Knowledge Dispersion Index for Measuring Intellectual Capital

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Abstract—In this paper we propose a novel index to quantify and measure the flow of information on macro and micro scales. We discuss the implications of this index for knowledge management fields and also as intellectual capital that can thus be utilized by entrepreneurs. We explore different function and human oriented metrics that can be used at micro-scales to process the flow of information. We present a table of about 23 metrics, such as change in IT inventory and percentage of employees with advanced degrees, that can be used at micro scales to wholly quantify knowledge dispersion as intellectual capital. At macro scales we split the economy in an industrial and consumer sector where the flow of information in each determines how fast an economy is going to grow and how overall an economy will perform given the aggregate demand. Lastly, we propose a model for knowledge dispersion based on graph theory and show how corrections in the flow become self-evident. Through the principals of flow conservation and capacity constrains we also speculate how this flow might seeks some equilibrium and exhibit self-correction codes. This proposed model allows us to account for perturbations in form of local noise, evolution of networks, provide robustness against local damage from lower nodes, and help determine the underlying classification into network super-families.

Index Terms—network flow, perturbations, intellectual capital, metrics.

I. INTRODUCTION

Lord Kelvin is often quoted for saying that if one can’t measure something they can’t improve it. This is critical in the field of knowledge management as metric provide convincing data for entrepreneurs to make decisions and help capitalize it for economic and social progress. The aspiration behind developing this index arose in response to lack of a quantifying measure for the following:

• The exchange of tactical knowledge concerning one particular field between employees.
• Capture of that information in a knowledge-base for use by other employees.
• The reuse rate of frequently accessed knowledge.

This index will be divided into two levels, each further consisting of its own metrics, the outputs from each level can be used as independent indicators and the gross measure will complete the Knowledge Dispersion Index (KDI) for a given location. It must be noted that this analysis involves human input therefore some aspects can not be captured effectively, although we do include an assumption called the Theory Y of management which asserts that management assumes employees may be ambitious, self-motivated, exercise self-control and if allocated adequate resources, they will perform at their very best. Given that assumption, we establish the two levels of our index:

• Organizational knowledge metric: This metric will account for aggregate dispersion at micro scales and indicate the growth of the industrial sector.
• General dispersion metric: This metric will account for dispersion at macro scales and indicate how the consumer side is performing.

II. MICRO SCALE (ORGANIZATIONAL KNOWLEDGE METRIC)

At the micro scale industries play a prominent role, the reason for including industries at the micro scale pertains to their role in the economy. The distributor’s side is generally smaller in comparison to the consumer side. In addition to that, there are some particular mechanisms that each of the firms employ to enhance their success and if they are not fine-tuned, the results can be disastrous. For that very reason we present a comprehensible list (see Appendix A for the list) to account for the flow of information, the gross result obtained from the table in the Appendix will present a reliable measure of the information infrastructure of a company

There is however another very important role that the organizational knowledge metric plays, that of identifying the most efficient method of dispersion and the faults that may occur in the dispersion through the use of a theoretical construction called a flow networks.

A. Flow Networks

Flow networks are the key structure in network analysis and here we show how the traditional flow network model can be employed by a company to analyze the flow of information in their infrastructure. First we review the traditional flow network model, a flow network is a directed graph where each edge has a capacity and each edge receives a flow. The amount of flow on an edge cannot exceed the capacity of the edge. A flow must satisfy the restriction that the amount of flow into a node equals the amount of flow out of it, except when it is a source, which has more outgoing flow, or sink, which has more incoming flow.

Formally, \( G(V, E) \) is a directed graph where each edge \( (u,v) \in E \) has a non-negative, real valued capacity given by a function \( c(u,v) \). There are however two special vertices where the capacity constrains don’t hold: a source \( s \) and a sink \( t \). The rest of the nodes \( u, v \) follow the following rules:

1In this paper we don’t provide definite benchmarks which can then be used to compare, a case study however, regarding those benchmarks is underway.
• Capacity Limit: $f(u, v) \leq c(u, v)$. This relation implies that the flow to one node cannot exceed the capacity limit given to that node.
• Skew Symmetry: $f(u, v) = -f(v, u)$. This relation implies that the net flow from one node to another or from $u \rightarrow v$ must be the same from $v \rightarrow u$.
• Flow conservation: $\sum f(u, w) = k$. This relation can be seen from the two above, the net flow to a node is some constant $k$ which holds the same value for each node at the same hierarchy but changes value at different levels of management, except for the two cases of source and sink.

Now we will explore how a model following these rules can help us explore the efficiency of the information infrastructure. First we see that the capacity limit holds to how much information should be made available to employees at each stage, this limit helps us understand better where in the graph is too much information is present as that in itself is a loss or waste since one employee can only utilize so much of what is given to them. Knowing the capacity limit for the nodes can also help us by reducing the flow to one stressed node by spreading it amongst other available nodes at the same level of hierarchy. The skew symmetry serves as a test that can be employed by the management to assess whether each employee at their current level is utilizing their resources to their maximum or not, the full employment of the resources at each level would result in for instance completion of more patents being filed or more solutions being completed by a company as the demand for that particular solution increases. It must be noted here that this relation holds dual values, the flow of information decreases as it reaches the top as can be seen in the case of a software development company, the CEO of the company is generally well-versed in business techniques and not in lower-level coding therefore the higher-level overview being presented to them in the form of a flowchart would be represented by a decrease in the flow of information reaching them. This should not be considered a short-coming of the model because each level of hierarchy will have a constant flow, so as information moves up that hierarchy and reached the management positions of a company, the flow will decrease and stabilize. The third rule indicates the communication infrastructure present in a company occurring among various nodes (employees) at each level. A company generally has several different departments or smaller level committees to perform various tasks, this rule applies to how well each of those departments interact with the other ones to finish a given task. The other two rules provided before can also be applied here to each of the departments to obtain more specifics. We argue that modelling a company as a flow model and following a combination of these three rules will provide a very good estimate of the information flow in a company. The data required to assess these rules will be provided by the gross result from the list in Appendix A.

1) Self Correction Codes: Using the flow model for information dispersion also gives us the ability to use the inherent correction features present in the flow model. We assert that a company modeled as a traditional flow model will have the tendency to correct itself as needed, this is also a basic assumption in game theory, that if each employee is seen a player in a game, each player will make the best possible move. We generalize that assertion in the following:

Conjecture 1: If leadership is employed in a multi-player show definitive game, the leader will make the best possible choice for the players.

This will help in the evolution of the network, as the company prospers the network will expand and stabilize for definite capacity limits at every level, this is true of a successful company. For a newly developing company, the governing dynamics will be different, each new employee is in a learning stage but are required to follow skew symmetry and flow conservation. As a result of that, there will be a discrepancy in the rules as the new employee will be a pseudo-node and this discrepancy can be analyzed in terms of a perturbation to the model. The flow model approach provides a solution for the model to be robust against such changes, to address local perturbations, we propose the following:

Conjecture 2: Given a recently established company, and a measure of reliability determined from our Appendix, some nodes with a high measure of reliability should be overloaded.

It should be noted here that overloading those nodes doesn’t necessarily imply a decrease in efficiency of those employees, the idea is to vary the flow amongst those reliable nodes and split flow conservation into two levels, one for the newer employees and the other for the reliable ones. This allows the learning stage of the new employees which acts as a perturbation to be absorbed in by the overloading of those nodes. The output provided by the newer pseudo-nodes\footnote{The new employees only act as pseudo-nodes while they are under some initial training, as soon as they are ready, we decrease the flow to the nodes at which the new employees are to work, that allows a smooth introduction of new nodes in the flow.} will also go through a similar process but the difference is that the output gets absorbed by the these overloaded nodes.

Now we will address how network super-families arise in this evolved flow, from Conjecture 2.2 we determined a reliability measure that can help use overload some nodes, those nodes at each hierarchical level will constitute our network super-family. Formally, the members of the yet to be formed superfamily will appear as outliers if a statistical analysis such as ANOVA is performed because of their reliability profile established from the Appendix metrics. Once super-families are identified in a flow, our network becomes very strong and is robust to local and internal damage.

Conjecture 3: Given a flow network with identified network super-families, local damage can be diverted to specified nodes, decreasing its impact.

Local or internal damage lacks a formal operational definition so we have to rely on a situational definition. Any intentional efforts to disrupt a well established flow of information constitutes local damage, if the causes of which are identified, for instance an attack targeting some confidential information can be diverted to the pseudo-nodes, rendering it useless since the pseudo-nodes have lower level clearance.
III. MACRO SCALE (GENERAL DISPERSION METRIC)

We now analyze how information disperses amongst the general public or the consumer side. It must be noted here that KDI would only be compete as an index once we can get results from both the metrics, implying that we need to quantify how information flows amongst industries which form the micro scale and the consumer side or the general public which form the macro scale. The methods of analysis being employed before simply become inefficient here because of the graphs modelling a large amount people would easily break down and is quite inefficient computationally. There are however some metrics that can help us here such as:

- Transport infrastructure
- Availability of communications facilities such as television and internet
- Public spending on broadcasting
- Access to internet
- Frequency of local awareness campaigns such as seminars and so on.

We will here employ another theoretical construction to analyze how information is spread to the general population or the consumers sector. Some characteristics of this study are that it must be general enough to account for a vast variety of sources and at the same time be able to provide a definite analysis for the comparison of the output from each source.

Definition 1: There are several sources that aid the process, such as television, newspaper, etc. However, for simplicity of analysis, we will collectively refer to these different sources as media.

A. Deep Current Sets

The most common source for information available to the public outputs vast amounts of interpreted information, this output can be viewed as a surface wave or a current in an ocean. This analogy of ocean currents is being used because the currents themselves are very dynamic and based on very delicate balance, we imply that in the same degree as ocean currents on the surface can influence the weather pattern of the atmosphere above, the general crowd is influenced by the larger waves or the media source that is most influential, imposing similar constant weather conditions over a large portion of the atmosphere. This construction helps analyze the behaviour and choices of the people in the given region in the past to make deductions about the future, from that we determine how the information flow that once only occurred amongst a small group of people has evolved now to spread to much larger networks. We present a worked example of deep current sets in the light of a hypothetical developing situation.

Conjecture 4: Given an area and a developing situation, the flow of information is given as follows:

Before the development: Those involved with an event may share or record their ideas, theories, or plans alone in a lab or personal journal, with friends or colleagues. The sharing of this information forms the "invisible college." Usually, the ideas generated by the "invisible college" are simply not available to the public and is nonexistent as a form of information today, especially for things in the distant past. This sets the stage for the currents to arise in the ocean.

As the development occurs: Early news releases may appear on TV or radio, in newspapers, over newswires, and on the Web. The initial information about these events generally accompanies the "who", "what", "where" and "when" and most often exclude the "why".

The next day or the days after: Articles appear in newspapers/newswires; information is disseminated on TV, radio, and the Web. Depending on the event, the information may be prolific or sparse.

In a week or the weeks after: Articles may appear in general or subject-focused popular magazines.

In a month or time that follows: Articles appear in scholarly journals. This is also when scholars and researchers may start holding conferences on the topic and eventually, conference papers will be published.

We see how through the development of this situation the ocean currents are forming, before sets up the currents and the next phase is when the currents are out in the ocean and their relative size determines how the weather is changes. From the changes in weather which are easily observable, we can reliably make deduction about the past history of the people. The advantage of this analysis provides is that even though a given region may have changed now, we can still see the effects of the currents in the future. This analysis of the past can also assist in the development of better dynamics modelling the behaviour of that region. In addition to that, we can also determine what forms of media are most prevalent in that given region. This analysis can be conducted based on a past event and hold its validity for a long time.

As we see, the quantization of information flow here can be further assisted through the use of metrics such as % access to cable, people with advanced degrees, average household income and so on. This can help determine the interests of people and classify them into sets, however in our construction, we can construct computer models based on using restricted boltzmann machines through a technique called deep learning.

If a technology firm sees an opportunity to start developing in a given region, if they can identify the type of issues being discussed amongst the community (where people can be organized into different sets based on interests), they can identify the region where it is best for them to work and since people in that community are willing to work on those issues, establishing new businesses there to give them an opportunity is the best way to unleash intellectual power.

IV. CONCLUSION

In this paper, we presented how intellectual capital can be measured through the use of a novel index, KDI. We also discussed how the metrics present in the index can help

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3This in some sense is similar to a pebble skipping across water, wherrever it lands, even for a brief moment of time, it leaves behind ripples that can be the analyzed to trace its path.

4Formally, where the largest set is interested in the same objective as the company

5We simply refer it to as a source, its arguable which source constitutes as the most widely available for different regions.
increase the efficiency of an organization by modeling the structure of a company using network flow models. The last section discussed how the information flow among people in a given region can help organizations unleash intellectual power and capitalize on it by providing the people the necessary resources. We are currently unable to provide numerical analysis of our index and therefore we are lacking milestones that can provide comparative analysis however a case study to quantify those milestones is being undertaken. Further research would include the aforementioned milestones and a more sophisticated models of flow networks.

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APPENDIX

Here is the list of metrics [1] that we will be using at micro scales (mostly applicable to companies/firms), we do make two assumptions here:

- These metrics can be easily obtained from available data and this will become self-evident to some extent.
- The use of IT and various related means yields to the best dispersion of knowledge/information within an organization.

| Patents pending | % Investment in IT | % R&D invested in basic research | Average years of service with the company |
|-----------------|--------------------|---------------------------------|----------------------------------------|
| Number of employees | Average duration of employment | Number of new solutions/products suggested | New patents/software/etc. filed |
| IT development expense/IT expense | Average age of employees | IT literacy of a staff | Company managers with advanced degrees |
| Revenues resulting from new business operations | IT performance/employee | IT capacity (CPU and DASD) | Changes in IT inventory |

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