An Over view of Qualitative Structural Analysis Using Diagrammatic Reasoning: Emerging Needs and Challenges

Prof. Deepak Ranjan Mohapatra[1], Prof. (Dr.) Ramesh Chandra Rath[2]

[1]Assistant Professor, in Civil Engineering, Sudhananda Group of Institution, Bhubaneswar India
[2]Dean, (R&D), Einstein Academy of Technology & Management, Bhubaneswar Approved by AICTE and affiliated to BPUT Rourkela, Odisha,

---***---

Abstract:- Now-a-days diagrammatic reasoning is an important type of reasoning in which the primary means of inference is the direct manipulation and inspection of a diagram. Diagrammatic reasoning is prevalent in human problem solving behavior, especially for problems involving spatial relationships among physical objects available in the environment. Our research examines the relationship between diagrammatic reasoning and symbolic reasoning in a computational framework. We have built a system, called REDRAW, which emulates the human capability for reasoning with pictures in civil engineering. The class of structural analysis problems chosen provides a realistic domain whose solution process requires domain-specific knowledge as well as pictorial reasoning skills.

In this invited research article, we hypothesize that diagrammatic representations, such as those used by structural engineers, provide such environment where inferences about the physical results of proposed structural configurations can take place in a more intuitive manner than that possible through purely symbolic representations. In this paper, we concentrate on how an artificial Problem-solving agent might perceive from or act on a diagram. In the last couple of decades, numerous Diagrammatic Reasoning Systems (DRS) have been built for different purposes, such as analyzing structural problems in civil

engineering [1] , assisting in geometry theorem proving [2], mathematical theorem proving [3], understanding juxtaposition diagrams of physical situations [4], reasoning about military courses of action [5, 6], and so on. A common requirement of all these systems is the ability to obtain information about spatial properties and relations from a diagram and to modify or create diagrammatic objects.

Where we Minimize(Distance(s,Q[1]+n−1i=1Distance(Q[i], Q[i+1])+Distance(Q[n], e))} ...... Reasoning and Problem-solving with diagrams require a large repertoire of Visual Routines (VRs) and Action routines (ARs). Different DR systems use different routines, for example, the RE- DRAW system [1] uses VRs, such as get-angular-displacement, get-displacement, symmetrical-p, connected-to, near, left, above, etc. and ARs, such as rotate, bend, translate, smooth, etc. to qualitatively determine the deflected shape of a frame structure under a load, a structural analysis problem in civil engineering; the ARCHIMEDES system [2] uses VRs, such as verify relationship, test for a condition , etc. and ARs, such as create an object with certain properties (e.g. create a segment parallel to a given segment through a given point), transform an object . Thus, we the researcher has trying to justify the aforesaid problem's real measurement by using the requisite tools and techniques in order to examining the diagrammatic reasoning in the basement of qualitative structural analysis

Key words: Diagrammatic Reasoning System (DRS), Construction Technology (CT), Structural Analysis (SA) Engineering of Archimedes System (EoAS), Re-Draw System (RDS)

1. Introduction:

Today, humans often use diagrams to facilitate problem solving in many fields, where many types of problems, including but not limited to problems involving behaviors of physical objects, drawing a diagram is a crucial step in the solution process. Drawing can reveal important information that may not be explicit in a written description, and can help one gain insights into the nature of the problem. Though such use of diagrams is an integral part of human problem solving behavior, it has not received nearly as much attention in AI as symbolic reasoning has. One important advantage of diagrammatic representation in some types of problems is that it makes explicit the spatial relationships that might require extensive search and numerous inference steps to determine using a symbolic representation. Larkin and Simon have shown that, even when the information contents of symbolic and diagrammatic representations are equivalent, a diagrammatic representation can offer computational advantage in problems where spatial relationships play a prominent role [Larkin & Simon 1987] . Since humans reason with so much apparent ease in some problems, a program that could reason directly with a diagrammatic representation would be more understandable to the user than a program that reasons exclusively with a purely symbolic representation of the same information. In addition, a diagrammatic reasoning program should offer insight into the relationship between diagrammatic reasoning and symbolic reasoning. Such a program may also be useful in imparting visualization skills to students of disciplines where such a facility is crucial, such as in civil or mechanical engineering and design. In this paper, we present our work aimed towards understanding the role of diagrammatic reasoning in problem solving. The problem we chose for studying diagrammatic reasoning is that of determining the deflection shape of a building frame structure under 240 loads. We have constructed a computer program called REDRAW (Reasoning with Drawings) that solves this problem qualitatively using a diagram in a way similar to human engineers.

Literature Review:

In this section of Literature Review, the researcher has collected with the following data in both primary and secondary mode of collection. But basically it is a review paper, before my work it has published by few of authors. Where, they experimented and advocates about a qualitative structural analysis of using diagrammatic reasoning shapes for solving various problems .Here, the author has taken the aforesaid research title **"An Over view of Qualitative Structural Analysis Using Diagrammatic Reasoning: Emerging Needs and Challenges",** which has specially designed by the researcher in order to testing its genuineness and authenticity. In this design, the researcher has taken two hypothesis, such as observed hypothesis (H_o) and Null hypothesis (H_1), where hypothesis one stated about a qualitative structural analysis would be enhanced the diagrammatic reasoning process for solving various problems in authentically where as the second hypothesis stated that, both the structural analysis and diagrammatic reasoning has no impact for solving various shaping problems if it has not well defined and analyzed properly as per the code of conduct of construction and design of civil engineering . However, the researcher has come to conclusion which you may see at last of the research work ends.

1.1 Roles of diagrams in Problem Solving:

Some research has been done on the roles that diagrammatic reasoning play in human problem solving. Novak and Bulko, [Novak & Bulko 1992], for example, have asserted that a diagram and its annotations serve as a short-term memory device in the problem solving process. Such a device allows temporarily-needed information to be retrieved later in the same manner that writing down intermediate results in multiplication problems frees the person to perform further calculations.

They also postulate that a diagram may act as a substrate or concept anchor that allows the new part of a problem to be described relative to well-understood problem base. Larkin and Simon discuss extensively the advantages of diagrams for facilitating inference about topological or geometric relationships [Larkin & Simon 1987]. Chandrasekaran and Narayanan [Chandrasekaran & Narayanan 1992], Novak and Bulko [Novak &Bulko 1992], Borning [Borning 1979] and others have also pointed out the usefulness of diagrams to human problem solvers as a device to aid in visualization, "gedanken experiments" or prediction.

Finally, Novak and Bulko [Novak & Bulko 1992], Koedinger [Koedinger 1992] and others have explored the idea that diagrams may sometimes be used not primarily for making base-level inference, but rather to help in the selection of an appropriate method to solve a problem; that is, as an "aid in the organization of cognitive activity" [Chandrasekaran et al . 1993]

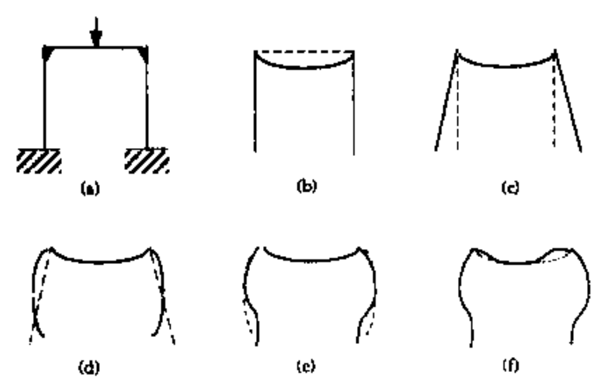


Figure 1: Steps in determining the deflected shape

A salient feature of diagrammatic reasoning in many situations is it's qualitative. People reason with diagrams to get rough, qualitative answers. If a more precise, quantitative answer is needed, they must resort to more formal, mathematical techniques. However, qualitative techniques are extremely useful in gaining valuable insight into the range of possible solutions. An initial qualitative understanding thus obtained can guide the later analysis for more detailed answers. In the context of structural analysis, knowing the qualitative deflected shape allows one to identify critical features of the shape. One can then set up relevant equations in order to obtain more precise information such as actual magnitudes of forces and displacements at specific points of interest.

How do diagrams actually help civil engineers to make qualitative inferences? From studying textbooks on elementary structural analysis, such as [Brohn 1984], that aim to develop an intuitive understanding of the response of the structure under a load, we find that diagrams fulfill many of the same roles as those articulated by researchers in other fields. First, diagrams are used as "a visual language of structural behavior that can be understood with the minimum of textual comments" [Brohn 1984]. The language allows the engineer to express explicitly the constraint or physical law that is relevant at each part of the proposed structure, in such a way that the constraints and some of the consequences are immediately apparent to the reader without further reasoning. Secondly, the diagram serves as a place holder or short-term memory device by allowing the designer to sketch out the result of one deformation and then go back to see if there is a further effect or interaction that needs to be addressed.

Finally, visual inspection of diagrams seems to guide the engineer in choosing the next step, resulting in a more efficient problem solving process than it would be otherwise. Having studied the use of diagrams in all these capacities in the context of determining deformation shape of frame structures, we have constructed REDRAW to use diagrams in all those capacities in ways similar to humans. We will first explain the deflection shape problem in Section-2.The architecture of REDRAW will be described in detail in Section 3.

2. Deflection Shape Problem

Determining the qualitative deflected shape of a frame structure under a load is a crucial step in analyzing the behavior of a structure. Structural engineers first make a simple, 2- D drawing of the shape of the given frame structure. Given a load on the structure, they modify the shape of the structural member under the load. They inspect the modified shape to identify the places where constraints for equilibrium of the structure are violated. Those constraint violations are corrected by modifying the shape of connected structural members, propagating deflection to other parts of the structure. This process is repeated until all the constraints are satisfied. The drawing thus produced shows the final deflected shape of the frame under the given load. Given a diagram of a frame structure and a load, the program produces an underlying symbolic representation in order to facilitate reasoning about engineering concepts. Then the program will use its structural engineering knowledge to propagate constraints on the diagram of the structure and will inspect and modify this picture until a final shape is produced that represents a stable deflected structure under the given load. As with the qualitative nature of human visual reasoning, the reasoning carried out by REDRAW is also qualitative. The answer it produces is a picture of a deflected shape. Although the resulting picture is qualitatively consonant with the problem solution, it is not (nor does it need to be) mathematically accurate or to scale.

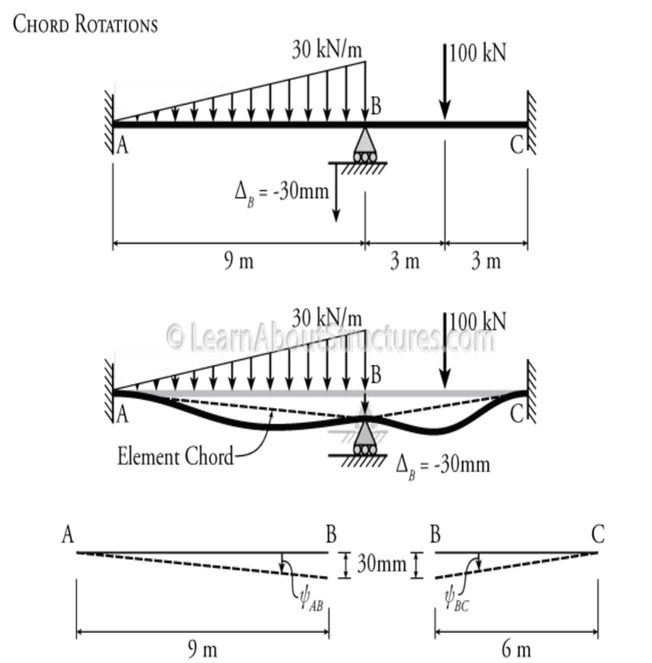


Figure 2: Steps in determining the deflected shape

REDRAW solves this type of deflected shape problems by directly manipulating a representation of the shape in the manner shown above. Although the problem could be solved by setting up equations, visualization is an indispensable first step that provides an engineer with an intuitive understanding of the behavior of the structure and enables her to recognize a good strategy for further analysis.

Before describing how REDRAW analyzes structures, we explain briefly the reasons for our choice of this deflected shape problem. An advantage of this civil engineering problem domain for studying the role of visual reasoning in problem solving is the fact that it is rich with domain-specific knowledge that has significant implications on how the diagram is manipulated and interpreted. One possible domain in which to study pictorial reasoning is geometry, where pictures are abstract diagrams without being a representation of anything in the world. In geometry, the only property one reasons about is the geometric property. There are no other types of information, apart from that represented in the diagram that one must take into account when manipulating and inspecting the diagram.

In contrast, pictures used for reasoning in engineering design are not simply abstract geometric shapes but actually represent things in the real world. Furthermore, how a picture is interpreted and manipulated depends significantly on what it represents. For example, a line in our domain represents a beam or a column. Changing the length of the line would change the information represented by the diagram. In a circuit diagram, on the other hand, one could change the length or curvature of the line representing an electrical connection without changing the informational content of the diagram. For the goal of better understanding the role of visual reasoning in problem solving and its relation to symbolic reasoning, it is important for us to work with a problem requiring a wealth of domain knowledge that has significant influence on the way diagrams are used and interpreted.

3. Architecture of the system:

From examining the way deflection shape problems are solved by humans, it is apparent that solving this type of problems requires not only an ability to manipulate and inspect diagrams but also substantial structural engineering knowledge. Structural engineering knowledge about the properties of various types of joints and supports is necessary to identify constraints on the shape for the structure to be in equilibrium. Such knowledge is best represented and manipulated symbolically. On the other hand, information about shapes is best represented as a picture.

Many types of modification and inspection of the shape are also more easily carried out with a picture. The requirement for both pictorial and non-pictorial representation and reasoning suggests a layered architecture. Thus, REDRAW includes both symbolic reasoning and diagrammatic reasoning components. The former contains the knowledge base of structural engineering knowledge about various types of structural members, joints, supports, and the constraints they impose on the structure. It also includes a constraint based inference mechanism to make use of the knowledge. The latter, diagrammatic reasoning component includes an internal representation of the two-dimensional shape of the frame structure as well as a set of operators to manipulate and inspect the shape. These operators, some of which are shown in Figure 2, correspond to the manipulation and inspection operations people perform frequently and easily with diagrams while solving deflected-shape problems.

The Structure Layer contains a symbolic representation of domain-specific knowledge. It represents non-visual information (such as hinged joint rotation), various types of structural members, equilibrium conditions, as well as heuristic knowledge for controlling the structural analysis process.

The Diagram Layer represents the two-dimensional shape of a structure. There are several operators that directly act on this representation to allow inspection as well as 243 transformation of the shape. These operators correspond to the operations people perform easily with diagrams. The internal representation of a shape is a combination of a bitmap whose elements correspond to each "point" in a picture, and a more symbolic representation where each line is represented by a set of coordinate points.

The Diagram Layer is independent of the structural engineering domain in the sense that it does not contain any structural engineering concepts. However, the types of both manipulation and inspection operators provided for the layer reflects the requirements of the domain. For example, the assumption that the frames consist of incompressible members made a particular set of operators necessary (e.g. the program requires a bend operator but not a stretch or compress operator), and also by the specific functioning of those required operators (for example, the bend operator creates a moderate curve rather than a complete bend that would cause the line endpoints to touch or cross; or, the inspect operator may look at components connected to the component in question, but will not compare that component to any other, as it might in some other domain.) Basically it has two layers such as

Structure Layer

- Objects: beams, columns, connections, supports, load, etc.
- Operators : generate-force-equilibrium-conditions, generate-moment-equilibrium-conditions, etc

.

Diagram Layer

- Objects : lines, splines, circles
- Operators: Manipulation: rotate, bend,

translate, smooth, etc. Inspection: get-angular-displacement, get-displacement, symmetrical p, etc

[Types of objects and operators in REDRAW program]

There is a close link between the information in the two layers. The system relates the representation of a particular beam in the Structure Layer to a spine in the Diagram Layer, and the concept of deflection of a beam to an operation on a spine to transform its shape. Likewise, the system is able to identify features of a shape (e.g.). Direction of bending, existence of an inflection point) and to communicate them to the Structure Layer. Communication between the two layers takes place by sending commands and posting constraints by the Structure Layer, which is carried out or checked by the Diagram Layer. Figure 3 shows the two-layered architecture schematically.

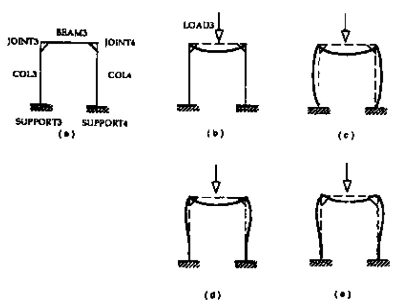
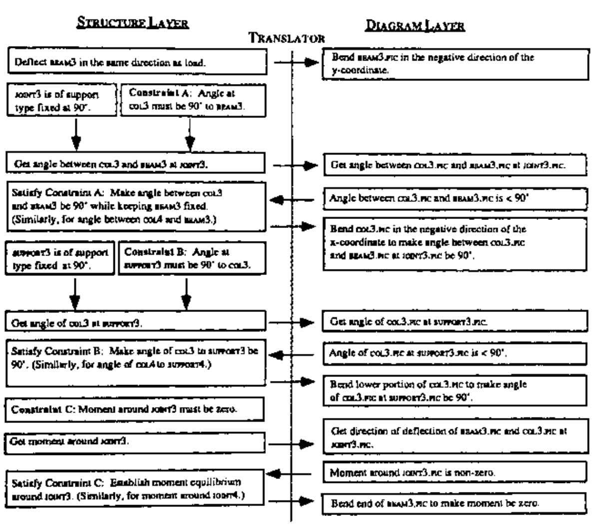


Figure 3: REDRAW solution to frame structure problem sketched in Figure 1



There is a translator between the two layers to mediate the communication between the two layers. When the Structure Layer posts a constraint or a command, the Translator translates it into a call to a Diagram Layer operator that can directly act on the representation of the shape to manipulate or inspect it. The result is again translated back to concepts that the Structure Layer understands.

Related Work

We have previously built a program called QStruc to solve the same deflected shape problem described in this paper, but using a traditional, symbolic AI approach [Fruchter et.al 1991]. There is no explicit representation of the shape of a structure in the program. The shape is implicitly represented by the existence of such physical processes as bending, and the qualitative values (positive, negative, zero or unknown) of such parameters as displacements. Both REDRAW and REDRAW-I I solve problems more efficiently than QStruc. Their efficiency is due to the fact that diagrams allow the systems to focus the solution process much better than QStruc, which blindly sets up all applicable equilibrium equations and tries to solve them. Our informal evaluation of the systems also shows that REDRAW programs are much more instructive in helping the user to gain intuitive understanding of the physical phenomenon. One of the first pieces of work that took the diagram as an integral part of understanding and solving a physical problem is Novak's work on physics problem solving. His system, ISAAC, solved problems in elementary dynamics [Novak, 1977]. ISAAC read a problem stated in English, generated an internal geometric model of the situation, set up mathematical equations, and solved them to produce an answer. It also drew a diagram to represent the given situation based on the geometric model. Though ISAAC did not actually use the diagram for problem solving, it used it to demonstrate its understanding of the problem to the user. In Chandrasekaran and Narayanan's work on commonsense visual reasoning [Chandrasekaran and Narayanan, 1990], they proposed a visual modality specific architecture, using a visual representation scheme, consisting of symbolic representations of the purely visual aspects (shape, color, size, spatial relations) of a given situation at multiple levels of resolution. The visual representation is linked to an underlying analogical representation of a picture so that visual operations performed on the analogical representation are immediately reflected on the visual representation and vice versa. Chandrasekaran and Narayanan's objective was "to propose a cognitive architecture underlying visual perception and mental imagery that explains analog mental imagery as well as symbolic visual representations" [Chandrasekaran and Narayanan, 1990]. Among the researchers of qualitative physics, Forbus was the first one to note the importance of diagrams in solving spatial problems. In his work on qualitative kinematics, he proposed the MD/P V model for representing spatial information [Forbus, 1980; Forbus et a/. 1991]. His MD/P V model consists of the Metric Diagram, which contains enough quantitative information to compute geometric features necessary for reasoning, as well as a Place Vocabulary, which is a set of relations that are appropriate for qualitatively representing (and solving) the particular problem at hand. Though, on the surface, our two-layered architecture with the Diagram and Structure Layers seems very similar to the MD/P V model, there are important differences. On one hand, Forbus' Metric Diagram is intended to represent quantitative information of a physical (spatial) situation, and the Place Vocabulary is a qualitative abstraction of the information in the Metric Diagram. On the other hand, our Diagram Layer is intended to represent diagrams used by people for solving problems. Whatever physical interpretation that the diagram may have is bestowed upon it by the Translator, which relates diagrams to the concepts in the problem domain. The information in the Structure Layer is not an abstraction of the diagram, but is the conceptual knowledge of the domain of structural analysis required to solve the deflection problems. This difference probably reflects the difference in focus: the main focus of our work is on the use of diagrams as essential medium of problem solving while Forbus' focus seems to be on solving qualitative kinematics problems. Whether this difference will result in different, degrees of re-usability of the architectures (e.g. relative ease of reusing the problem solving architectures, especially the Metric Diagram and the Diagram Layer, for other domains) remains to be seen. The work by Decuyper and his colleagues [Decuyper cl a/. 1995], as well as an earlier piece of work by Gardin and Meltzer [Gardin and Meltzcr, 1989], both take a very different approach to reasoning about liquid from those based on symbolic qualitative reasoning. Instead of representing a body of liquid or a solid object as one entity as is usually done in symbolic reasoning systems, they represent both types of things as a one- and two dimensional collection of particles. Each particle represents a small piece of liquid or solid stuff. They use a two-dimensional array to represent the position of each piece, and simulate the movement of each piece to predict the behavior of the collection. For simulation of the movement, Decuyper et al. apply physics laws to each cell, while Gardin and Meltzer use local rules, which Govern the exchange of messages between neighboring particles. By changing the rules restricting the permissible angle between particles, Gardin and Meltzer can also simulate the behavior of solid objects, such as rods and rings, of different flexibility. As with Forbus' Metric Diagram, their analogical representation is not intended u> be a representation of a diagram but a representation of a model, composed of particles, of a physical situation. Their approaches seem promising, especially for reasoning about highly deformable objects. For such problems, relatively simple diagrams such as those used by REDRAW may not be very useful, and those that do reflect the situation fairly accurately may be difficult to draw or to manipulate.

Conclusion:

We have described our research on understanding the role of visual reasoning in a concrete problem-solving context. We have built prototype programs that reason qualitatively using diagrams in the same way that people do. Our decision to work with the deflection of shape problem in the domain of civil engineering was based on two considerations: First, since we had already built a system to solve the deflection problem using a traditional symbolic approach, we could directly compare the diagrammatic and symbolic reasoning approaches; and secondly, this was a knowledge-rich, real-world domain, which would allow us to study the role of diagrammatic reasoning in solving problems that required both types of reasoning. In addition to examining the role of diagrammatic reasoning in problem solving, we are considering the generality of our work and its extendibility to other areas of technical design such as in architecture and mechanical engineering. Larkin and Simon [Larkin and Simon, 1987] showed that even with a symbolic representation, problem solving efficiency in some cases can be greatly improved by organizing the information in a way that reflects the physical structure of the object represented. By developing a strong understanding of the role that visual reasoning plays in the overall problem-solving process, we hope to construct a general tool that can be used to build diagrammatic reasoning systems in many other problem domains. Acknowledgments This research was supported by the Center for Integrated Facility Engineering of Stanford University as well as by the National Science Foundation, NSF Grant No. IRI9408545.

References

[1] Borning. Thing lab - a Constraint-Oriented Simulation Laboratory. PhD thesis, Department of Computer Science, Stanford University, Stanford, CA, 1979.

[2] [Allen, 1978] R. Allen. Elementary deflected structural theory. Department of Civil Engineering, Stanford University, 1978. [Borning, 1979] Allan [3] H. [Brohn, 1984] David Brohn. Understanding Structural Analysis. Oxford, BSP Professional Books, Oxford, UK, 1984.

[4] [Chandrasekaran and Narayanan, 1990] B. Chandrasekaran and Hari Narayanan. Towards a theory of cornrnon sense visual reasoning. In Foundations of software, technology and theoretical computer science. Springer-Verlag, 1990.

[5] [Chandrasekaran et ai, 1993] B. Chandrasekaran, Hari Narayanan, and Yumi Iwasaki. Reasoning with diagrammatic representations: A report on the AAA1 spring symposium. AI Magazine, 14:49-56, 1993.

[6] [Chandrasekaran and Narayanan, 1992] B. Chandrasekaran and Hari Narayanan. Perceptual representation and reasoning. In, 4, 4, 4/ Symposium on Reasoning with Diagrammatic. Representations, 1992

[7] [Forbus, 1980] Kenneth D. Forbus. Spatial and qualitative aspects of reasoning about motion. In Proceedings of the First National Conference on Artificial Intelligence, 1980.

[8] [Fruchter et al, 1991] Renate Fruchter, K incho H. Law, and Yumi Iwasaki. Qstruc: an approach for qualitative structural analysis. In the Second International Conference on the Application of Artificial Intelligence to Civil and Structural Engineering. Civil Comp Press, 1991.

[9] [Gardin and Meltzer, 1989] Francesco Gardin and Bernard Meltzer. Analogical representation of naive physics. Artificial Intelligence, 38(2):139-159, 1989. [Koedinger and Anderson, 1990] Kenneth Koedinger and John R. Anderson. Abstract planning -md perceptual chunks: Elements of expertise in geometry. Cognitive Science, 14:511-550, 1990.

[10] [Koedinger, 1992] K. Koedinger. Diagrammatic reasoning by simulation. In AAA J Symposium on Reasoning with Diagrammatic Representations, 1992.

[11] [Lindsay, 1992] Robert K. Lindsay. Diagrammatic reasoning by simulation. In AAAI Symposium on Reasoning with Diagrammatic Representations, 1992.

[12] [McDougal, 1995] Thomas F. McDougal. Using diagrammatic features to index plans for geometry theorem-proving. In Janice Glasgow, Hari Narayanan, and B. Chandrasekaran, editors, Diagrammatic Reasoning: Computational and Cognitive Perspectives on Problem Solving with Diagrams. AAAI Press, Menlo Park, CA, 1995.

Author Profile: 01

Prof. Deepak Ranjan Mohapatra
He is an Assistant professor since last 17 years; he has completed his **AMIE, Civil Engg. From Institution of Engineers (India)** and M.Tech degree in "**Structural Engineering"** from Einstein academy of technology and management, affiliated to BPUT, Rourkela and approved by AICTE Govt. of India, New Delhi in 2016. He has served as HOD in Black Diamond School of Engineering, BRJN, and Jharsuguda for seven years and served as HOD in Ganapati Institute of Engineering and Technology, Jagatpur, Cuttack for 2 years. Presently he is working as an assistant professor, in Sudhananda Group of Institutions, Nachipur, Bhubaneswar, and Odisha. He has interested for doing his research work, Estimating, Structural Engineering, Green Technology high strength concrete design and RCC Designing etc.

Author Profile: 02

[Prof. (Dr.) Ramesh Chandra Rath]
He is an eminent professor & academician of an international repute in the field of management education (Mkt. &HR) and served 24 years service in various Government Colleges. Universities in Odisha and abroad .He has obtained his PG in Psychology from Sambalpur University, Concurred his MBA Degree from Delhi University in 1996, PhD, Degree Department of Management Studies "Birla Institute of Technology , Meshra , Ranchi" in 2000 on the area of ***Green Marketing & Supply Chain Management*** *(Marketing Management specialization) and Concurred his Post-Doctorate Degree from Patna University in 2003,on the area of* ***"Advanced physiology and Criminology "*** *He has presently working as a Professor-Cum-Dean at Research &Development Cell, EATM Bhubaneswar. Dr. Rath has guided four PhD research scholars on the specialization area of Green Marketing & supply Chain Management, Consumer Behaviour, and Organizational Behaviour, Production & Operational Management etc. There are 25 International journals and 28 National Journals with two books of publication in his credit.*