MAXIMIZE THE POTENTIAL PERFORMANCE OF COLLECTIVE INTELLIGENCE

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Abstract: *By reviewing the history of the field, this paper shows that it can be separated into two distinct time periods, pre and post the last decade in the twentieth century. The divergent event between these two time periods is the technological advancements made during the 1990's. This paper then presents various current research projects that have been recently completed within the field. Through this review of current research projects, the wide range of the field is demonstrated. Then briefly the some of the future directions of research within the field are examined.*

INTRODUCTION

What do the following groups, the U.S. Army Research Laboratory, Massachusetts Institute of Technology, and Google all have in common? All of these organizations are launching research into Collective Intelligence. The motivations behind each group's research into the field are as varied as the groups themselves. Some are hoping to learn more about sociology and or psychology. Others are attempting to learn how to use the knowledge gained to enhance group productivity, marketing or even advertising schemes. Regardless of each group's individual reasons for studying Collective Intelligence, one thing is clear. A deeper understanding of Collective Intelligence can benefit everyone by helping us to understand how groups of people can work more efficiently together.

Before we begin our discussion about current research and the future direction of the field, we first must understand exactly what Collective Intelligence is. According to Thomas W. Malone, Director of the Massachusetts Institute of Technology Center for Collective Intelligence, the most basic definition is that "collective intelligence is groups of individuals doing things collectively that seem intelligent (Malone, 2006, p. 1)". This however is a very broad definition by anyone's standards. To really understand what exactly collective intelligence is, we have to start our investigation in the history of our civilization.

Collective Intelligence Pre 1999

The human race uses collective intelligence, perhaps better than any other form of life on our planet. Human beings first started to use Collective Intelligence as means merely to survive. The first example of this is the basic family, where parents work together to raise children. This initial group grew when multiple families joined together, at which point they formed the first hunter/gather groups. Eventually these groups joined other groups to form tribes, clans, kingdoms, countries, etc. At each stage in history we can see Collective Intelligence at work, groups of individuals working together doing things collectively that seem intelligent. The two most important historical milestones in Collective Intelligence up until the late 20th century were the formation of governments and companies. Both are groups of individuals working together with group intelligence, which is greater than the sum intelligence of its individual members.

The first scholarly ideas on the subject can be found in William Morton Wheeler's work as an entomologist. In his 1911 book, 'Ants of the American Museum Congo Expedition', he observed that ants can work so closely together that they

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begin to act as one single organism; he called a "superorganism" (Wheeler, Bequaert, Lang, & Chapin, 1911, p. 7). The next contributor to the topic came only one year later in 1912. Emile Durkheim published the first real findings on Collective Intelligence in humans in his book 'The Elementary Forms of Religious Life'.

"Collective representations are the result of an immense co operation, which stretches out not only into space but into time as well; to make them, a multitude of minds have associated, united and combined their ideas and sentiments; for them, long generations have accumulated their experience and their knowledge. A special intellectual activity is therefore concentrated in them which is infinitely richer and more complex than that of the individual. (Émile, 1912, p. 14)"

Other academics, scholars, researchers, etc… from all fields of work have contributed to the notion of Collective Intelligence, however their contributions where ancillary. The field was never their primary area of study, nor was it the main focus in their publications. The term Collective Intelligence in fact only emerged recently in 1999. The phrase was coined in Pierre Levy's book, "Collective Intelligence: Mankind's Emerging World in Cyberspace". Pierre Levy defined Collective Intelligence as:

"What is collective intelligence? It is a form of universally distributed intelligence, constantly enhanced, coordinated in real time, and resulting in the effective mobilization of skills. I'll add the following indispensable characteristic to this definition: The basis and goal of collective intelligence is the mutual recognition and enrichment of individuals rather than the cult of fetishized or hypostatized communities. (Levy, 1999, p. 17)"

Collective Intelligence Post 1999

The fact that the term was coined in 1999 is very important, because during this time period the internet and personal computers were becoming widely adopted by the general public. This drastically accelerated research into Collective Intelligence for two main reasons. The first reason was because the new technology caused an increase in the amount of interaction between people. Another effect was the new ways people were beginning to interact with each other. Of course people have always interacted with each other; however it was now being done more than ever before and in new ways. This gave researchers the added benefit of having definitive data and new forms of interactions to study.

The Massachusetts Institute of Technology has in fact created a whole new department to study the topic. The new department, aptly named the Center for Collective Intelligence, has launched a large array of research projects into the field. All of the projects however are geared towards attempting to help answer the following question on which the department was founded, "How can people and computers be connected so that—collectively—they act more intelligently than any individuals, groups, or computers have ever done before?" (The MIT Center for Collective Intelligence, 2012, p. 1).

Some of the new areas Collective Intelligence manifested in after the technology boom of the late 1990's include business organizations, computer science and artificial intelligence, biology, computer-supported collaborative work and prediction markets. Specifically one of the best examples in business is YourEncore. YourEncore is an e-business, which was started by Eli Lilly and Proctor & Gamble in 2003 as a joint-venture. The joint-venture would earn revenue by helping customers solve complex mathematical, scientific, and engineering problems. Some of the clients who are publicly known to have benefited from this Collective Intelligence include Boeing, Proctor & Gamble, DuPont, General Mills and Eli Lilly, HSBC, etc.

YourEncore is a perfect example of Collective Intelligence post 1999. It essentially operates as a think-tank; however the company itself does not solve problems. Instead they publish their clients' problems on the YourEncore forums for members to solve. Members consist of individuals who are mainly retired scientists, engineers, mathematicians, market research experts, product developers, etc... Since members are not full-time employees they do not draw a regular paycheck, instead they would be compensated in the form of rewards if their online response solved the client's problems. Rewards range from hundreds to hundreds of thousands of dollars.

What makes YourEncore a perfect example of Collective Intelligence after the technology boom of the 1990's, is because of the way its members collaborate to solve problems. Members are invited to join together through online "Project Communities" which then allows them to collaborate on a sub-forum within the YourEncore website. Group members then collaborate with each other through their Project Community page, wiki's, chat rooms, bulletin boards, etc. (YourEncore, 2012).

The second modern example of Collective Intelligence is in the field of computer science and artificial intelligence. An excellent example of this is that of the NASA "Participatory Exploration" program which had two objectives. The first was to educate the public about the work that NASA is involved in, which they hoped would enhance public support for their other programs. The second objective was to enlist individuals to help them analyze and quantify large volumes of data. This data analysis required only basic common sense, something computers lack, and would save NASA an enormous amount of employee time. The first phase of the program ran from 2000 to 2001 and was dubbed "clickworkers". The Clickworkers project used public volunteers online to help count craters on celestial bodies. These volunteers were not trained scientist but they didn't need to be, this task simply required human perception and common sense. Volunteers were shown images primarily of the Moon and Mars as well as many other celestial bodies. When the volunteer spotted a crater they would outline it in the web based interface. After volunteers finished an image it would be uploaded into NASA database where it would undergo, "statistical corrections aggregate the input into a format of scientific utility for researchers" (NASA, 2010).

Another phase of the project was run in 2007, in which NASA worked with Microsoft to enhance the cartography of the planet Mars. Volunteers in this project did almost the same tasks as they did in the 2001 phase of the project. This time however they were analyzing images of Mars taken from the Mars Reconnaissance Orbiter. These new images not only needed impact craters identified, but also mountain ranges, volcanoes, etc. This project took advantage of the Collective Intelligence of the volunteers by utilizing "crowd sourcing" to accomplish Microwork. Crowd sourcing is a distributed problem-solving and production model. In this model tasks are distributed to groups of both online and offline users. The key fact that distinguishes this technique is that the tasks are outsourced to the general public. In this example NASA used "crowd sourcing" to accomplish Microwork. Microwork is defined as a crowdsourcing technique that involves human users to accomplish tasks that computers cannot do well for a relatively low cost (NASA, 2010; Van Kleef, Steinel, & Homan, 2013).

CURRENT RESEARCH

Thus far we have addressed what Collective Intelligence is and how it's used in conjunction with advances in modern technology. It's obviously a powerful factor which is used in almost every area of our society. To maximize its benefits, researchers are currently conducting a wide array of research projects. Although the goals of each individual project may seem quite different, they are all working toward developing a deeper understanding of Collective Intelligence. Through which, as mentioned in the introduction of this report, we can gain a better understanding of how groups can work more efficiently together.

Measuring Collective Intelligence

One of the most important projects currently being conducted is by the Massachusetts Institute of Technology Center for Collective Intelligence. The research project entitled 'Measuring Collective Intelligence' is being conducted by members of MIT, Carnegie Mello and Union Collage. The goal of the project, according to its home page is to, "find out whether such an instrument is feasible, and if so, to develop and test it, and then to use it to assess the effectiveness of interventions designed to enhance performance." To accomplish this objective the group plans to, use what's already known about measuring individual intelligence, to then hypothesize ways to measure Collective Intelligence. In order to test these hypotheses, they gathered volunteers and first measured each individual's IQ (Intelligence Quotient). Second, they grouped the volunteers in teams where they completed performance based tasks. After

analyzing the data to, "determine whether the striking pattern of correlation in individuals' performance across a wide range of tasks even exists for human-machine groups. Then we will develop statistically validated tests for measuring the key components of collective intelligence in human-machine groups" (Malone, Woolley, Chabris, & Hashmi, 2006).

The second area of focus for this project will be to understand the "active ingredients" that comprise Collective Intelligence. They will use new models, in conjunction with their prior knowledge of group interaction, to examine how human-machine groups process information. Their goal in this area of focus will be to determine the critical components that affect human-machine group performance. To do this they will observe multiple human-machine groups and modify certain critical factors such as the size of the group, the capabilities of the individuals within the group and the communication medium or patterns used by the groups.

In a paper the group submitted in entitled, 'Evidence for a Collective Intelligence Factor in the Performance of Human Groups', they published their results. In total between the two studies, 699 volunteers participated in groups of two to five people. After analyzing the results of the group's performance based tasks, the researchers identified a measure which they claim is representative of a group's general collective intelligence factor. This factor identified as C, surprisingly didn't strongly correlate to the average or maximum intelligence of individual group members. Instead they state that it directly correlates to the, "average social sensitivity of group members, the equality in distribution of conversational turn-taking, and the proportion of females in the group" (Woolley, Chabris, Pentland, Hashmi, & Malone, 2010, p. 5).

Collaboration in Wikipedia

Thus far we have talked extensively about how Collective Intelligence has been affected by developments in new technology. Specifically, we have considered the new applications in which Collective Intelligence is used when it's combined with computers and the internet. A new research project on this topic was recently completed in 2012 by Gerald C. Kane and Sam Ransbotham. Both of Boston College, they suggest that the mere presence of IT-enabled collaborative tools such as wikis, blog communities and social networks, "does not ensure effective collaboration or the creation of valuable knowledge. People and organizations must use these tools effectively to generate valuable outcomes" (Kane & Ransbotham, 2012, p. 4).

To prove their hypothesis, the researchers used 16,068 articles written through the collaboration of 40,479 members from the Wikipedia's Medicine Wiki Project. They studied the relationship between the member's collaboration and the quality of articles the members produced. In their examination of the articles, the pair of researchers also examined whether the quality of the articles produced was associated with the level of group collaboration among its members. Then they investigated whether there was a recursive relationship between the quality levels of the articles in relation to the amount of contributions each article received (Kane & Ransbotham, 2012, p. 6).

The results of the project were quite interesting. They did indeed confirm that the quality of the articles written and the collaboration methods used to write them, were not independent of each other. This proves that information technology is a factor in determining the quantity of Collective Intelligence. They also found a "recursive relationship between information quality and collaboration" (Kane & Ransbotham, 2012, p. 8). Their research also showed that the quality of the articles were affected by the work that members did on other articles in the Wikipedia Medicine Wiki Project database. Furthermore, they found a correlation between articles written with a large number of contributors and the quality of the article. They did also find that the relationship attenuates as time increases.

Collective Creativity

Another project that is currently underway is being researched by Lixiu Yu of Carnegie Mellon University as well as by Jeffrey Nickerson and Yasuaki Sakamoto, both of The Stevens Institute of Technology. Their project focuses on one aspect of Collective Intelligence, Collective Creativity. The group states that up until the recently, there were only two categories of creativity: individual creativity and group creativity. However, as a result

of technological advances during the late 1990's, which led to the emergence of the Collective Intelligence field, a new category called Collective Creativity emerged. Collective Creativity is different from the previous two categories both qualitatively and quantitatively. Furthermore, this new category also differs from the previous two since it occurs in the crowd, which means it is also geographically distributed. This makes it hard organize and analyze. The researchers published the initial findings of their research in a paper entitled, 'Collective Creativity: Where we are and where we might go'. In which they have defined Collective Creativity as the actions of a crowd of individuals, "involving non-routine tasks out of which new ideas emerge" (Yu, Nickerson, & Sakamoto, 2012, p. 1). They also show that this new category occurs in three types of systems: games, contests and networks. Their results also show that there are ways to enhance the products of Collective Creativity, by improving the systems on which it occurs.

One way they state that Collective Creative Systems can be improved is "if tasks that are routine can be automated so that people's attention can be devoted to more complex activities: the system then becomes more powerful" (Yu, Nickerson, & Sakamoto, 2012, p. 6)". They go on to conclude that there is a large amount of design space for Collective Creativity and most of it remains unexplored.

Motivations for Participating

So why do people participate in all these different types of online systems such as social networks, blogs and wiki's? A research project that was recently completed in 2012 attempted to answer this question. It was conducted by Jon Chamberlain, UdoKruschwitz and Massimo Poesio, from the University of Essex, School of Computer Science and Electronic Engineering. To answer this question the group choose to study a game called Phrase Detectives, which is an online game known as a GWAP or Game with a Purpose. Most GWAPs', including Phrase Detectives, is operated on social networking platforms such as Facebook. The purpose of this game is for users to help create an annotated language resource. The motivations for creating games like this are to aggregate data from non-expert players and to get them to make collective decisions. These collective decisions often turn out to be very similar to the decisions that would be made by paid experts (Chamberlain, Kruschwitz, & Poesio, 2012). So why are people motivated to participate?

The group from the University of Essex published the results of their research in a paper entitled, 'Motivations for Participation in Socially Networked Collective Intelligence Systems'. The researchers identified three incentives which motivated people to participate in the game. The first was personal incentives. People were found to have played for personal incentives simply because it was entertaining and interesting. The second motivation for participation was Social Incentives. These incentives were fulfilled by allowing players to compete for the highest scores amongst their friends. Players were found to use their friend's high score records as benchmarks for goal of their next segment of play. Financial Incentives were the third and last motivational factor which encouraged players to participate in the game. Money was rewarded to those who held the top five best scores of the month. This caused the most active tiers of players to participate more and also encouraged other users to start playing the game for the first time. Other results of the group's research found that most of the workload was being completed by only a handful of the thousands of players. This handful of players completed a staggering 70% of the workload. The more casual players only completed about 30% of the workload; however they made up more than 90% of the total number of players. The researchers also found that women are more likely to participate and accounted for 65% of the players (Chamberlain, Kruschwitz, &Poesio, 2012, p. 7).

Crowd Memory

As discussed earlier in the modern example of Collective Intelligence concerning the NASA "Clickworkers" project, Crowd sourcing is a distributed problem-solving and production model. In this model, tasks are distributed to groups of both online and offline users. The key fact that distinguishes this technique is that the tasks are outsourced to the general public (NASA, 2010). The inherent problem with crowdsourcing is that workers are unreliable since the tasks they

accomplish are unpaid, or on a volunteer basis. What this means is that the algorithms that are used in designing crowdsourcing programs are designed in such a way, that they don't take into account the ability of the crowd to learn over time. This results in a limitation of the types of tasks that these crowdsourcing programs can be used on. The main reason why algorithms haven't been designed to take into account this learning factor is simply because researchers don't understand how crowds learn.

In an effort to understand how crowds learn research was recently undertaken by Lasecki, White, Murray, and Bigham, all from The University of Rochester, Department of Computer Science. Their recently published paper entitled, 'Crowd Memory: Learning in the Collective', demonstrated that crowds can and do in fact learn overtime. Most crowd workers learned basic patterns in as quickly as two rounds. Their research then showed that workers retained this knowledge for the duration of the testing, which was greater than 12 hours. Further results also showed that crowds do in fact teach each other. Knowledge is passed from initial workers to second and third generation workers (Lasecki, White, Murray, & Bigham, 2012, p. 7).

The results of this research are quite simple to put into use. First the researchers suggest that crowdsourcing software should be designed to use both an instant messaging system and some sort of automatic recording module. Workers were found to teach each other at a higher rate when there was an instant messaging system in place that facilitated communication between them. Furthermore, this type of instant massager software is very easy to incorporate. Workers were also found to be able to learn extremely quickly, when given the opportunity to view a recorded sequence of tasks that could be replayed at an accelerated speed (Lasecki, White, Murray, & Bigham, 2012, p. 1).

Social Influence Effects on the Wisdom of Crowds

Thus far we have established that groups of individuals working together may exhibit Collective Intelligence and we have established that crowd sourcing is a technique to utilize this Collective Intelligence. We have also established that crowds can in fact learn and they teach each other if given the proper tools. But what affect does social influence have on the wisdom of crowds? In 2012 several Chairs of Systems Designs from ETH Zurich, embarked on a research project to investigate this question. The researchers: PavlinMavrodiev, Claudio J. Tessone and Frank Schweitzer decided to "build a minimalist representation of individuals as Brownian particles coupled by means of social influence" (Mavrodiev, Tessone, & Schweitzer, 2012, p. 1). This model was used instead of actual volunteers to study the topic because it would "allow them to draw more fundamental conclusions about the role of social influence" (Mavrodiev, Tessone, & Schweitzer, 2012, p. 2).

The project proved to yield some rather interesting initial results. They found that the best decisions made by groups occurred when, over time, the group aggregated multiple heterogeneous opinions. They also discovered that certain key factors affected the wisdom of the group. For instance, the diversity among the individual makeup of group members has a strong affect. If diversity is to low, the group members tended to all yield to one another's opinions. In contrast if the degree of diversity was large, group member's incorrect opinions would cancel each other out and eventually the correct or a more correct choice was made. Another important factor the group discovered was the independence of opinions (Mavrodiev, Tessone, & Schweitzer, 2012, p. 2). If the degree of independence of decisions was too low, it had the potential to limit: communication, learning and the general social influence process. Another finding of the group's research was rather disappointing. They found that if individual group members learned about the social aspects of other members, they would simply submit to the other member's opinion.

By the end of the project the team of researchers came up with some rather interesting conclusions. They had set out to determine if social influence affected the wisdom of crowds in a negative or positive way. There end result was that in the long run, it depends on a variety of factors. Statistically they determined that if a group's initial opinion was very far from the correct one, the group would benefit from social influence. The opposite is true however for groups that start out with an initial

opinion that is accurate. The more social influence in these scenarios, the more detrimental the effect is on the accuracy of the group's decisions (Mavrodiev, Tessone, & Schweitzer, 2012, p. 6).

FUTURE DIRECTIONS

Collective Intelligence in Humans

JuhoSalminen of The Lappeenranta University of Technology recently published a paper detailing his research entitled, 'Collective Intelligence in Humans: A literature Review'. In this paper the author recognizes that due to the broad nature of the field, combined with the lack of a common framework used to study it, the field is at risk of becoming fragmented. Salminen further recognizes that "a lack of overarching structure could make the field appear confusing and make it challenging to tie the efforts of different disciplines together in a coherent way" (Salminen, 2012, p. 1). Due to the lack of a common framework or an overarching structure, researchers within the field also may have difficulty understanding what is already known. This problem is compounded when researchers attempt to assess what research has already been done, outside of their area of specialty.

Further study of the completed research projects and various papers led the Salminen to attempt to define a conceptual framework for studying Collective Intelligence in humans. Through extensive study on the research produced within the field, a pattern was recognized. This pattern resulted in Salminen recognizing three distinct levels of abstraction. These levels are the micro-level, macro-level and level of emergence. At the micro-level, the author defines collective intelligence as a combination of three elements of study: psychological, cognitive and behavioral. The macro-level is defined as one that is largely a statistical phenomenon. Finally the 'level of emergence', is identified as a third level that exists between the micro and macro levels (Salminen, 2012, p. 2).

Salminen states that his proposed framework should be used merely as a starting point. He explicitly states that further research is required to fully encompass the field under one unifying framework. Specifically, he points to the fact that more research is required to understand "how micro level actives lead to macro-level behavior in human contexts" (Salminen, 2012, p. 5). An additional area of future research is required to further examine how a multidisciplinary approach and simulations can be used to identify other mechanisms of the cognitive process. Another possible direction future research could take, would be to determine what effect violations of factors that facilitate Collective Intelligence have on systems.

Army Research Laboratory

As indicated in the introduction of this paper, the Department of Defense is also interested in studying Collective Intelligence. A Future research project will be conducted by the (ARL) Army Research Laboratory under the direction of Dr. Joseph Myers. Although currently in the planning stages, Dr. Joseph Myers has publicized areas in which he intends to conduct research and how it will benefit the United States Military.

The goal of Myers's research will be to "predict performance of an existing group or organization on new and different tasks, to predict performance of a not-yet assembled group on a variety of tasks, to select group members from a population in order to form maximally-functional teams, and eventually to do all of the above for human-machine groups as well" (Myers, 2011). This research will be conducted by funding projects from both The Massachusetts Institute of Technology and Carnage Mellon University. These projects will conduct trials that include soldiers from the Air Defense Artillery group which operates out of The United States Army Fires Center of Excellence in Fort Sill, Oklahoma.

This research indicates an entirely new future direction for the field of Collective Intelligence for two reasons. The first reason is because Collective Intelligence has never been studied in the unique hierarchical social structure that exists in the military. The new dimension of rank and seniority will certainly present new facets of study for each trial. The second reason is because the United States Military is one of the largest users of artificial intelligence, for example the current robotic aircraft drones. If research on Collective Intelligence is applied to robotic drones of this nature, it will open up an entirely new sub-field of research and application. Collective Intelligence is already

applied to the field of artificial intelligence but not on the scale the United States military uses.

Language Endangerment

Another and quite different future direction for Collective Intelligence is to apply the technique to prevent endangered languages from becoming extinct. Christopher Horsethief from Gonzaga University has embarked on this type of research project. His goal is to determine how Collective Intelligence may be applied to prevent the extinction of the Native American Ktunaxa Language. In a paper recently published he documented how Collective Intelligence has so far been implemented through an online language community. This online language community not only keeps the language alive among its geographically dispersed users, but it also is being used to teach others the language (Horsethief, 2012, p. 1).

Members of this online language community collaborate through the use of common online tools such as blogs, postings, and wiki's as well as member recorded audio files. Horsethief observes that as the members continued to interact with each other, a new network intelligence emerged. This network intelligence enabled components of the network to blueprint themselves and then encouraged self-replication. This result then led to the generated knowledge being passed on to future iterations. This attribute allows a collective memory to develop through the implemented collective intelligence of the online group of members (Horsethief, 2012).

The future direction of research into Collective Intelligence being applied in this application will be to "focus on specific aspects of collective network intelligence" (Horsethief, 2012, p. 7). Specific aspects include the necessity of focusing on identifying the network leaders, small world architectures, and ways to coordinate micro-motives. Furthermore, future directions will also include the necessary investigation of instances where members negotiate cultural identities online as well as how to maximize access to other members of this small community.

Predicting the Wisdom of Crowds

An interesting future direction for the field of Collective Intelligence is learning to predict the wisdom of a crowd of online collaborators. A research project currently underway on the topic is being conducted by Haym Hirsh of the Rutgers University Department of Computer Science. The project was started because the only current method to determine the wisdom of an online crowd is to use Crowdsourcing systems. Crowdsourcing systems use votes by crowd members to determine the crowd's wisdom. This type of system has its limitations because it requires the participation of almost every member of the crowd. Due to this large sample size needed it can lead to exceedingly high costs. The difficulty in solving this problem lies in the fact that labelers, or voting crowd members, have a range of "capabilities, motives, knowledge, views personalities, etc." (Ertekin, Hirsh, &Rudin, 2012, p. 1).

In an attempt to overcome this limitation, the researchers are investigating the development of a new algorithm. This algorithm called CrowdSense will be able to use previously collected data on the crowd members to determine which members are representative of most other members of the crowd. It will then use dynamic samples of subset labelers to calculate whether it has enough votes to make a decision. If this not be the case, the algorithm will then request more information and continuously update the labeler's level of diversity. Since each individual member of the crowd is assigned a quantified value representative of their similarity to the overall crowd, each members vote cannot be calculated with the same weight. To overcome this problem the algorithm will use a weighted majority vote multiplied by the labelers quality estimate. By doing this the algorithm will place a greater emphasis on the votes of higher quality members (Ertekin, Hirsh, & Rudin, 2012, p. 7).

The initial results showed that CrowdSense was in fact able to at times approximate the crowd by using a subset of labelers. CrowSense however did show some limitations and further development was recommended by its programmers. The future direction of projects like this, are likely to result in variations of the algorithm. Further results point to the fact that variations of the next generation of algorithms will need to incorporate certain assumptions pertaining to the joint distribution of the crowd members. The statistical independence of labelers is a factor that will need to be

incorporated to model larger crowds (Ertekin, Hirsh, & Rudin, 2012, p. 8).

CONCLUSION

Collective Intelligence is a field that addresses an aspect of cooperation which has been in existence since the first individuals joined together in groups. It deals primarily with the intelligence that is displayed by groups which is greater than the sum intelligence of all individual group members. This paper has defined two distinct periods of Collective Intelligence. The first period was prior to the late 1990's. During this time, study within the field was largely ancillary in nature. Collective Intelligence existed only when people physically came together in groups and was hampered by slow and cumbersome technology. The most prevalent examples in the past include groups comprising families, companies and governments.

Technological advancements in the late 1990's ushered in the second period of Collective Intelligence. During this period, the widespread adoption of personal computers and use of the internet by the general public created many new facets and dimensions of Collective Intelligence. These new facets and dimensions manifest themselves primarily in technology driven online interactions amongst individuals. Tools provided by the advances in information technology, allowed individuals of vastly different geographies, cultures, languages, specializations, fields of study, etc. to collaborate on a wide array of projects. These new manifestations are responsible for sparking the current explosion of research into various aspects of Collective Intelligence.

The field itself has become so vast and all-encompassing that there is an obvious need to develop a framework for researchers within the field to use. The problem is further compounded by the fact that so many different researchers from varying backgrounds are currently studying Collective Intelligence. If a framework is adopted research into various areas of Collective Intelligence will likely become more efficient. This is largely due to the fact that contributors will be able to clearly asses which areas have already been studied and which have not. Without some sort of framework, the field risks becoming further fragmented than it already is.

Research in the field however is likely to yield a great number of benefits. The potential benefactors from such research include corporations, non-profit organizations, governments, militaries, grass roots organizations, universities, etc. All of these groups can benefit from a greater understanding of Collective Intelligence. By understanding the factors that drive Collective Intelligence it will enable predictions to be made about how well certain groups of individuals will perform. Another benefit will be realized by existing groups. By understanding what factors impact Collective Intelligence the composition of groups can be modified to maximize the potential performance.

References

[1] Barry Devlin, H. F. (2011), Integrating Structured and Unstructured Data. *Business Intelligence*, 16(4), 40-51.

[2] Chamberlain, J., Kruschwitz, U., &Poesio, M. (2012). Motivations for Participation in Socially Networked Collective Intelligence Systems.University of Essex, School of Computer Science and Electronic Engineering. Ithica: Cornell University Library.

[3] Chaudhuri, S., Dayal, U., &Narasayya, V. (2011). An Overview of Business Intelligence Technology. Communications of the ACM, 52(8), 50-62.

[4] Cheung, C., Lee, W., Lang, W., Wang, Y., &Yeung, W. (2011). A Multi-faced and Automatic Knowlege Elicitation System (MAKES) for Managing Unstructured Data. Expert Systems with Applications, 38, 5245-5258.

[5] Cripe, B., & Tuson, N. (2008, June 2). Utlizing Unstructured Data to Provide Business Intelligence. Retrieved April 14, 2012, from Beye Network: *http://www.b-eye-network.com/view/7579*

[6] Dayal, U., Castellanos, M., Simitis, A., & Wilkinson, K. (2009), Data Intergration Flows for Business Intelligence. EDBT, 9(3), 122-132.

[7] Devlin, B., Fryman, H., Gonzales, M., Shrader, D., & Stodder, D. (2011), BI Experts' Perspective: Integrating Structured and Unstructured Data. Business Intelligence Journal, 2, 26-35.

[8] Dr. Myers, J. (2011, February 14). ARL funding develops concepts in collective intelligence. Retrieved April 18, 2012, from Army Research Laboratory: *http://www.arl.army.mil/www/default.cfm?page=559*

[9] Émile, D. (1912), The Elementary forms of the Religious Life, a Study in Religious Sociology. (R. A. Jones, Trans.) London, UK: G. Allen &Unwin.

[10] Ertekin, S., Hirsh, H., &Rudin, C. (2012), Learning to Predict the Wisdom of Crowds. Massachusetts Institute of Technology, Rutgers University, MIT Sloan School of Management, Department of Computer Science, MIT

Center for Collective Intelligence. Ithica: Cornell University Library.

[11] Fitzgerald, M. (2010), Mobile BI. Computerworld, 44(15), 26.

[12] Gash, D. (2011), Looking to the Clouds for Business Intelligence. *Journal of the Internet Commerce*, 10(4), 261-169.

[13] Grimes, S. (2008), BI and the "Unstructured Data" Challenge. Retrieved April 3, 2012, from Alta Plana Corporation: altaplana.com/TDWI.BI-Unstructured.pdf

[14] Henry, H., & Hiltbrand, T. (2011), The 2020 Workplace and Evolution of Business Intelligence. Business Intelligence, 17(12), 1-8.

[15] Henschen, D. (2011, October 31). Oracle Buys Its way Into Unstructured Data. Informaton Week, p. 14.

[16] Horsethief, C. (2012), Re-differentiation as Collective Intelligence: The Ktunaxa Language Online Community. Gonzaga University, Doctoral Program in Leadership Studies.Ithica: Cornell University Library.

[17] Kane, G. C., & Ransbotham, S. (2012), Collaborative Development In Wikipedia. Boston College, Computer Science. Ithica: Cornell University Library.

[18] Kumar, A., & Khatter, H. (2011), Analysis the Effect of Data Mining Techniques on a Database. *Science Education Review*, 47(1), 164-169.

[19] Lahl, D. (2010), Make Better Decisions by Analyzing Structured and Unstructured Data Together. *Business Intelligence*, 16(10), 9-16.

[20] Lasecki, W. S., White, S. C., Murray, K. I., & Bigham, J. P. (2012), Crowd Memory: Learning in the Collective. University of Rochester, Department of Computer Science. Ithica: Cornell University Library.

[21] Levy, P. (1999), Collective Intelligence: Mankind's Emerging World in Cyberspace. (R. Bononno, Trans.) Cambridge, MA, USA: Perseus Publishing.

[22] Lixiu, Y., Nickerson, J. V., & Sakamoto, Y. (2012), Collective Creativity: Where we are and where we might go. Carnegie Mellon University, Stevens Institute of Technology.Ithica: Cornell University Library.

[23] Malone, T. W. (2006, October 13), What is Collective Intelligence and What Will We Do About It? Official Launch of the MIT Center for Collective Intelligence. Massachusetts Institute of Technology.

[24] Malone, T. W., Woolley, A. W., Chabris, C., &Hashmi, N. (2006, Febuary 20), The MIT Center for Collective Intelligence. Retrieved April 15, 2012, from Measuring Collective Intelligence: *http://cci.mit.edu/research/measuring.html*

[25] Mavrodiev, P., Tessone, C. J., & Schweitzer, F. (2012), Effects of Social Influence on the Wisdom of Crowds. ETH Zurich, Chair of Systems Design. Ithica: Cornell University Library.

[26] McClure, M. (2009), Information Today. Attivio Brings Order to Data, 26(2), p. 14.

[27] NASA. (2010, April 26). Participatory Exploration Office. Retrieved April 30, 2012, from NASA: *http://www.nasa.gov/open/plan/peo.html*

[28] Salminen, J. (2012), Collective Intelligence in Humans: A Literature Review. Lappeenranta University of Technology, Lahti School of Innovation.Ithica: Cornell University Library.

[29] Spinelli, L. (2011), BI helps Helzberg Diamonds Cut a Competitive Edge. KM World, 20(4), p. 3.

[30] Staff, E. (2011), The Case for the Cloud. Insurance Newtorking News, 14(3), 11.

[31] Sterm, J. (2010), The Business Intelligence Market Outlook: Key Drivers, Market Challenges and Vendor Strategies for Future Growth. P.A. Newswire, 11(4), 12.

[32] The MIT Center for Collective Intelligence. (2012), Home. Retrieved April 25, 2012, from MIT Center for Collective Intelligence: *http://cci.mit.edu/*

[33] Van Kleef, G. A., Steinel, W., & Homan, A. C. (2013), On being Peripheral and Paying Attention: Prototypicality and Information Processing in Intergroup Conflict. *Journal of Applied Psychology*, 98(1), 63-79.

[34] Wheeler, W. M., Bequaert, J. C., Lang, H., & Chapin, J. P. (1911), Ants of the American Museum Congo Expedition : A Contribution to the Myrmecology of Africa. New York, NY, USA: American Museum of Natural History.

[35] Woolley, A. W., Chabris, C. F., Pentland, A., Hashmi, N., & Malone, T. W. (2010), Evidence for a Collective Intelligence Factor in the Performance of Human Groups. Science Magazine, 330(6004), 686-688.

[36] YourEncore. (2012), News & Events. Retrieved April 17, 2012, from YourEncore Corporate Website: *http://www.yourencore.com/about-yourencore/news-events.asp*