the consolidated credit risks of its debtors $D^\tau(i)$

$$CCR^\tau(i) = \sum_{j \in D^\tau(i)} \frac{c_i^\tau \cdot w_{ji}^\tau \cdot CCR^\tau(j)}{d_i^\tau} \tag{1}$$

where $d_i^\tau = \sum_{k \in C^\tau(j)} c_k^\tau \cdot w_{jk}^\tau$. Equation 1 specifies a vector $\vec{v}$, the components of which are the consolidated credit risk incurred at time τ $CCR^\tau(i)$, as follows

$$\vec{v} = R^\tau \vec{v} \tag{2}$$

where $R^\tau = (r_{ji}^\tau)$ with

$$r_{ji}^\tau = \begin{cases} \frac{c_i^\tau \cdot w_{ji}^\tau}{d_i^\tau} & \text{if } d_i^\tau \neq 0 \\ 0 & \text{otherwise} \end{cases}$$

is the "conceptual risk matrix". Define $R'^{\tau} = (r'^{\tau}_{ji})$, the "risk matrix", as follows

$$r'^{\tau}_{ji} = \begin{cases} \frac{c_i^{\tau} \cdot w_{ji}^{\tau}}{d_i^{\tau}} = r_{ji}^{\tau} & \text{if } d_i^{\tau} \neq 0 \\ \frac{1}{N} & \text{otherwise} \end{cases}$$

where N is the number of traders on the market. R^{τ} is not necessarily column-stochastic, but R'^{τ} is. R'^{τ} can be interpreted as follows: A trader who is debtor of no one is treated as being debtor of all traders in equal parts. In general, Equation 2 does not admit a solution, but the following Equation 3 does:

$$\vec{v} = R'^{\tau} \vec{v} \tag{3}$$

Whether such a solution is of practical interest depends on the credit risk graph R'^{τ} is the adjacency matrix of. The matrix R'^{τ} being real, non-negative and column-stochastic and each diagonal element of $R'\tau$ being positive, it follows from celebrated theorems by Perron and Frobenius [21, 8, 30] that provided R'^{τ} is irreducible, 1 is a simple and strictly dominant eigenvalue of R'^{τ} the eigenvector associated with is called Perron vector of R'^{τ}. The irreducibility of R'^{τ} is equivalent to the graph it is the adjacency matrix of being strongly connected. We show below that this is the case.

Since 1 is a simple eigenvalue of R'^{τ}, the Perron vector of R'^{τ} is the unique real solution of Equation 3. This makes it acceptable a credit risk vector: If Equation 3 had several real solutions, then here would be no reasons to choose the one instead of another as a credit risk vector.

Finally if a vector $\vec{u}$ is not orthogonal to the Perron vector of R'^{τ}, then normalised power sequences of R'^{τ} and $\vec{u}$ converge to the Perron vector of R'^{τ}. This makes it possible to apply the power method to compute the Perron vector of R'^{τ}.

The graph R'^{τ} is the adjacency matrix of consists of nodes representing the traders on financial markets: Private and social persons who take credits and handle with derivatives and financial institutions which take and give credits and handle with derivatives. We include central banks as additional nodes on the ground that the currencies they manage can be seen as credits (without interests). If b is a central bank, then the currency it manages conveys at time τ a risk w_{bi}^{τ} to every trader in the currency zone of b. Set $w_{bi} = 1$ for all $i \neq b$ on the ground that a central bank does not absorb any risk.[10] It follows that the graph R'^{τ} is the adjacency matrix of is a strongly connected graph.

Setting the value of c_b^{τ} requires tuning. An appropriate value would probably be close to $\sum_{i \in T} c_i^{\tau}$ where T is the set of all traders.

Contributing to financial markets' transparency. The consolidated credit risk $CCR^{\tau}(f)$ of a financial institution f at time τ can be used as a bottom line: Regulations forbidding f's own risk assessment to be much below $CCR^{\tau}(f)$ would make sense. If f feels that its debtors are too cautious, then it should publicly provide evidence for them to reduce their own risk estimates, that is, exploit the afore mentioned reflexivity. $CCR^{\tau}(f)$ would also help in setting f's capital coverage less crudely than it is done today.

Aggregated credit risks over time intervals, for business branches, or for social groups could be published so as to further exploit the afore mentioned reflexivity. Aggregated credit risks for

[10] $CCR^{\tau}(b)$ expresses the risk associated with the currency of b.

France or Greece would for example sustain, or disprove, the claims often made in Germany and Finland that the former countries accepting too high credit risks.

Pragmatics. The scheme proposed requires that all derivatives being traded with being registered. However, it does not require that derivatives being traded through clearing houses like, currently, futures are.

The scheme proposed can be applied in a single currency zone at the costs of possibly arbitrary estimates for credit and derivative offers outside that currency zone.

The scheme proposed can be seen as a smooth, or continuous, "bailout in the small" the costs of which are covered by the market through the grace period insurance (GPI). Arguably, this would be preferable to the bailouts in the large that from time to time are so far needed and the costs of which are not covered by the market. The GPI with its mandatory deposit can be seen as a "Transaction tax [25] with a purpose" from which each trader as well as the financial market as a whole benefit.

Finally, the HC credit risk rating can be seen as a "PageRank [20] for credit risk". Deploying it would amount to building up a "Google of credit risk". An essential feature of the approach is the taping in the reflexivity it gives rise to for an undelayed self-regulation of financial markets.

Conclusion

This position paper investigated economical aspects of Human Computation (HC) and perspectives of HC in economics. The considerable perspectives both fields have for each other have been demonstrated on several examples among other a HC-based approach to credit risk rating.

The author is convinced that much of the future of HC lies with economics and that credit risk rating, and more generally markets, in the future will exploit HC, if not exactly as proposed in this article, none the less in a similar manner.

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