International Journal of Science and Engineering Applications
Volume 11-Issue 05, 56 - 60, 2022, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1105.1001

Role of Media and Indigenous Communities to Combat Climate Change

Parnika Gupta
University of Iceland
Reykjavik, Iceland

Abstract: Since the industrial revolution, the greenhouse gas emissions have been on the constant rise and the global average temperature has increased by 1.1 degree Celsius as compared to pre-industrial era. This alarming climate change situation caused by human activities has already been causing devastating effects everywhere on the planet. The melting of sea ice, thawing of the permafrost, increase in natural hazards and their frequencies, reduction in the biodiversity of ecological areas, increase in sea levels, deterioration of species & wild populations, etc. are all pointing towards a direct threat to human well-being posed by the climate change. This research paper, whose idea germinated in the mind of the author while attending Arctic Circle Assembly 2021 in Reykjavik Iceland, circles around the role and position of media and indigenous communities in climate change mitigation and adaption by exploring key questions like challenges and narratives of climate coverage by media, a requirement for revolutionizing the institution of media, the importance of indigenous peoples and traditional knowledge for combatting climate change to name a few. The paper argues various elements affecting media and indigenous communities and concludes the crucial involvement for media and indigenous peoples to act for saving the planet considering the huge scale of this catastrophic climate change scenario.

Keywords: media; indigenous community; climate change; media and indigenous peoples; media, climate and indigenous peoples

1. INTRODUCTION

The environment is moving rapidly towards an undeniable event, Climate Change. Everyone in the world, one way or another, is getting affected by a sharp increase of the global average temperature owing to the industrial revolution. Humans have single-handedly driven the planet Earth on an alarming track of endangering the survival of every species including themselves. Even though climate scientists have proven the role of homo sapiens pivotal in causing these climate variations, many still keep questioning whether the scientists are right. Among all these meaningless hypothesis of many ignorant people, one cannot help but wonder about the role of media and indigenous communities in protecting the planet.

During Arctic Circle Assembly 2021, held at Harpa Conference Hall in Reykjavik (Iceland), many interesting sessions took place. Some of them also revolved around the climate change and its impact around the globe, specifically in 'The Arctic'. The huge number of journalists circling around everywhere and trying to capture each and every little event at the conference highlighted the significance of connecting the conference participants (speakers, audience, etc.) with the people directly or indirectly being affected by decisions or discussions happening at these events. The number of journalists was in contrast with the number of indigenous people present at the conference. But that small number didn't deter them from speaking their mind and calling out the hypocrisy of the people in power or in business. This was more than enough to showcase that their strength was not represented by their numbers, rather it was depicted through their deep knowledge and sense of responsibility for the planet they have been struggling to nurture for long. The harmony between indigenous communities and nature is commendable and it shows how the so-called developed world has long forgotten its relationship with nature. These key issues related to media and indigenous people in context of climate change are the main inspiration behind the idea for writing this research paper.

Ever since humans arrived on Earth, their opinions on issues have been largely based on the narrative placed in front of them. This is where media comes into picture. In order to educate every human on the planet, its role becomes extremely important to paint a portrait of reality depicting the degradation of climate based solely on scientific data without using subjective interpretations (for example, when the media portrays politicians before elections). Media inspired and guided by science is the need of the hour in order to act collectively for reversing the impacts of climate change before the situation gets out of hand. Media is even responsible for creating stereotypes about indigenous communities and it needs to undo its own mishaps. Whilst "technologically advanced" people have been busy utilizing the resources swiftly, indigenous communities have been living sustainably using natural resources in an optimal manner. It is the indigenous communities who better understand the threat of climate change hanging over the heads like a poorly tied sharp edge sword. This understanding and acceptance of the threat comes from the acknowledgement of dependability of every species on environment and the curiosity that has not been sabotaged by the hysteria of the industrial revolution.

This paper seeks to answer certain questions about the role of media and indigenous communities to accelerate actions and initiatives towards a better climate. The questions raised are as follows: i) Is media establishing required scientific narratives in human minds? Does media have the capability and will to do so? Can media help in accelerating actions required for climate change? What are the challenges faced by journalists while reporting climate news? ii) How and why do indigenous people are important in context of climate change? What indigenous knowledge and traditions do they possess that can be helpful for climate protection? Can they lead the way for ignorance prevalent in the world amongst non-scientific people? iii) Can media and indigenous communities join hands to move towards climate change mitigation?

2. BACKGROUND

Media is any means used to communicate to the masses, be it broadcasting, publishing and/or internet. Even though communication methods might have been different, the term 'media' came into use only in the 1920s to indicate the constructs of such communication (Dooley, 2015). It is well known that human behaviors are often based on their surroundings and can be swayed through the repetitiveness of information and false propaganda spread through fear and control. Media plays a major role in painting narratives about anything happening anywhere in the world. The media coverage for climate change can be seen rising but it seems to be more in the countries with tough Kyoto emission targets (Andreas et al., 2013).

History, as well as media, has not been kind to indigenous communities, and they have always received various stereotypical labels due to their sustainable lifestyle and unwillingness to accept the economic development by sacrificing environment. Indigenous people have recently been recognized globally for their continuous efforts of working in harmony with the environment and treating the planet like an extension of their own body.

3. MEDIA: PUBLIC PERCEPTION, REQUIRED EVOLUTION AND CHALLENGES

(In context of Climate Change Awareness & Mitigation)

Climate Crisis is happening every day and it calls for urgent public attention and drastic actions. Media coverage of this catastrophe can help shape public opinions by facilitating the scientific consensus on climate change that the global average temperature has evidently increased by 1.1 degree C, and it is all due to greenhouse gas emissions induced by humans. People consume news everyday but the amount of news about climate change is still less in proportion to the news about sports, celebrities, politics, economy and now covid19 pandemic. Even if the media coverage of climate change has increased, it still is not enough in countries with high carbon emissions and low emission reduction targets (Andreas et al., 2013). Public opinions and perceptions about climate news are based on the amount of trust they have in the media houses. More trust means more consumption of news from that media source.

Media cannot sustain in the present economic environment without having financial funding. While crowd-funding mediums remain more aligned towards central ideologies, the mediums funded by private corporations, often end up having left-right ideologies. This polarization within media is what leads to polarization of the masses and their ideologies (Newman et al., 2018). Due to transformation of media system, the news media sources which used to be based on stating facts on the situation have now turned into opinionated sources (Newman et al., 2018). Various studies have depicted how the right-wing media follows condescending tone relative to the certainty and urgency of climate change, whilst the left-leaning media networks could be seen consistent with scientific consensus and linking climate change as human-caused event (Feldman et al., 2014). This has played a major role in forming opinions in mass populations that deviates from scientific facts. Now, the question that arises is that does media have the capability to do so? Well, the answer is both yes and no. Media while communicating scientific data to masses often rely on journalists covering the issues who, more often than not, do not have scientific backgrounds. This leads to an error in data transfer and understanding at two levels. Firstly, whilst understanding the climate science themselves, the journalists may lose the scientific understanding and secondly, while trying to interpret the result into a language easily comprehended by masses, the climate science news may start to lose the evidential factors that the news rely on. News Framing is very important and a lag in the structure can even lead to individual framing of issues far away from truth (Swain, 2017). For example, media reports about the impact of climate change on polar bears will have different effects than destruction caused by floods due to climate change. The former one may affect the policy makers more while the latter is more likely to cause trauma in people's minds. The pandemic has also led to increase in the feeling of isolation and hopelessness. Due to this, the media reports have also increased about the pandemic and global economic downfall, which is far from the topic of climate change. More media reports can be seen when major events like COP26 happen due to the involvement of politics and international recognition.

The attitudes and values of reporters (broadcasting climate change news) with respect to climate change can also influence their knowledge and understanding of scientific consensus and their intellectual interpretation of climate change topics (Swain, 2017). Media also face a lot of challenges while reporting climate change news. One of them is finding correct sources for the information. For example, relying on government sources may give limited access to dissenting voices of environmentalists. Another challenge is interpreting scientific interviews. Since scientific understandings evolve over years, media can only capture glimpses of this knowledge which inevitably leads to narrow analysis and interpretations. This eventually leads to loss of finer points of a climate story (Swain, 2017). A small error in reporting is enough to discredit both scientists and media organizations, and this results into misinformation (Swain, 2017). Dramatization of reports in order to increase viewership is also an obstacle faced by various independent media organization while reporting climate change. Social media trends also degrade the evidence-based conversations around climate change mitigation due to speed with which the statements circulate through it (Mavrodieva et al., 2019). So, what can be done to accelerate climate change mitigation through media? There are various ways to change public perception and bridge the gap between scientists and general public opinion. While creating balanced media reports, cherry picking misleading bits of information for the sake of providing appearance of artificial balance is to be avoided. The interview segments in media reports should give equal coverage to both scientists and policy makers in context of climate change. Separating media from government institutional dependency is a crucial way to mitigate climate change through media influence. Forming an independent research team of scientific journalists can also prove to be beneficial in this long fight for climate. Climate stories need follow-ups on new channels to stay in public minds. Investigative journalism and independent media have also assisted in shifting public perception of governmental institutions and required policy changes.

4. INDIGENOUS COMMUNITIES WITH INDIGENOUS KNOWLEDGE

The term 'indigenous' translates to originating or occurring naturally in a certain place. There has not been any single universal definition of indigenous peoples. United Nations Working Group on Indigenous Populations (WGIP) accepted

a preliminary definition in the year 1982. It was proposed by Mr. Jose R. Martinez-Cobo who was a special rapporteur on Discrimination against Indigenous Populations. The definition states: "Indigenous communities, peoples and nations are those which, having a historical continuity with pre-invasion and pre-colonial societies that developed on their territories, consider themselves distinct from other sectors of the societies now prevailing in those territories, or parts of them. They form at present non-dominant sectors of society and are determined to preserve, develop and transmit to future generations their ancestral territories, and their ethnic identity, as the basis of their continued existence as peoples, in accordance with their own cultural patterns, social institutions and legal systems." (IWGIA, 2011) Apart from this definition, other criteria are also set out by ILO Indigenous and Tribal Peoples Convention, 1989 (No. 169), for identification of the peoples concerned.

There are a lot of risks to livelihood of indigenous peoples. Indigenous Peoples are among the poorest section in the society, and this makes them more vulnerable than others to the effects of climate change (Oelz et al., 2017). They depend on natural resources which are at risk due to climate variability. They live in topographical regions and ecosystems that have been exposed to the impacts of climate change (Oelz et al., 2017). Due to lack of recognition and institutional supports, they even have limited access to remedies which increases their vulnerability and weakens their abilities to mitigate and adapt to climate change (Oelz et al., 2017).

Why are indigenous people important when talking about climate change? Even after being a vulnerable group, indigenous peoples are crucial for accomplishing effective climate action, sustainable development and green growth (Oelz et al., 2017). The sustainable green economy and unique indigenous knowledge makes them key agents for climate change mitigation and adaptation (Oelz et al., 2017).

Currently, the indigenous communities amount to 5% of total world population and yet protect about 80% of remaining biodiversity on this planet (Oelz et al., 2017). On average, there has been significant alteration of land-based and marine environment by human beings and their activities. But these developments have been less harsh in areas which have been kept or handled by Indigenous Peoples and local communities (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2019, May 6). The significance of indigenous peoples for conservation of environment is being slowly recognized through acknowledgement of human rights of indigenous peoples, especially by UN. Indigenous peoples have been seeking active participation in mitigating climate change by taking part in international environmental conferences along with activism and political engagement both at regional as well as national levels (Etchart, 2017).

Indigenous peoples have plethora of traditional knowledge through which they live in synch with the environment without disturbing the natural balance. Enormous number of practices followed by indigenous communities have been keeping the natural environmental equilibrium in place since ages. For more than 1200 years, farmers have grown common carp in rice paddies in South China. Fish and rice are beneficial to each other. Paddies with fish utilize considerably less pesticide and fertilizer when compared to the amounts used by rice monoculture (Lansing & Kremer, 2011). Rice-fish cocultures have also been reported in many other regions like India, Egypt, Vietnam, Indonesia, Thailand, Bangladesh, the Philippines, etc. (Lansing & Kremer, 2011) Rice–fish polyculture promotes positive interactions and complementary use of resources between species to significantly reduce the requirement for chemical inputs (Lansing & Kremer, 2011). In Alaska, Eastern Alaska natives use traditional fire suppression techniques through community interactions for forest management. These procedures incorporate "bridging" landscapes by setting specified burns between natural areas (wetlands, marshes, and rivers, etc.) which then leads to reduction of density of fuel load and frequency of fire. This can help in preventing a huge fire from propagating ahead and destroying nearby village or region. (Brewer II & Warner, 2014) Intercropping techniques for planting maize, beans, and vegetables around rice paddies is also quite common (Van Huynh et al., 2020). Techniques of building 'Johad' for rainwater harvesting goes way back to ancient era used by indigenous communities in India, especially in the state of Rajasthan. A johad is a type of dam that gathers rainwater to direct it into the ground to restock the supply of underground water that not only prevents water scarcity but also provide soil moisture for forests or farmlands around the area (Suutari & Marten, 2005). The list of traditional practices followed by indigenous communities is a long one but this shows the pre-existing sustainable practices within indigenous communities that can have positive impact on environment and can be used to mitigate and adapt climate change.

But for this traditional knowledge to be exchanged and understood by others outside indigenous communities, the inclusion of indigenous peoples in various roles is a key factor. The indigenous groups still lack significant participation and roles in decision making process of environmental governance. They also need to be connected to the scientists for better understanding of the processes and for exchange of traditional and sustainable practices.

5. DISCUSSION & CONCLUSION

Media's coverage of climate change has been extensively criticized and this calls for improvements in the media systems. Since climate change is a complex phenomenon and it continues to gather new dimensions, the journalists should get proper training while doing scientific journalisms. A synergy is also needed between media and the information sources, for example, sources like NGOs, politicians and scientists. The framing of climate change in news affects the response of audiences. To get positive response, the climate change narrative needs to be framed without ambiguities. The stories should also be relevant to the audience. For example, public is more likely to act after seeing news about flood events due to climate variations in contrast to reports of endangered polar bears in foreign land owing to warming of the climate. The digital media like cinema can also change public perception of various climate events happening around the globe. More documentaries involving the scientists narrating the catastrophic effects of climate change at various regions and on different species can propagate necessary actions. The need for moving from sensational media towards more factual, scientific, and relatable media is also a key in achieving climate change mitigation and adaptation.

The indigenous peoples are significant for making progress towards climate change mitigation and adaptation. Their immense connection with nature and conscious use of resources highlights the need to include them in dialogues while formulating climate policies. They have the potential to ameliorate the destructive impacts of climate change. Owing to their knowledge of their region and natural resources, they are more likely to adapt to climate change than non-

indigenous communities, provided they are given proper rights and platform to discuss their knowledge and experiences. Research and curriculum based on indigenous peoples and their ancient knowledge can help them redefine their identity and educate the new generation of scientists and academicians. Even indigenous peoples understand that their traditional knowledge alone cannot mitigate the climate change due to the intensity and pace of the issue. There is also a need to involve them in adaptation strategies that integrate traditional knowledge with the scientific knowledge, like the Ealát network Study whose objective is to prepare reindeer herders and national authorities in the changing Arctic region.

Massive shifts in policy as well as public behavior is necessary in order to keep the greenhouse gas emissions below the dangerous levels and to prevent this from becoming irreversible. Combatting climate change is not individual fight anymore considering the scale of this event and there is an urgent need to include media and indigenous groups in order to save the human species from experiencing mass extinction, because one way or another nature will find a way to replenish itself, but humans won't be able to catch up with it.

6. ACKNOWLEDGMENTS

The author is grateful to the professors and administration at University of Iceland for providing the opportunity, resources, support, and invaluable insights. The author is thankful to the organizers and attendees of The Arctic Circle Conference 2022. The author is also thankful to family, friends and colleagues for the continuous motivation.

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International Journal of Science and Engineering Applications
Volume 11-Issue 05, 61-65, 2022, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1105.1002

Prediction of Copper Mineralization by the Artificial Neural Network (GRNN & BPNN) in Mesgaran Exploration Area, Eastern Iran

Hamed Nazerian
University of Catania
Italy

Bahareh Hedayat
Shahrood University of Technology, Shahrood,
Iran

Aref Shirazi
Amirkabir University of Technology
Iran

Adel Shirazy *
Amirkabir University of Technology
Iran

Abstract: Mesgaran exploration area is located in South Khorasan province, 26 km south of Sarbisheh city. The mineral potential of coppersmiths is copper mineralization. According to 75 surface samples taken, the analysis results are examined using the method of radial artificial neural network and error propagation. Also, after training to see the networks, the results can be used for other places. The strength of this study is that it does not require costly analyses to predict copper levels in other parts of the range, and simple analyses can estimate copper levels with an acceptable probability percentage and use the results to advance operations. In this area, the neural method was identified with higher accuracy.

Keywords: Artificial Neural Network, ANN, BPNN, Radial Neural Network, South Khorasan, Copper.

1. INTRODUCTION

In mineral exploration, methods and studies have been very extensive [1-15]. An artificial neural network is an information processing idea inspired by the biological nervous system and processes information like the brain. The critical element of this idea is the new structure of the information processing system. The system comprises a large number of highly interconnected processing elements called neurons that work together to solve a problem. ANNs, like humans, learn by example. An ANN is set up to perform specific tasks, such as identifying patterns (predicting) and categorizing information, during a learning process. Learning is accompanied by adjustments to the synaptic connections between nerves in biological systems [16-18].

With their remarkable ability to infer meanings from complex or ambiguous data, neural networks can be used to extract patterns and identify methods that are very complex and difficult for humans and other computer techniques to be aware of. A trained neural network can be used as an expert in the information given to it for analysis. It can estimate new desired situations and answer "what if" questions [19-21].

Another advantage of these networks is adaptive learning, which is the ability to learn how to perform tasks based on the information given for practice and introductory experiences. The second is self-organization, in which an ANN can create or present itself for the information it gains during the learning period. The third is the timely performance of ANN calculations that can be performed in parallel and special hardware designed and built to take advantage of this feature .

Fourth is the error tolerance without interruption in the coding of information; the small failure leads to the corresponding performance degradation. However, several network capabilities may remain even with significant damage [22-24].

To create chaotic neural networks, a chaotic neuron has been introduced. The ability to act on information in return networks is more significant than in conventional networks due to feedback loops. In-network training, the error propagation algorithm is used for modeling. Compared to other neural networks, the number of hidden layer neurons in chaotic networks is more petite, and their ability to generalize is higher .

There is a neural network in which processor units are process-focused on a particular situation. This focus is modeled through radial functions or RBF for short. In terms of the overall structure, they often have a faster learning and preparation process. Because neurons focus on a specific operating range, it will be easier to adjust them.

Another type is the error propagation network, a collection of neurons arranged in different layers. After multiplying the weights in the weights in the passages between the layers, the input values reach the next neuron and accumulate there. After passing through the relevant network function, form the output of the neurons. The obtained output is compared with the desired output, and the obtained error is used to correct the network weights.

2. GEOLOGY & GEOLOCATION

Mesgaran mining area is located 29 km south of Sarbisheh city. It has an area of 10 square kilometers and is rectangular. The geographical location of the range in the UTM system is between latitudes 0770500 to 0773000 east and latitudes 3577500 to 3581500 north (Figure 1) [25-27].

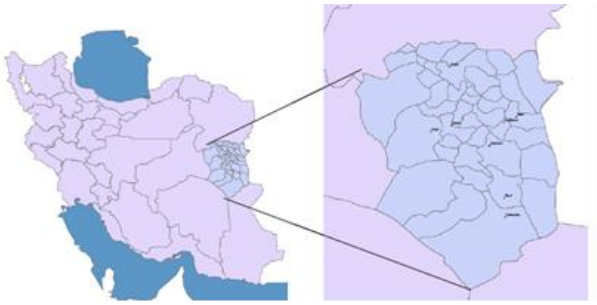

Figure 1: Location of the study area in South Khorasan Province, Sarbisheh

Access to this area is possible through the main road Sarbisheh-Nehbandan.

There are no rough heights in this area, mainly in the form of hills and plains. Roads are available in most places and can be easily accessed anywhere [28].

Due to the presence of mafic and ultramafic rock assemblages (ophiolite sequences) and erosion performance on these units, the area's topography is gentle and calm hills. Sedimentary parts of the region, especially areas with limestone, have a harsher topography than the mineral boundary.

The study area is a small part of the structural zone of eastern Iran in terms of structural-sedimentary divisions of the country. It is metallurgically located in the northern part of the Ahangaran-Bandan gold zone [29].

Lithologically, the exploration ranges include ultrabasic units, diabase dikes, pillow basalts, calcareous outcrops, phyllite, and schist lenses. One of the newest lithological units is the travertine unit. This complex is exposed as porous travertine around the travertine springs. The rock units exposed in the area of Mesgar show a complete ophiolite sequence. However, due to the compressive stresses in the region, the boundaries of these units are mainly faults, and the protrusion of super-basic rocks, basics, and ocean sediments does not follow any order.

3. DISCUSSION AND METHODOLOGY

This review is programmed in MATLAB and SPSS software, and its codes can be downloaded at the end of the article [8, 21, 30, 31].

First, the data, which included the analysis of samples in 44 elements, were randomly divided into two categories: educational and experimental. It is worth mentioning that educational and experimental data were separated by 70% and 30%. According to Table 1, the correlation between calcium, aluminum, phosphorus, and sulfur was high, and these elements were selected in the network training [32].

Then two methods of the artificial neural network after propagation of error and radial artificial neural network were applied to these data, and the results were presented.

This correlation was performed by the Spearman method due to non-normal data.

Table 1: Spearman's element correlation matrix

	Al	Ca	P	S
Al	1.000	.033	-.368**	-.558**
Ca	.033	1.000	-.116	-.040
P	-.368**	-.116	1.000	.732**
S	-.558**	-.040	.732**	1.000

3.1 GENERAL REGRESSION NEURAL NETWORK (GRNN)

In this method, according to experience, the value of the grid radius was considered 0.02. This is a numerical radius between 0 and 1, which must be obtained by changing the optimal value [33].

This method has a good speed so that the radius can be changed quickly, and the results can be seen. It is worth mentioning that this method can also use linear regression and compare the results if it answers and is acceptable to confirm the results.

The results can be seen in Figures 2 to 4.

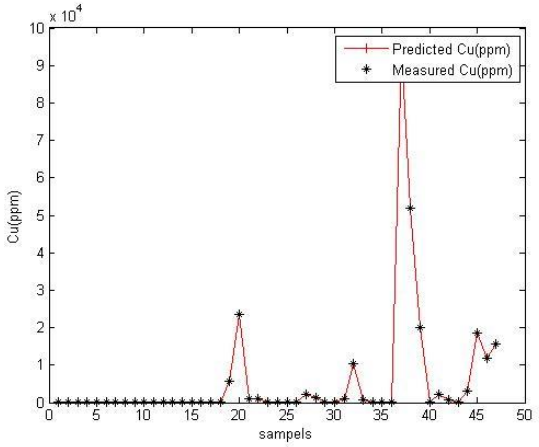

Figure 2: Estimated amount of copper in educational data

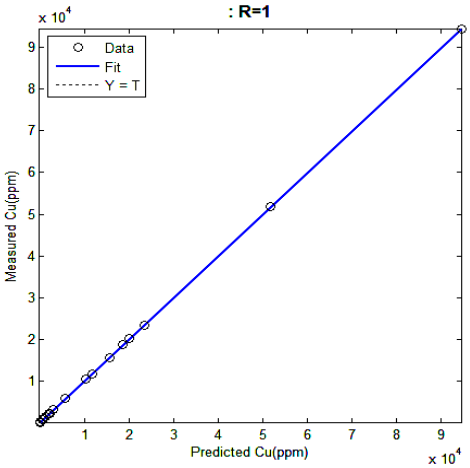

Figure 3: Regression of estimated and real data on educational data

International Journal of Science and Engineering Applications
Volume 11-Issue 05, 61-65, 2022, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1105.1002

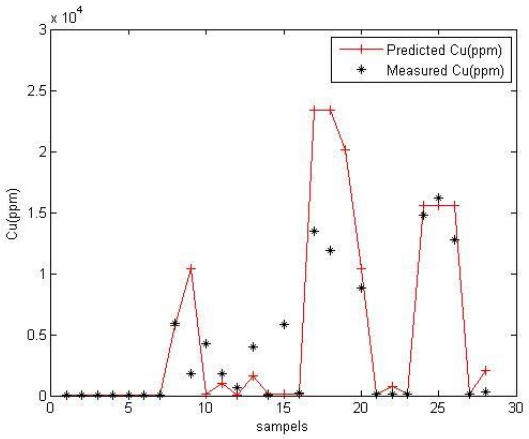

Figure 4: Estimated amount of copper in experimental data

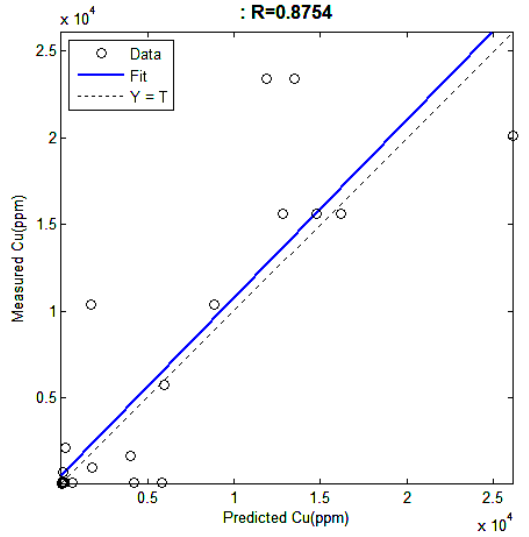

Figure: Regression of estimated and actual data on experimental data

According to the result of this method, the data can be estimated with 87% accuracy, which is acceptable.

3.2 BACK-PROPAGATION NEURAL NETWORK (BPNN)

In this method, according to the experience, the number of network neurons was ten, and the segmental input function was also considered normalized [27, 29].

In this type of network, experimental data should be divided into two categories so that no more fitting is done. For this purpose, experimental data were randomly divided into two categories and used in the method.

The results can be seen in Figures 5 to 8.

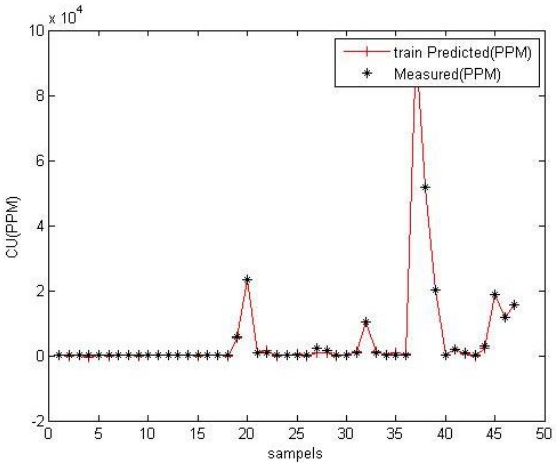

Figure 5: Estimated amount of copper in educational data

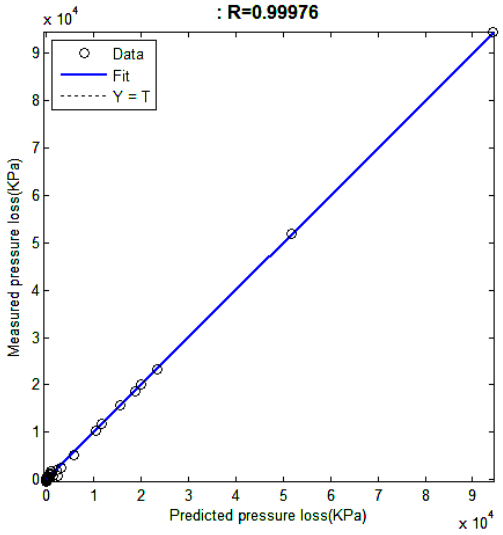

Figure 6: Regression of estimated and real data on educational data

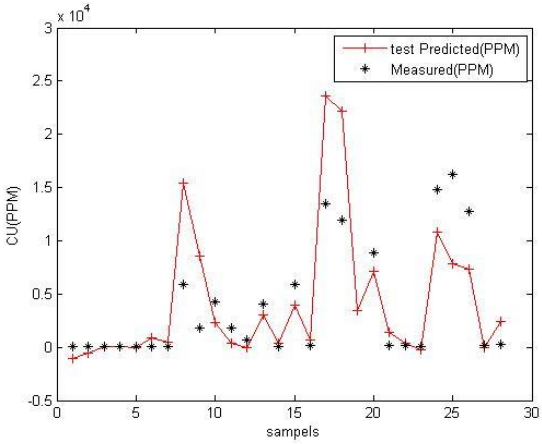

Figure 7: Estimated amount of copper in experimental data

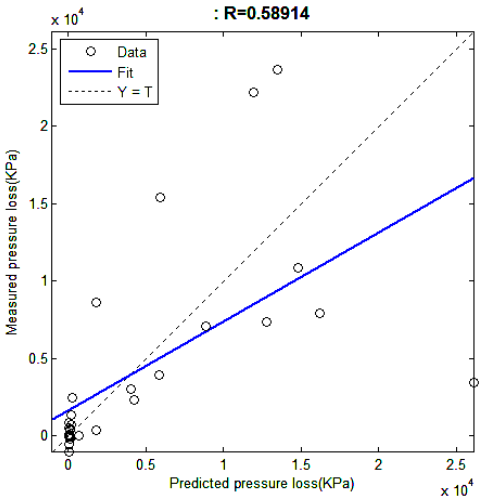

Figure 8: Regression of estimated and actual data on experimental data

According to the result of this method, the data can be estimated with 59% accuracy, which is somewhat acceptable [34].

4. CONCLUSION

Mesgaran exploration area is located in South Khorasan province, 26 km south of Sarbisheh city. The mineral potential of coppersmiths is copper mineralization. According to 75 surface samples taken, the analysis results are examined using the method of radial artificial neural network and error propagation. Also, after training to see the networks, the results can be used for other places. The strength of this study is that it does not require costly analyses to predict copper levels in other parts of the range, and simple analyses can estimate copper levels with an acceptable probability percentage and use the results to advance operations. The radial neural method with 88% accuracy and the error propagation with 59% accuracy for the experimental data estimated the amount of copper in this range. Due to the significant percentage of the radial neural network, this method can be considered superior in this area. Also, according to the presented graphs, the results can be calculated for other points. The codes used in this study were presented for further research and use elsewhere.

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International Journal of Science and Engineering Applications
Volume 11-Issue 05, 66 - 71, 2022, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1105.1003

A Literature Survey of Complexity Metrics for Object-Oriented Programs

Nevy Kimani Maina[1]
School of Computing and Information Technology
Murang' a University of Technology, Kenya

Geoffrey Muchiri Muketha[2]
School of Computing and Information Technology
Murang' a University of Technology, Kenya

Geoffrey Mariga Wambugu[3]
School of Computing and Information Technology
Murang' a University of Technology, Kenya

Abstract: Software complexity refers to the factors that determine the complexity level of a software project. High complexity is caused by the many attributes used in the system and the complex logic relationships among these attributes and features. The increased complexity of software is undesirable and affects maintenance. Over the years, Software Engineering scholars recommended several metrics like Halstead metric, cyclomatic complexity, and line of code metrics to deal with the complexity. With the complexity increasing as time goes by, there is a need for better metrics that can evaluate software more effectively. This research aims to develop a metrics model to determine the features that cause high complexity in software design architectures and to implement the multi-language complexity evaluation model for software architectures. Although this is the case, the literature on complexity metrics that implement diagram-centric complexity measures are inadequate. This study presents the outcomes obtained from our survey on metrics utilized in object-oriented environments. The survey comprises a small set of the most common and frequently implemented software metrics, which could be adopted to a group of object-oriented metrics and object-oriented programming. After reviewing the literature, Findings indicate that metrics that employ diagram-centric complexity measures are lacking.

Keywords: Software quality, Software metrics, complexity metrics, Object-oriented programs

1. INTRODUCTION

Attributes of a software are measured using a software metric to improve its quality. Many software metrics for software quality assurance have been proposed and continue to be presented. Software complexity metrics for procedural languages have been demonstrated to highlight program areas that are sophisticated to understand, test, or are prone to errors. Objected-oriented programs for software complexity metrics have been proposed by several researchers. Traditional procedural metrics (McCabe's Cyclomatic Complexity, and Halstead's Software Science) and modifications of them and class and inheritance measures are among the metrics presented so far. However, little research has been done to show that these measurements accurately reflect the complexity of object-oriented programs. Furthermore, it's unclear whether or not typical procedural sizes bear object-oriented complexity. Although most of these measures apply to all programming languages, some metrics are particular to a subset of the languages. Among metrics of this kind, are those that have been proposed for object–oriented programming languages.

Researchers agree that high complexity suggests poor design, which can be uncontrollable at times and impacts software quality. Measures of diagram design can be used to identify large diagrams that could be split or choose design reviews for select diagrams.

Thus, this paper is a literature survey analyzing the current software complexity metrics to determine whether there are gaps in the literature.

The study is partitioned in the following sections and format; section 2 is a brief overview of the basic ideas of object-oriented programs, and section 3&4 presents the existing complexity metrics for software. Future recommendations and the conclusions are presented in section 5.

2. BASIC CONCEPTS OF OBJECT-ORIENTED PROGRAMS

OOP (Object-Oriented Programming) has been advertised to lead to high-quality software and enhance efficiency of the programmer by reusing code.

The following are some of the most widely used terminologies in object-oriented metrics:

1. Object: An object is a type of entity that may save a state and perform various operations on that state.
2. Message: it can be defined as a request for an object to operate on another object.
3. Class: A collection of objects with a shared structure and behavior expressed by methods. It acts as a template from which an item can be created.
4. Method: A method on an object that is available to all class instances does not have to be unique.
5. Instantiation: Creating an object instance and binding or adding data to it.

International Journal of Science and Engineering Applications
Volume 11-Issue 05, 66 - 71, 2022, ISSN:- 2319 - 7560
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6. Inheritance: A class-to-class connection where an item in one class inherits features from more than one classes.
7. Cohesion: How closely the methods in a class are related to one another.
8. Coupling: Object A and Object B are connected if and only if A sends a message to B.

The main distinctions between object-oriented programming (OOP languages) with classic procedural programming (CPP) are message forwarding, encapsulation, and inheritance. OOP encapsulates data and behavior (methods) in classes and objects (instances of classes). The meaning of encapsulation is that a programmer only interacts with an object via its interface while the inner workings of an object are hidden. Encapsulation also prevents unintended consequences in other items. Rather than calling a procedure or function, objects in an OOP setup sends message to entities responsible for performing the activity. Inheritance enables programmers to create class hierarchies in which characteristics of more broad and straightforward parent classes are inherited by sub-classes. Sub-classes can also be specialized by overriding or including parts of the inherited code. One of the main benefits of OOP is that inheritance encourages and enables code reuse. Because OOP is so young, there are several ideas, recommendations, or methodologies accepted globally for writing programs that are of high-quality. Furthermore, little research has been conducted to analyze what makes an OOP application difficult and complex.

3. TRADITIONAL SOFTWARE COMPLEXITY METRICS

Software complexity measurements indicate how easy or difficult it is for a programmer to accomplish normal programming activities like understanding, testing, and maintaining a program. The degree to which the qualities assumed to lead to complexity within the code is measured by software complexity metrics rather than the complexity itself. The extent to which certain code qualities appear in the code influences how easy or difficult it is for a programmer to work with it. It might be difficult to test if a program has a convoluted control flow and multiple application routes. As a result, the number of conditional or looping statements might be used to measure complexity.

The metrics described here were chosen from among the most widely used traditional software metrics that have been proposed and could easily be applied to object-oriented programming.

3.1 Line of Code (LOC)

The LOC has been in existence for quite some time, it is more basic, and the most common metric for calculating the size of a program [1,2] Line of code LOC refers to a program's number of instructions in the SLOC (Source Line of Code), excluding comments and black lines. LOC has been criticized for lacking accountability, functionality, cohesiveness, lack of counting standards, and language and programmer dependency [2]. SLOC has other alternatives which include thousands or KLOC (Kilo Lines of Code), thousands of delivered source instructions (KDSI), bytes or number of characters, and non-commented lines of code (NCLOC) [2]. Both LOC and its derivatives, on the other hand, have restrictions.

3.2 McCabe Complexity Model

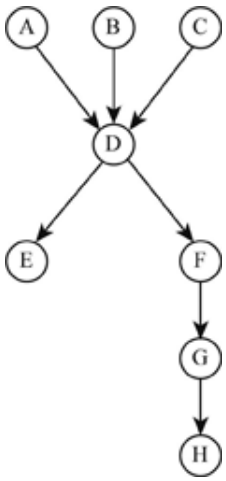
This model focuses on data flow in the architecture [3]. The program is represented by the metrics as a graph, and the definition of complexity, C is as follow;
C=E-N+2P

N represents the number of nodes, P represents the number of connected components, and E represents the number of edges.

One of the issues with McCabe's complexity is that it does not have different control flow statements (conditional statements) and nesting levels of varying control flow structures.

For instance, an edge can be a function/method call, a use relationship, or an inheritance link.

The restrictions must be remembered while using this metric, and the mapping between the graph and the model elements should be clearly defined.



3.3 Halstead Complexity

Software science by Halstead is based on the advancement of determining the size of the program through counting lines of code [4]. Halstead's metrics determine the number of operands and the number of operators and their respective occurrence in the code (program). The operands and operators are considered when measuring Program Vocabulary, Length, Estimated Program Length, Potential Volume, Effort, and Difficulty.

Critics have characterized Halstead as being complex to compute and depending on a complete code [5]. They are also criticized for being inadequate and confused. However, from a perspective of measurement theory, they are reasonable [6] and have solved line of code weaknesses where the computer algorithm is defined as a collection of tokens [7].

3.4 Henry and Kafura's Metrics

The complexity of a module based on the fan-out and fan-in of data flow is defined by the Henry-Kafura Information flow [8]. The module indicates that all sets of procedures refer to a certain global variable.

International Journal of Science and Engineering Applications
Volume 11-Issue 05, 66 - 71, 2022, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1105.1003

A procedure's complexity considers the sophistication of its code in terms of the length of lines and how complex its connected to its surrounding in terms of whether it is fan-out or fan-in. **Fan-in** is the amount of local flows that end at the procedure and the number of worldwide variables from which the function obtains data. **Fan-out** is the amount of regional flows from the process and the number of variable updates.

$$\text{Complexity} = \text{length of the procedure} \times [\text{fan - in} \times \text{fan - out}]^2$$

The metrics used to determine the structural sophistication are fan-in and fan-out. They also help to define maintainability. These two measures can be defined for files and procedures. An example is shown in the figure below, which links them as edges and modules as nodes. For example, consider the following graph with the modules as nodes and the links as edges.

Fan-in of a particular module shows the total modules that depends on it. A particular module's fan-out indicates the number of modules that depend on this module. The figure above shows that Module-D has a fan-out of 2 links and a fan-in of 3 links.

If the fan-in of a module is higher, it represents a better design structure; that is, the module has been used several times. Thus, it can be utilized for re-usability and decreases cost redundancy.

Fan-out shows are coupled among various modules. If the fan-out is high, this is an indication that the module is highly coupled. The higher the fan-out, the more the maintainability.

Shepperd [9] recommended changing H&K's data flow metric. The measure of Information Flow in the Shepherd's refinement to the complexity of Henry and Kafura for module M is;

$$\text{Complexity} = (\text{fan-in} * \text{fan-out})^2$$

The refinement was proposed to measure while excluding the length factor. Improvements by Shepperd [9] recorded a particular perception of the structure of information flow; thus, they coincide with measurement theory. The empirical validation by Shepherd the relationship between the measure and a certain process measure referred to as development time. In Shepperd's data, the relationship between K&F measure and development time was insignificant. But, his pure-data flow structure was found to be significantly related. Thus, the level of data flow is closely related with development time [10].

The Shepherd's refinement to the H&K measure of IFC for a module was analyzed by Sofia Nystedt and Claes Sandros [11] and indicated that the two are not extremely helpful while predicting program's errors. However, various metrics packages calculate the information flow complexity with multiple formulas.

4. OOP SOFTWARE COMPLEXITY METRICS

Code reuse is the strongest argument that favors OOP. This is because it permits applications to be built faster and, at the same time, enhances software quality. Although this is the case, the benefits are only evident if the reused code is evident and is of high quality. In the recent past, various OOP software complexity metrics have been recommended as a measure of the quality of software. The majority of them are either quantitative measures of OOP or traditional software complexity metrics extension, measuring features perceived to lead to complexity.

The analysis of these metrics is presented in the subsequent sections.

4.1 Chdamber and Kemerer Metrics

Various metrics have been defined for the object-oriented domain. One of the most common metrics are Chidamber and Kemerer metrics. Chidamber & Kemerer (1994) are Weighted Methods per Class (MMC), and Depth of Inheritance Tree (DIP), which can be used to determine the maximum length from the root to the node of the tree, where greater design complexity is made by deeper trees. Number of Chidren (NOC) shows the number of immediate sub-classes that are subordinated to a class from the class hierarchy. Coupled between Object Classes), which is the count of number of classes which couples it. Response for a Class (RFC) refers to a set of methods can be adopted to respond to a message gotten by an object class and Lack of Cohesion in Methods (LCOM) which refers to the degree of similarity of methods. A class is more cohesive if the amount of similar methods is more significant. Various researchers have empirically approved the metrics [12,13,14,15]. Although this is the case, researchers have found them theoretically deficient [16,17].

4.2 MOOD Metrics Suite

The MOOD metrics object-oriented domain structural complexity measures. These metrics were proposed in 1994 [24]. Method Hiding Factor (MHF), Attribute Inheritance Factor (AIF), Attribute Hiding Factor (AHF), Coupling Factor (CF), Polymorphism Factor (PF) and Method Inheritance (MIF) were recommended in 1994 [18]. The MHF and AHF were proposed as measures of encapsulation. The MHF metric is the ratio of the invisibilities specified method in all classes to the sum of attributes defined.

In contrast, the Attribute Hiding Factor is the ratio of all attribute invisibilities declared in all classes to the sum of all attributes. Both AIF and MIF are based on inheritance. The Method Inheritance metric is the sum of all methods inherited in the entire classes divided by the sum of all available methods. The AIF statistics on the other hand, is the sum of all attributes inherited in all classes divided by the total number of attributes available in all classes. PF is the ratio of the real number polymorphic scenarios for a given class to the maximum number of various polymorphic scenarios for the same class. The coupling factor is the ratio of the greatest

possible number of non-inherited connections [25]. These measures have been chastised for failing to anticipate class errors [26].

4.3 Mishra Inheritance Metrics

Two inheritance metrics were proposed by Mishra (2012), which are program level ACI (Average Complexity Inheritance), and class level CCI (Class Complexity due to Inheritance). There is a light at the end of the tunnel since the metrics have been found to be mathematically correct through the use of Weyuker's properties. Although the metrics need to be verified empirically to determine whether they can be useful measures of software quality.

4.4 Li Metrics

Six metrics were proposed by Li (1998) to solve the limitations of C&K metrics [17]. The metrics include Number of Ancestor Classes (NAC), Number of Descendent Classes (NDC), Number of Local Methods (NLM), Couple Through Abstract Data Type (CTA), Class Method Complexity (CMC), and Coupled Through Message Passing (CTM). The NAC determines the total number of ancestor classes inherited by a class. The total number of local methods in a class is measured by the number of local methods that can be analyzed outside the class. The CMC metric totals the internal structure complexity of all local methods. An NDC metrics provides the sum of sub-classes of a class. The CTA measures the total number of classes that are utilized as abstract data types. In conclusion, the Coupling Through Message Passing metric returns the number of various messages sent from a class to different classes without considering the inheritance characteristic [23]. HoI metrics solved the gaps in C&K metrics since they required modifications to effectively approximate maintainability.

4.5 Abreu and Carapuca Metrics

Five metrics were defined by Abreu and Carapuca (1994) that are utilized to determine inheritance in OOP [18]. These include Total Progeny Count (TPC), Total Children Count (TCC), Total Parent Count (TPAC), Total Length of Inheritance Chain (TLI), Total Ascendancy Count (TAC). The TCC is the number of classes directly inherited. TPC is the number of classes that directly or indirectly inherits from a class. TPAC is the number of sub-classes from which a class is inherited directly. TAC was represented and defined as the number of super-classes from which a class inherits directly or indirectly. Lastly, the inheritance total length is the amount of edges in the inheritance hierarchy graph. The metrics focused only on the inheritance perception of the OOP and other structural perception of a program.

4.6 Lorenz and Kidd Metrics Suite

Three metrics were derived by Lorenz and Kidd (1994) which include NMI (Number of Methods), NNA (Number of New Methods), and NMO (Number of Methods Overridden) [19]. The number of methods measures the total number of methods which a subclass inherits from. In contrast, the number of methods overridden by a subclass and a class, and number of new methods measures the number of new strategies in a subclass [20]. The metrics have been criticized to measure class properties and to be simplistic. This is an indication that they cannot be depended on to analyze the quality of a software [21, 22].

4.7 Misra, Adewumi, Fernandez-Sanz and Damasevicius Metrics

Objected oriented complexity measures were proposed [27]. MC (Method Complexity), AC (Attribute Complexity), CWC (Coupling Weight for a Class), CLC (Class Complexity), and CC (Code Complexity) are some of the measures used. The MC metric is calculated by adding all of a class's allocated weights. The weights of calls and called methods are added to the CWC metric. The sum of features of a class is determined using the AC metric. By adding AC and MC, the CLC measure determines class complexity. Finally, the CC metric considers the interaction between classes, which increases the complexity of the classes. The weights of subclasses are multiplied, and all classes in the same level are allocated the same weight. These measures have been shown to be theoretically valid, but they must be tested in real-world applications to be useful.

5. CONCLUSIONS AND FUTURE WORK

This study's findings indicate that almost all software metrics calculate are model-centric measurements of software and not diagram-centric. Class metrics, for example, tally all of a class's attributes, affiliations, operations, and so on. It makes no difference whether these elements appear on any diagrams or the classes themselves. Diagram-centric metrics are also intriguing for practical reasons. We can utilize said diagram size and complexity metrics to find large diagrams that can be divided up or choose diagrams for design reviews and inspections.

In an attempt to solve the lack of diagram-centric complexity measures that implement diagram size and complexity measures, future studies should focus on defining complexity metrics for the measurement of complexity during the design modules. The metrics should be capable of use at the architectural and detailed design stages and assist in preventing module implementation and maintenance problems. Further, the results of the experimental evaluation of these metrics will assist in demonstrating the benefits of the design method in controlling complexity through the software life-cycle and hence in demonstrating the ability to assist in producing maintainable design products and software.

Nevy Kimani Maina is an ICT OFFICER at the Department of Information Communication Technology at Murang'a County Assembly, Kenya. He earned his Bachelor of Business and Information Technology (BBIT) from Murang' a University of Technology in 2016. He is currently pursuing his MSc. in Information Technology at Murang'a University of Technology, Kenya. His research interests include software metrics, software quality, and business intelligence.

Geoffrey Muchiri Muketha is the Director, Directorate of Postgraduate Studies Murang' a University of Technology, Kenya. He received his BSc. in Information Science from Moi University in 1995, his MSc. in Computer Science from Periyar University, India in 2004, and his Ph.D. in Software Engineering from Universiti Putra Malaysia in 2011. He has wide experience in teaching and supervision of postgraduate students. His research interests include software and business process metrics, software quality, verification and validation, empirical methods in software engineering, and component-based software engineering. He is a member of the International Association of Engineers (IAENG).

Dr. Geoffrey Mariga Wambugu Dean of the School of Computing and Information Technology, Murang' a University of Technology, Kenya. He obtained his BSc Degree in Mathematics and Computer Science from Jomo Kenyatta University of Agriculture and Technology in 2000, and his MSc Degree in Information Systems from the University of Nairobi in 2012. He holds a Doctor of Philosophy in Information Technology degree from JKUAT. His interests include Machine Learning and Text Analytics. Dr. Mariga has been involved in the design, development and implementation of IT/ICT and Computer Science Curricula in different Universities and Colleges in Kenya.

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