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Virtual Group Dynamics and Social Networks

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

With the growing interest in complex adaptive systems, artificial life, swarms and simulated societies, the concept of "collective intelligence" is coming more and more to the fore.

The basic idea is that a group of individuals (e.g. people, insects, robots, or software agents) can be smart in a way that none of its members is. Complex, apparently intelligent behavior may emerge from the synergy created by simple interactions between individuals that follow simple rules.

To be more accurate we can ***define intelligence as the ability to solve problems.***

A system is more intelligent than another system if:

in a given time interval it can solve more problems, or find better solutions to the same problems.

A group can then be said to exhibit collective intelligence if it can find more or better solutions than the whole of all solutions that would be found by its members working individually.

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All organizations, whether they be firms, institutions or sporting teams, are created on the assumption that their members can do more together than they could do alone.

- Yet, ***most organizations have a hierarchical structure***, with one individual at the top directing the activities of the other individuals at the levels below. Although no president, chief executive or general can oversee or control all the tasks performed by different individuals in a complex organization, one might still ***suspect that the intelligence of the organization is somehow merely a reflection or extension of the intelligence of its hierarchical head***.
- ***This is no longer the case in small, closely interacting groups*** such as soccer or foot-ball teams, where the "captain" rarely gives orders to the other team members. *The movements and tactics that emerge during a soccer match are not controlled by a single individual, but result from complex sequences of interactions.* Still, they are simple enough for an individual to comprehend, and since soccer players are intrinsically intelligent individuals, it may appear that the team is not really more intelligent than its members.

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Obstacles to collective intelligence

1. First, however competent the participants, their individual **intelligence is still limited**, and this imposes a fundamental restriction on their ability to cooperate.

2. Another recurrent problem is that people tend to **play power games**. Everybody would like to be recognized as the smartest or most important person in the group, and is there- fore inclined to dismiss any opinion different from his or her own. Such power games often end up with the establishment of a “pecking order”, where the one at the top can criticize everyone, while the one at the bottom can criticize no one. The result is that the people at the bottom are rarely ever paid attention to, however smart their suggestions.

3. ***coordination***. To tackle a problem collectively, the different subgroups must keep close contact. This implies a constant exchange of information so that the different groups would know what the others are doing, and can use each other’s results. But this again creates a great information load, taxing both the communication channels and the individual cognitive systems that must process all this incoming information. Such load only becomes larger as the number of participants or groups increases.

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Collective Problem-Solving

To better understand collective intelligence we must first analyse intelligence in general, that is, ***the ability to solve problems***.

A ***problem*** can be defined as a difference between the present situation, as perceived by some agent, and the situation desired by that agent.

Problem-solving then means finding a sequence of actions that will transform the present state via a number of intermediate states into a goal state.

Of course, ***there does not need to be a single, well-defined goal: the agent's "goal" might be simply to get into any situation that is more pleasant, interesting or amusing than the present one***.

The only requirement is that the agent can *distinguish* between subjectively "better" (preferred) and "worse" situations (Heylighen 1988, 1990).

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Collective Problem-Solving

To generalize this definition of a problem for a collective consisting of several agents it suffices to aggregate the desires of the different agents into a collective preference and their perceptions of the present situation into a collective perception.

- In economic terms, t***he aggregate desire becomes the market "demand" and the aggregate perception of the present situation becomes the "supply"*** (Heylighen, 1997).
- It must be noted, though, that ***what is preferable for an individual member is not necessarily what is preferable for a collective*** (Heylighen & Campbell, 1995):
- in general, a ***collective has emergent properties that cannot be reduced to mere sums of individual properties***.

(Therefore, the aggregation mechanism will need to have a non-linear component.)

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Mental maps

The efficiency of mental problem-solving depends on the way the problem is *represented* inside the cognitive system (Heylighen 1988, 1990).

Representations typically consist of the following components:

1. ***a set of problem states***,
2. ***a set of possible actions***,
3. and ***a preference function or "fitness" criterion*** for selecting the most adequate actions.

The ***fitness criterion***, of course, ***will vary with the specific goals or preferences of the agent***. Even for a given preference, though, there are many ways to decompose a problem into states and actions.

Changing the way a problem is represented, by considering different distinctions between the different features of a problem situation, may make an unsolvable problem trivial, or the other way around (Heylighen 1988, 1990).

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Mental maps

Actions can be represented as ***operators or transitions that map one state onto another one***.

A state that can be reached from another state by a single action can be seen as a neighbor of that state.

Thus, ***the set of actions induces a topological structure on the set of states, transforming it into a problem space***.

The ***simplest model of such a space is a network, where the states correspond to the nodes of the network, and the actions to the edges or links that connect the nodes***.

The ***selection criterion***, finally, can be represented by a ***preference function that attaches a particular weight to each link***.

This problem representation can be seen as the agent's *mental map* of its problem environment.

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Mental maps

To solve a problem, you need a general heuristic or search algorithm, that is, a method for selecting a sequence of actions that is likely to lead as quickly as possible to the goal.

- If we assume that the ***agent has only a local awareness of the mental map***, that is, that the agent can only evaluate actions and states that are directly connected to the present state,

- then ***the most basic heuristic it can use is some form of "hill-climbing" with backtracking***. This heuristic works as follows:

    - from the present state choose the link with the highest weight that has not been tried out yet to reach a new state;
    - if all links have already been tried, backtrack to a state visited earlier which still has an untried link;
    - repeat this procedure until a goal state has been reached or until all available links have been exhausted.

The efficiency of this method will obviously depend on how well the nodes, links and preference function reflect the actual possibilities and constraints in the environment.

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Mental maps

The better the map, the more easily problems will be solved.

- ***Intelligent agents***, then, ***are characterized by the quality of their mental maps***, that is, by the knowledge and under-standing they have of:
  - *their environment*,
  - *their own capacities for action*,
  - and *their goals*.

Increasing problem-solving ability will generally require two complementary processes:

1. ***Enlarging the map with additional states and actions***, so that until now unimagined options become reachable;

2. ***Improving the preference function***, so that the increase in total options is counterbalanced by a greater selectivity in the options that need to be explored to solve a given problem.

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Coordinating individual problem-solutions

Let us apply this conceptual framework to collective problem-solving. Imagine a group of individuals trying to solve a problem together.

Each individual can explore his or her own mental map in order to come up with a sequence of actions that constitutes part of the solution.

It would then seem sufficient to combine these partial solutions into an overall solution.

Assuming that the individuals are similar (e.g. all human beings or all ants), and that they live in the same environment, we may expect their mental maps to be similar as well. However, ***mental maps are not objective reflections of the real world "out there": they are individual constructions, based on subjective preferences and experiences*** (cf. Heylighen 1999).

Therefore, the maps will also be to an important degree different.

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Coordinating individual problem-solutions: the maps

The mental maps' diversity is healthy, since it means that different individuals may complement each others' weaknesses.

- Imagine that each individual would have exactly the same mental map. In that case, they would all find the same solutions in the same way, and little could be gained by a collective effort. (In the best case, the problem could be factorized into independent subproblems, which would then be divided among the participating in- dividuals. This would merely speed up the problem-solving process, though; it would not produce any novel solutions).

As it is clear that a CMM cannot be developed by merely registering and editing individual contributions, we will need to study different methods to collectively develop a mental map.

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Mechanisms of CMM Development

Probably the most basic method for reaching collective decisions and avoiding conflicts is ***voting***.
This method assumes that all options are known by all individuals, and that the remaining question is to determine their aggregate preference. In the simplest case, every individual has one vote, which is given to the options that this individual prefers above all others. Adding all the votes together determines the relative preferences of the different alternatives for actions.

The three basic mechanisms of

- ***averaging***,
- ***feedback*** and
- ***division of labor***

gave us a first idea of a how a CMM can be developed in the most efficient way, that is, ***how a given number of individuals can achieve a maximum of collective problem-solving competence.***

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Mechanisms of CMM Development

A ***collective mental map is developed basically by superposing a number of individual mental maps***.

- There must be ***sufficient diversity*** among these individual maps to cover an as large as possible domain,

- yet ***sufficient redundancy*** so that the overlap between maps is large enough to make the resulting graph fully connected, and so that each preference in the map is the superposition of a number of individual preferences that is large enough to cancel out individual fluctuations.

- The best way to quickly expand and improve the map and fill in gaps is to ***use a positive feedback that encourages individuals to use high preference paths discovered by others, yet is not so strong that it discourages the exploration of new paths***.

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In the work at MIT's Center for Collective Intelligence, the Malone's team have gathered nearly 250 examples of Web enabled collective intelligence (for more, see "About the Research").

At first glance, what strikes one most about this collection of examples is its diversity, with the systems exhibiting a wildly varying array of purposes and methods. But after examining these examples in depth, they identified a relatively small set of building blocks that are combined and recombined in various ways in different collective intelligence systems. To classify these building blocks, they use two pairs of related questions.

- ***Who is performing the task? Why are they doing it?***
- ***What is being accomplished? How is it being done?***

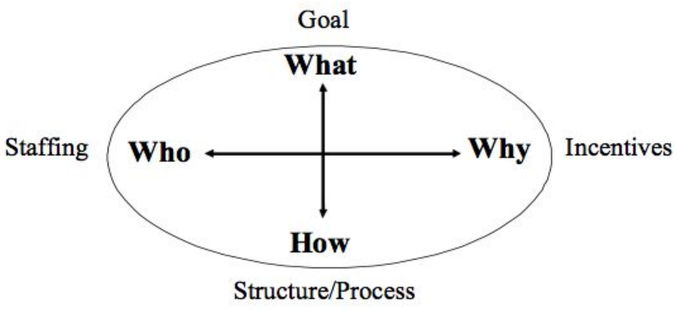

Figure 1: Elements of collective intelligence building blocks or "genes"

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The genes of collective intelligence

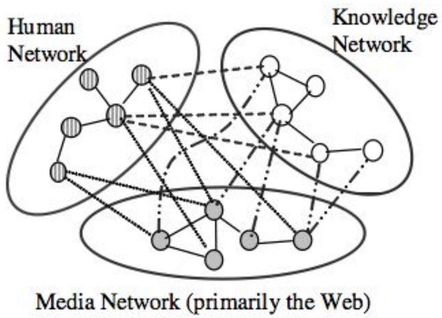

Figure 2 Illustration of the supernetowrk of community intelligence

Malone's team calls these ***building blocks the "genes" of collective intelligence systems***. And they define a ***gene as a particular answer to one of the key questions*** (Who, Why, What, or How) ***associated with a single task in a collective intelligence system.*** (Malone, 2009)

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Who? and Why?

The first question to be answered is, ***Who undertakes the activity***? Here there are two basic genes.

Hierarchy. In traditional hierarchical organizations, this question is typically answered when ***someone in authority assigns a particular person or group of people to perform the task***.

The task may be assigned to personnel inside the firm or to people outside it, through the hiring of a subcontractor.

For instance, even though the Linux community is not a traditional business firm, Linus Torvalds and his lieutenants use the Hierarchy gene when they decide which of the many modules that people have submitted will actually be included in the next release of the software.

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Who? and Why?

Crowd*.* In the Crowd gene, ***activities can be undertaken by anyone in a large group who chooses to do so****,* without being assigned by someone in a position of authority.

For example, *anyone who wants to can submit a module for possible inclusion in Linux. While crowds have done certain things, like voting in elections, for a long time, low cost electronic communication enabled by the Internet now makes it feasible for crowds to do many more things than ever before*. (Malone, 2009)

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Closely related to the Who question is Why? ***Why do people take part in the activity?*** What motivates them to participate? What incentives are at work?

As a simplified overview of the possibilities, however, ***three basic Why genes can cover the high level motivations that lead people to participate in collective intelligence systems***. Even if Maslow rules …. we can suggesting a trivial three factors model:

Money. The promise of financial gain is an important motivator for most actors in markets and traditional organizations. ***Love***. Love is also an important motivator in many situations, even when there is no prospect of monetary gain. The Love gene can take several forms: people can be motivated by their intrinsic *enjoyment* of an activity, by the opportunities it provides to *socialize with others,* or because it makes them feel they are *contributing to a cause* larger than themselves. Studies of Wikipedia have shown that its participants are motivated by all three of these variants of the Love gene. ***Glory***. Glory or recognition is another important motivator. The programmers in many open source software communities, for example, are motivated by the desire to be recognized by peers for their contributions.

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Why?

What is novel about many of the collective intelligence systems that have emerged in recent years is their reliance on the Love and Glory genes, in contrast to traditional organizations, which have relied more heavily on Money as a motivating force.

- For instance, *collective intelligence systems often explicitly engineer opportunities for recognition by compiling and publishing "top contributor" lists or by institutionalizing performance-based classes of membership that confer various degrees of status, such as "power seller" on eBay and "top reviewer" on Amazon.*

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What? and How?

The third question to be answered for any activity is: ***What is being done***? In traditional organizations, the answer to this question is often spoken of as *the mission or goal.*

For What, the many organizational goals encountered in collective intelligence systems can be boiled down into two basic genes.

Create*.* In this gene, the actors in the system generate something new—a piece of software code, a blog entry, a T-shirt design.
Decide*.* In this gene, the actors evaluate and select alternatives—deciding whether a new module should be included in the next release of Linux, selecting which T-shirt design to manufacture, deciding whether to delete a Wikipedia article.

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What? and How?

The final question to be answered concerning an activity is, ***How is it being done***? In traditional organizations, the How question is typically answered by describing the *organizational structures and processes*.

Many collective intelligence systems still use hierarchies for some of their tasks, but *what is novel is how they use crowds*. So we focus here on instances of the How gene where the crowd does the Create or Decide task.

A **key determinant of the answer to this question is whether the different members of the crowd make their contributions and decisions *independently* of each other or whether there are strong *dependencies* between their contributions.**

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What? and How?

This insight gives rise to four primary How genes for Crowds (see Table 1).

	Independent	**Dependent**
Create	Collection	Collaboration
Decide	Individual Decisions	Group Decision

Table 1: Variations of the How gene for Crowds

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Collection and Collaboration

The two How genes associated with the Create task are ***Collection*** and ***Collaboration****.*

Collection*.* This gene occurs when the items contributed by members of the crowd are created independently of each other.
For example, YouTube videos are created mostly independently of each other, and this makes YouTube a collection. Other examples of this common gene include Digg, a collection of news stories, and Flickr, a collection of photographs.
An important subtype of the Collection gene is the ***Contest* gene**. In contests, like Threadless, one or several items in the collection are designated as the best entries and receive a prize or other form of recognition. In another example of contests, *InnoCentive,* companies offer cash rewards, typically totaling in the five or even six figures, to researchers anywhere in the world who can solve challenging scientific problems such as how to synthesize a particular chemical compound.

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Collection and Collaboration

Collaboration The Collaboration gene occurs when members of a Crowd work together to create something and important dependencies exist between their contributions.
For example, even though there is extensive hyper-linking between them, articles in Wikipedia are meant to stand on their own as independent entities. This means Wikipedia as a whole is a Collection of articles. But the additions and editorial changes that different contributors make within a single Wikipedia article are strongly interdependent. So each individual Wikipedia article is a Collaboration, comprised of contributions submitted by a number of users. Another important example of the Collaboration gene is Linux, and any other open source software project, where there are strong interdependencies among the modules submitted by different contributors.

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Decision

For Decide tasks, there are two possible genes: ***Group Decision*** and ***Individual Decisions***.

Group Decision. The Group Decision gene occurs when inputs from members of the crowd are assembled to generate a decision that holds for the group as a whole.

In some instances, such as Threadless, this decision determines the subset of contributed items that will be included into the final output. In other instances, such as Digg, the decision relates to generating a common rank-ordering of the contributed items. In yet other instances, such as prediction markets, the decision relates to aggregating individual inputs to form a publicly visible estimate of a quantity. (Malone, 2009)

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Decision

Important variants of the Group Evaluation gene are ***Voting***, ***Consensus***, ***Averaging***, and ***Prediction Markets.***

Voting. New technologies make the Voting gene feasible in many situations where it would not otherwise have been practical. For example:

- An important sub-variation of voting is ***implicit voting***, where actions like buying or viewing items are counted as implicit "votes." *For instance, iStockPhoto displays photos in order of the number of times each photo has been downloaded, and YouTube ranks videos by the number of times they have been viewed.*
- Another important sub-variation involves ***weighted voting***. *For example, Google ranks search results, in part, on the basis of how many other sites link to the sites in the list. But Google's algorithm gives more weight to links from sites that are, themselves, more popular.*

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Important variants of the Group Evaluation gene are ***Voting***, ***Consensus***, ***Averaging***, and ***Prediction Markets.***

Consensus*.* Consensus means that all, or essentially all, group members agree on the final decision.

For example in Wikipedia, the articles that remain unchanged are those for which everyone who cares is satisfied with the current version. Thus Wikipedia uses a kind of consensus to make editing decisions on individual articles.

- Consensus is also used in an interesting way in *reCAPTCHA,* a Web security utility. *Two words are displayed on the screen, with users required to type both to gain access to a Web page. One of the words is a security key and the other a word previously scanned as part of a project to digitize old books. Words the optical character recognition software finds difficult to read are served up to multiple users as one half of each reCAPTCHA. Only after the transcriptions provided by multiple users reach a level of consensus, as determined by a statistical algorithm, is that word deemed to have been correctly transcribed.*

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Decision

Important variants of the Group Evaluation gene are ***Voting**, **Consensus**, **Averaging**,* and ***Prediction Markets.***

***Averaging**.* In cases where decisions involve picking a number, another common practices is to average the numbers contributed by the members of the Crowd. In some cases, such as guessing the weight of an oxiv, simple averaging works surprisingly well.

Averaging is commonly used in systems that rely on a point scale for quality rating. For example,

- **users of *Amazon*** can rate books or CDs on a five star scale, and these ratings are averaged to provide an overall score for each item. Similar systems allow users of *Expedia* to rate hotels and users of *Internet Movie Database* to rate movies.
- ***NASA Clickworkers**.* In 2001-02, NASA let anyone look at photos of the surface of Mars on the Internet and identify features they thought were craters. Crater locations were designated by sets of coordinates in two dimensional space. When the coordinates contributed by amateurs were averaged, they were found to be just as accurate as the classifications made by expert scientists.
- ***Marketocracy*** runs an investment portfolio that is selected by averaging the stocks and bonds chosen by the 100 most successful investors from over 55,000 who participate on the website.

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Decision

Important variants of the Group Evaluation gene are ***Voting***, ***Consensus***, ***Averaging***, and ***Prediction Markets.***

Prediction markets. A useful way of letting crowds estimate the probability of future events is with prediction markets. In prediction markets, people buy and sell "shares" of predictions about future events. If their predictions are correct, they are rewarded, either with real money or with points that can be redeemed for cash or prizes.

- *Google, Microsoft, and Best Buy have all used prediction markets to tap the collective intelligence of people within their organizations.*
- *Microsoft used its prediction market to estimate completion dates for projects. When one of the first of these markets opened, the share prices for a project declined within minutes to a price indicating a 1 percent probability of on time completion. The managers in charge had thought everything was on schedule, but the prediction market's results led them to investigate further, and they found problems. The project was eventually completed three months late. Awareness of the problem was available in the organization, but the prediction market was required to bring this decentralized knowledge to the attention of people who could act on it. (Malone, 2009)*

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Individual Decisions.

The Individual Decision gene occurs when members of a Crowd make decisions that, though informed by crowd input, do not need to be identical for all. For instance, individual YouTube users decide for themselves which videos to watch. They may be influenced by recommendations or rankings from others, but they are not required to watch the same videos as others.

Two important variations of the Individual Decisions gene are: ***Markets*** and ***Social Networks****.*

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Individual Decisions.

Two important variations of the Individual Decisions gene are: ***Markets*** and ***Social Networks****.*

Markets*.* In Markets, there is some kind of formal exchange (like money) involved in the decisions.

1. Each member of the crowd makes an individual decision about what products to buy or sell.
2. Purchasing decisions by buyers in the crowd determine collective demand, which, for its part affects the availability of products and their prices.
3. And in turn, the quantities and prices of the goods put up for sale by sellers in the crowd influence, but do not bind, purchasing decisions.

Markets for many kinds of goods and services have existed for millennia, but new technologies will enable new electronic forms of markets.

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Individual Decisions.

Two important variations of the Individual Decisions gene are: ***Markets*** and ***Social Networks***.

Social Networks. In Social Networks, members of a crowd form a network of relationships that, depending on the context, might translate into levels of trust, similarity of taste and viewpoints, or other common characteristics that might cause individuals to feel an affinity for one another. Crowd members assign different weights to individual inputs on the basis of their relationship with the people who provided them and then make individual decisions. For example:

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Collective intelligence: The model of Malone

Collective Decisions: few examples

In the ***blogosphere***, authors have the habit of placing links to content they like, including entries by other bloggers, notable news articles, or interesting videos. Readers, in turn, have favorite blogs that act as personalized entry points to the blogosphere. By reading these blogs and their links every reader makes an individual decision about what content to consume. But these individual decisions are shaped by the structure of the social network of the crowd. For example, bloggers often cluster in cliques that link frequently to one another. Clicking on a blog entry by one member of such a clique can quickly give a reader access to an interlinked web of related content.

In ***YouTube***, every user is associated with a “channel.” On these channels, users can upload their own videos and/or link to selections of other users’ videos, via a favorites option. Users can subscribe to other users’ channels and receive notifications when their favorite channels have been updated. Users thus form social networks that affect their choices of what videos to watch.

In ***Epinions.com***, a product review site, users form trust networks with other reviewers. Empirical evidence suggests that users weigh reviews written by members of their trust network more heavily than other reviews, leading to personalized assessments of individual product quality.

Amazon.com provides personalized recommendations to users. Amazon does this by automatically constructing an implied social network that relates each user to other users who have purchased or rated similar products in the past. The system then recommends products that many “similar” users have liked but which the target user has not yet purchased. This is an example of the broader class of systems that are referred to by (Malone, 2009)

Malone, T. W., Laubacher, R., & Dellarocas, C. (2009). Harnessing crowds: Mapping the genome of collective intelligence.

Collective Intelligence

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Question	*Gene*	*When useful*
Who	**Crowd**	• Resources useful in doing activities are distributed widely or in places not known in advance • Activities can be divided into pieces satisfactorily (necessary information can be shared; gaming and sabotage can be managed)
	Hierarchy	• Conditions for crowd aren't met
Why	**Money** **Love** **Glory**	• Many factors, too complex to list here, are relevant, with two rules of thumb – Appealing to Love and Glory, rather than Money, can often (but not always) reduce costs – Providing Money and Glory can often (but not always) influence a group's direction and speed.
How—Create	**Collection**	Conditions for Crowd, *plus*… • Activity can be divided into small pieces that can be done (mostly) independently of each other.
	Contest	Conditions for Collection, *plus*… • Only one (or a few) good solutions are needed.
	Collaboration	• Activity *cannot* be divided into small independent pieces (otherwise Collection would be better) • There are satisfactory ways of managing the dependencies among the pieces
How—Decide	**Group Decision**	Conditions for Crowd, *plus* . . . • Everyone in the group needs to abide by the same decision, *plus* …
	Voting	• It is important for the Crowd to be committed to the decision
	Averaging	Conditions for Voting, *plus*... • Decision consists of estimating a number • Crowd has no systematic bias about estimating the number
	Consensus	Conditions for Voting, *plus*… • Achieving consensus in reasonable time is feasible (group is small enough or has similar enough views)
	Prediction market	• Decision consists of estimating a number • Crowd has some information about estimating the number (biases and non-independent information are okay) • Some people may have (or obtain) much better information than others • Continuously updated estimates are useful
	Individual Decisions	Conditions for Crowd, *plus*... • Different people can make their own decision, *plus* …
	Market	• Money is needed to motivate people to provide the necessary effort or other resources
	Social network	• Non-monetary motivations are sufficient for people to provide the necessary effort or other resources • Individuals find information about other's opinions useful in making their own choices.

Table 5. Conditions for when collective intelligence genes are useful

Malone, T. W., Laubacher, R., & Dellarocas, C. (2009). Harnessing crowds: Mapping the genome of collective intelligence.