World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:2, No:4, 2008

An Intelligent System Framework for Generating Activity List of a Project Using WBS Mind map and Semantic Network

H. Iranmanesh, and M. Madadi

Abstract*—Work Breakdown Structure* (WBS) is one of the most vital planning processes of the project management since it is considered to be the fundamental of other processes like scheduling, controlling, assigning responsibilities, etc. In fact WBS or activity list is the heart of a project and omission of a simple task can lead to an irrecoverable result. There are some tools in order to generate a project WBS. One of the most powerful tools is *mind mapping* which is the basis of this article. Mind map is a method for thinking together and helps a project manager to stimulate the mind of project team members to generate project WBS. Here we try to generate a WBS of a sample project involving with the building construction using the aid of mind map and the artificial intelligence (AI) programming language. Since mind map structure can not represent data in a computerized way, we convert it to a *semantic network* which can be used by the computer and then extract the final WBS from the semantic network by the *prolog* programming language. This method will result a comprehensive WBS and decrease the probability of omitting project tasks.

***Keywords*—**Expert System, Mind map, Semantic network, Work breakdown structure,

I. Introduction

WORK breakdown structure (WBS) is the process necessary for subdividing the major project deliverables and project work into smaller, more manageable components and it is one of the processes of project scope management [1].

WBS can be considered as the heart of the project, because it can be served as a project planning and controlling framework and enables project team to achieve the following fundamental project management actions (Fig. 1): [2]

- Assign the responsibility of the project work.
- Schedule the project work and summarization.
- Estimate and aggregate cost or resources
- Develop the response to risks associated with project
- Measure performance.
- Aggregation project control and proactive actions

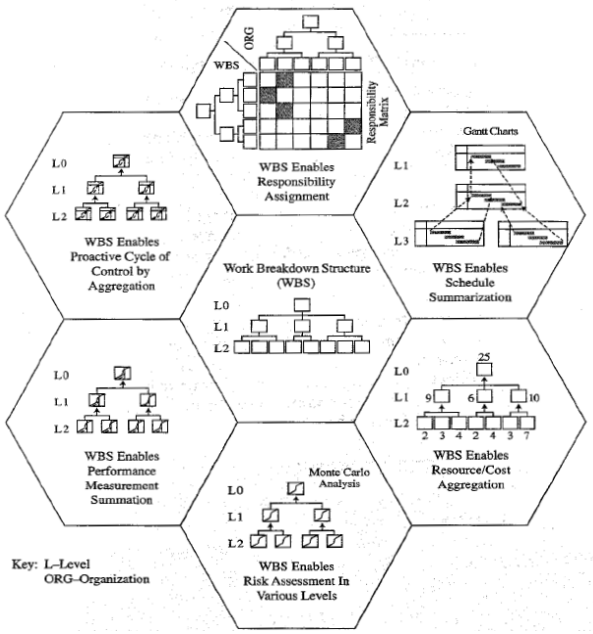


Fig. 1 WBS serves as the framework for integration of project planning and control

So creating WBS can be considered as a vital process. Rad (1999) presented the rationale and method to obtain a deliverable_oriented WBS [3]. Hashemi et al (2007) proposed a framework which plan WBS of a limited project domain using neural networks [4]. There are some ways for generating and developing a WBS. One of the most powerful tools is mind mapping which is the base of this article. A schematic WBS is shown in Fig. 2.

In this article we try to extract project WBS from the obtained mind map of brainstorming project team by an artificial intelligence (AI) tools which is prolog programming language. Expert systems (ES) and artificial intelligence (AI) can be used in different aspects of project management widely. These tools can help project management teams to capture their experiences and share such experiences with others. An expert system (ES) is a computer program designed to solve procedural problems based on human expert's skills.

H. Iranmanesh, Assistant Professor, "University of Tehran" & "Institute for Trade Studies & Research" ,Tehran, Iran (corresponding author, phone: +9821-88021067, fax: +9821- 88013102, e-mail: hiranmanesh@ut.ac.ir).
M. Madadi, M.S. Candidate, Socio-Economic Systems Engineering, University of Tehran, Tehran, Iran (e-mail: ma.madady@gmail.com).

Hosley et al (1987) explained how project managers can use AI/ES to more effectively practice project management and reviewed the principles defining AI and ES and described a process for creating an ES [5]. Adedeji et al (1988) examines the emerging technology of ES that enables project managers to analyze cost by integrating multiple cost factors [6]. They explained ES's function and three categories-data structure, knowledge base, and inference engine-and the ways that ES differs from traditional decision support systems. Kangari, et al. (1989) described a method of using expert systems (decision-support programs containing a large body of knowledge from field experts) to resolve the difficulties associated with traditional risk management models and examined a prototype expert system for construction projects, a system named Expert-Risk [7]. Nordin et al. (1990) explained the development of a knowledge-based schedule planning system [8]. Kermit et al. (1991) developed a prototype expert system, called PROJCON, that helps to generate management plans and strategies for a given construction task [9]. The system also helps to survey, control and revise the plans according to the current change of condition. Mango, Ammar (1992) introduced a new planning system that provides valuable historical and development process expertise to the planning team which is particularly useful for a cross-functional/multi-projects organization with a complex process [10]. Leung et al. (1998) presented a knowledge_based system to identify potential risk factors incorporating work breakdown structure [11]. Carlos Zozaya-Gorostiza (1999) reviewed the capabilities and application of a knowledge_based expert system named Construction Planex system which is used in construction projects [12]. Schuyler, John R (2000) overviewed expert systems, explained how they work, and cited numerous examples. He described artificial neural networks (NNs) and inference engines and offers a set of guidelines for deciding when a problem is appropriate for an expert system solution [13]. Avots, Ivars examined how ES can help project managers to analyze and control project schedule [14]. Nemati, H.R. et al. showed how a hybrid intelligence system with expert system and artificial neural network components can be used to aid in project estimate validation and quality prediction of the deliverables [15]. Xiaoqing (Frank) Liu et al. (2006) discussed design, implementation, and evaluation of an experimental intelligent software early warning system based on fuzzy logic to make sponsors, users, project managers aware of many potential risks as early as possible [16]. K.C.Lam et al. (2007) proposed a model for risk allocation decision in construction contracts using a set of knowledge_based fuzzy interface rules according to the expert knowledge [17]. K.C. Iyer et al. (2007) devised a rule_based expert system to assist contract administrator to evaluate worth of their claims before taking it to litigation and decrease the number and frequency of claims and disputes beside time and cost overrun in Indian construction contracts [18].

As you see ESs and AI were applied in different scope of project management like risk, scheduling, controlling, contracts, etc. In spite of the importance of planning process especially WBS in project management there are no or limited work in this scope. So we proposed a method which can be used in every domain for generating WBS using AI tools.

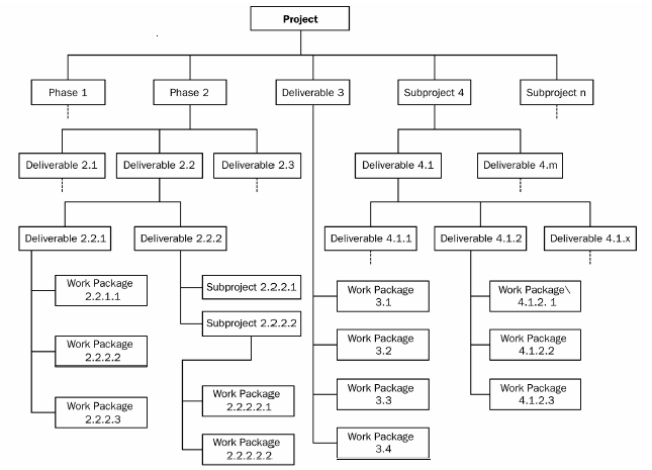


Fig. 2 A schematic WBS

In the following sections we describe mind map and its application in project management and especially in generating and developing WBS. Then we define semantic network as a knowledge representation tools. At the end we try to generate the WBS of a sample project (project of building a construction) with the aid of prolog programming. The proposed method is shown in Fig. 3.

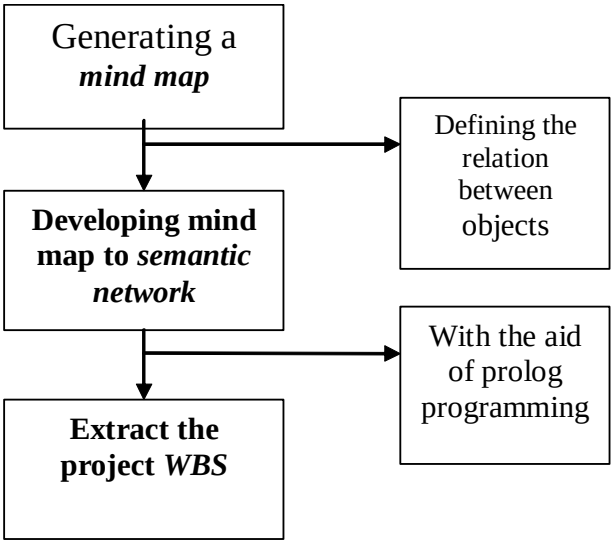


Fig. 3 (Proposed method) The process of extracting WBS

II. Proposed Method

A. Mind Map

A mind map is a diagram used to represent words, ideas..., or other items arrange radially around a central keyword or idea. It is used to generate, structure, classify ideas as an aid of study, problem solving, decision making, etc.

Mind mapping involves writing down a central idea or object and thinking up new and related ideas which radiate out from the centre (in a none _linear manner) and arcs that represent semantic or other connection between object, idea and portion of information. Arcs are the most significant part in a mind map and without them you would only have a gigantic untidy of headlines and it would be quite hard to understand.

With the aid of mind map you are mapping knowledge in a manner which will help you to understand and remember new information and think creatively with brainstorming approach. Mind mapping helps you to boost your creativity, create winning ideas, enhance your memory, structure your knowledge, and sharpen your focus. Mind map is one of the best methods to optimize ones' learning capacities and understanding of how the elements of complex structure are connected. Mind maps have been used for centuries for learning, brainstorming ,visual thinking, problem solving, decision making, etc. by educators, engineers, psychologists and people in general .But the claim to the origin of mind map has been made by a British Popular psychologist, author, Tony Buzan.

Buzan claims that mind map is vastly superior to note taking method and utilizes the full range of left and right human cortical, skills, balances the brain, taps into the alleged 99% of your unused mental potential [23]. Buzan originally envisioned mind mapping as a tool to stimulate individual creativity, and "using both sides of your brain." The brain works according to certain basic principles and you can use mind maps to take the advantage of them to improve your creativity and memory [19].

B. Mind Map as a Project Management Tool

Mind maps have great applicability in project management. Left-brain or linear thinking may be important for scheduling, resource allocation, and monitoring project progress. But, the definition and early planning stages (like definition of WBS) require more whole brain thinking [20].

Imagine there is a project you want to do. You have thousands of ideas spinning around in your head and it is making you dizzy. Your problem is that there are too many things you want to do, too much you need to take care of [19].

You can easily overcome that situation completely using mind maps and it's most common technique: brainstorming.

Mind mapping allows project manager and project team to more easily collaborate, brainstorm, solve problem, visualize structure, classify and gather ideas, analyze complex ideas and concept, and because of these, it is a suitable project management tool and can be used for assigning priorities, determining which specific resources are needed for both individual tasks, scheduling, processing , time management, task management, agenda setting, event planning, and creation of effective presentation..

This means that team can get a lot accomplished in single meeting and in a very short time.

All in all mind mapping is a powerful brainstorming, visualization and facilitation tool for project management and can save an organization time and money in its project planning and management process [21].

A sample mind map is shown in Fig. 4 [20].

Finally what mind map can do is:

- Promote inter-team communication, thereby aiding decision-making.
- Optimize and simplify any project may you have.
- Quickly gain insight into the big picture of any project.
- Boost your creativity.
- Help your mind to become a powerful idea generator.
- Instantly see connections and links between different subjects.

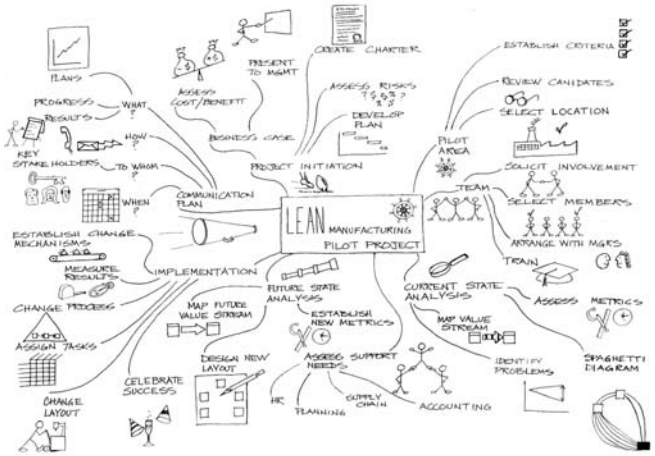


Fig. 4 A sample mind map for lean manufacturing project

C. Mind Map as a WBS Generating and Developing Tool

WBS is a hierarchical breakdown of the work to be done in the project or as it is defined in PMBOK is the process necessary for subdividing the major project deliverables and project work into smaller, more manageable components [1].

Maybe all of us have the experience of the omission of important project details that led to irrecoverable and serious outcomes. Many of these unwanted events happen because of being inattention to think strategically and creatively at the time of planning projects. The tendency for planners to jump immediately to scheduling and "doing" is a function of organizational biases toward "left-brain" or linear thinking that led to these events [20].

The value of WBS can be stated as follows:

- WBS organizes the project work and creates a framework which integrates the management of the project and other processes like controlling, planning, scheduling, etc.
- WBS enables project team to organize the work into small deliverable and make easy the assigning responsible for each deliverable and activity.

In the initial and planning stage, a successful manager should use his team creativity, in fact a creative leadership is not enough and leader should facilitate the context and introduce an

appropriate tool to his team for exchanging opinions and making new and creative ideas. In this stage we may face to these questions:

- What will be the major project deliverable?
- What tasks must be done to complete these deliverables?
- What might go wrong if we implement the project in this way (with these tasks)?

A WBS can be created using any techniques of listing and groping project activity and tasks. One of the most powerful tools for finding the best solution for these questions and creating WBS is mind mapping. Mind maps are useful for any topic or task in which seeing the big picture, recognizing relationships, and stimulating creativity are important. They rely on a branching format to show relationships and to deconstruct a large entity into its component parts. Mind mapping can provide a mechanism for bringing out a group's creativity and stimulating whole-brain thinking at these critical steps.

With this approach project team begin to brainstorm, keeping in mind the various categories of major deliverables and appreciating connections. Each major component gets a branch, and the team captures ideas in words and symbols using color, size, and shape to add emphasis. Writing down each output on a separate note and brainstorm with the project team to find all the tasks that would need to be completed to deliver the output the mind map is formed (as it is shown in Fig. 5)[20].

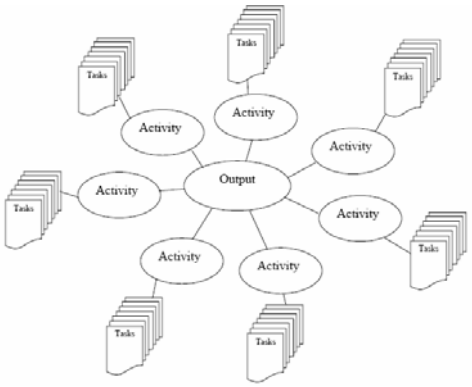


Fig. 5 Mind map showing an output broken to tasks

D. Semantic Network

A *semantic network* is a graphic notation for representing knowledge in pattern of interconnected nodes which represent concepts, and arcs which represent semantic and binary relationship between concepts. Knowledge representation (in AI) is used to represent knowledge in a manner to facilitate drawing conclusion from knowledge and its fundamental aim is to store knowledge so that computer program can process it and achieve the verisimilitude of human intelligence. There are some ways of knowledge representation like: rules, frames, etc. but we use semantic network.

Semantic networks were motivated by cognitive models of human memory; they are a compromise between the logic "declarative" and the "procedural" forms of knowledge representation.

Semantic network originally developed in the early 1960s. Firstly semantic network have long been used in psychology, philosophy and linguistic. But later they have been developed for artificial intelligence and machine translation [23].

Mind map and semantic network are similar to each other, but there are some differences between them: In mind map there are no restrictions on the kinds of links and relationships used, in fact in mind map kind of the relation between objects are not important but in semantic network a binary relation between objects must be determined. A fairly major difference between mind maps an semantic networks is that the structure of a mind map, with nodes propagating from a centre and sub nodes propagating from nodes is *hierarchical*, whereas semantic networks, where any node can be connected to any node, have a more *heterarchical* structure.

The most important relations between concepts are subclass relations between classes and sub classes, and instance relations between particular object and their parent class.

However any other relations are allowed. Some of common relations are as follows:

- **ISA** – relates an object to a class, i.e. it defines an instance of a class
- **AKO** (a-kind-of) – relates a class to another class, or may define a subset. This link type demonstrates the relationship between classes.
- **PARTOF** (part-of) – represents how an object is composed of other objects, or inherits only part of the parent class.
- **HASA** (has-a) – relates an object to a property or attribute.

But it is possible to define any relation between objects in a semantic network [22].

A sample semantic network is shown in Fig. 6.

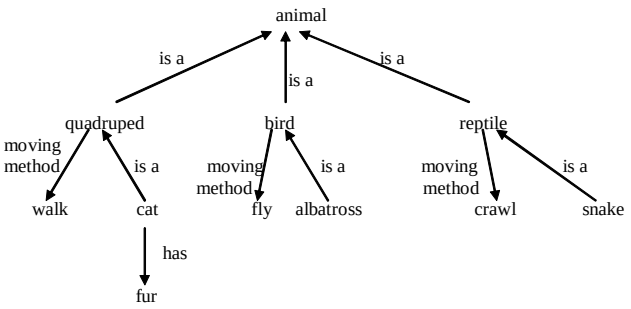


Fig. 6 A sample semantic network

E. Generating WBS of a Sample Building Project

At the end we try to generate WBS of a sample building construction project which has three floors with the mentioned approach. The schematic plan of each floor is shown in Fig. 7.

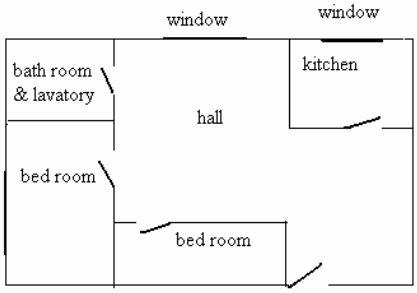


Fig. 7 The schematic plan of construction

A part of the related mind map and semantic network of this sample project are shown in Figs. 8 and 9 respectively.

Finally we extract the project WBS with the aid of prolog programming. Some of tasks which are extracted from the related semantic network are as follows:

- Execute of foundation.
  - Excavation of foundation.
- Execute base of columns.
- Execute columns.
- Execute walls.
  - Plastering of wall of grand floor.
  - Painting of wall of grand floor.
  - etc.
- Install of powerhouse's equipments
- Execute hot/cold water piping.
- Install of door and windows
- Water proofing of roof.
- Execute of face:
  - Install face's stone.

- Etc.

Pseudocode of prolog programming is:

- If has(X, Y), isa(Y, equipments); then create an activity which is installation of Y on X.
- If has(X, Y), not (isa(Y, equipments)); then create an activity which is execution of Y on X.
- If has(X, Y), op_of(X, Y); then create an activity which is execution of X with the sub activity of X on Y.

A part of source code of this program is shown in appendix 1 and a part of out put of mentioned prolog program is shown in appendix 2 as well. This example shows this framework can be used for extracting the Task list of a project successfully.

III. Conclusion and Further Work

With respect to the importance of WBS in planning stage, developing of a method for creating WBS is a vital need. As you see mind mapping and AI are suitable tools for this goal and can lead to a comprehensive WBS.

As a future survey, brainstorming of experts in an especial domain and generating a mind map WBS in the first phase and developing an expert system with the aid of AI and semantic network in the second phase to create and develop WBS of project can be suggested.

Appendix I
A Typical Source Code of Prolog for Sample Building Project

```
has(foundation,base).
has(frame,column).
has(frame,beam).
has(column,base).
has(gf,powerhouse).
has(f3,roof).
isa(equipment,equipments).
has(powerhouse,equipment).
has(f1,coolers).
has(f2,coolers).
has(f3,coolers).
isa(coolers,equipments).
has(f1,coolerscanal).
has(f2,coolerscanal).
has(f3,coolerscanal).
isa(coolerscanal,equipments).
has(gf,floor).
has(f1,floor).
has(f2,floor).
has(f3,floor).
has(gf,ceiling).
has(f1,ceiling).
has(f2,ceiling).
has(f3,ceiling).
has(ceiling,beam).
has(gf,wall).
has(f1,wall).
has(f2,wall).
has(f3,wall).
has(gf,hotcoldwaterpipe).
has(f1,hotcoldwaterpipe).
has(f2,hotcoldwaterpipe).
has(f3,hotcoldwaterpipe).
has(f1,face).
has(f2,face).
has(f3,face).
has(face,stone).
isa(stone,equipments).
has(f1,kitchen).
has(f2,kitchen).
has(f3,kitchen).
has(kitchen,cabinet).
isa(cabinet,equipments).
has(gf,doorwindow).
has(f1,doorwindow).
has(f2,doorwindow).
has(f3,doorwindow).
isa(doorwindow,equipments).
has(gf,staircase).
has(f1,staircase).
has(f2,staircase).
has(f3,staircase).
has(foundation,leanconcrete).
has(foundation,foundationframework).
op_of(cimentmortarexecution,floor).
op_of(excavation,foundation).
op_of(parapetinstalation,staircase).
op_of(columnexecutian,wall).
op_of(walling,wall).
op_of(plastering,wall).
op_of(plastering,ceiling).
op_of(painting,wall).
```

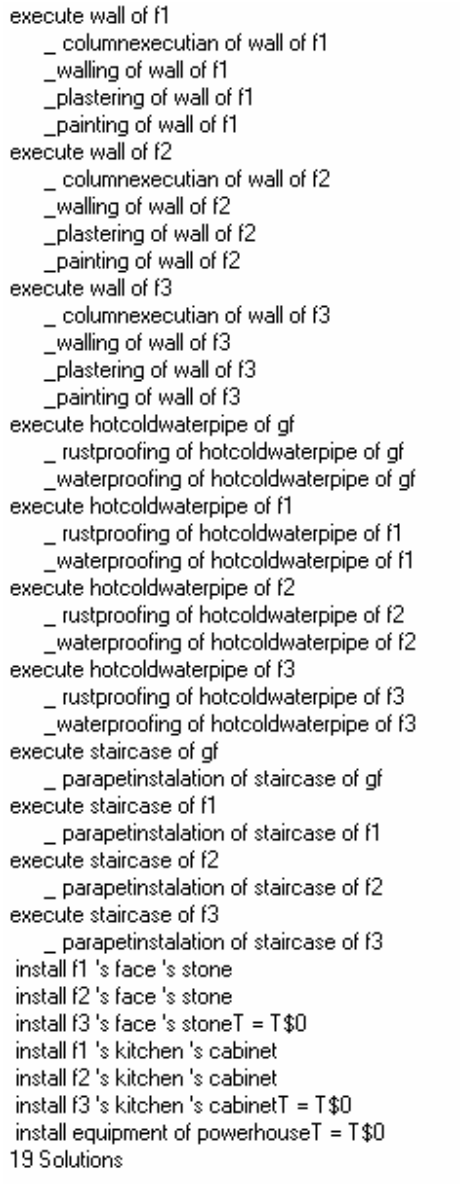
```
op_of(painting,ceiling).
op_of(waterproofing,roof).
op_of(rustproofing,hotcoldwaterpipe).
op_of(waterproofing,hotcoldwaterpipe).
not(P):-
P,!,fail
; true.
task(T):-
  op_of(X,Y),  not(has(Z,Y)),
  write(" execute ",Y),nl,write("      _ ",X," of ",Y).
task(T):-
  has(X,Y),has(Y,Z),not(isa(Z,equipments)),
  write("  execute ",X," 's ",Z," of ",Y).
task(T):-
  has(X,Y),not(has(Z,X)),
  isa(Y,equipments),
  write(" install ",X,"' s ",Y).
task(T):-
  has(X,Y),
  op_of(Z,Y),retract(has(X,Y)),
  write("execute ", Y," of ",X),nl,
   write("      _ ",Z," of ",Y, " of " ,X),
  nl,w(X,Y,Z,Z1).
    w(X,Y,Z,Z1):-
      op_of(Z1,Y),not(Z1=Z),
      write("      _ ",Z1," of ",Y, " of " ,X),nl,fail.
member(X,[X,L]).
member(X,[Y|L]):-
  member(X,L).
task(T):-
  has(X,Y),has(Y,Z),

has(W,Y),not(has(X,Y)==has(W,Y)),has(V,Y),not(has(W,Y)==has(V,Y)),
  not(has(X,Y)==has(V,Y)),  isa(Z,equipments),
  write(" install ",X," 's " ,Y," 's ",Z),nl,retract(has(X,Y)),
  write(" install ",W," 's " ,Y," 's ",Z),nl,retract(has(W,Y)),
  write(" install ",V," 's " ,Y," 's ",Z),retract(has(V,Y)).
task(T):-
   has(X,Y),has(Y,Z),retract(has(X,Y)),not(has(W,Y)),
   isa(Z,equipments), write(" install ",Z ," of ",Y),!.
```

APPENDIX II

A PART OF PROGRAM OUTPUT

```
task(T)
 execute foundation
     _ excavation of foundationT = T$0
  execute frame 's base of columnT = T$0
  execute gf 's beam of ceilingT = T$0
  execute f1 's beam of ceilingT = T$0
  execute f2 's beam of ceilingT = T$0
  execute f3 's beam of ceilingT = T$0
 install f1' s coolersT = T$0
 install f2' s coolersT = T$0
 install f3' s coolersT = T$0
 install f1' s coolerscanalT = T$0
 install f2' s coolerscanalT = T$0
 install f3' s coolerscanalT = T$0
 install gf' s doorwindowT = T$0
 install f1' s doorwindowT = T$0
 install f2' s doorwindowT = T$0
 install f3' s doorwindowT = T$0
execute roof of f3
     _ waterproofing of roof of f3
execute floor of gf
     _ cimentmortarexecution of floor of gf
execute floor of f1
     _ cimentmortarexecution of floor of f1
execute floor of f2
     _ cimentmortarexecution of floor of f2
execute floor of f3
     _ cimentmortarexecution of floor of f3
execute ceiling of gf
     _ plastering of ceiling of gf
     _painting of ceiling of gf
execute ceiling of f1
     _ plastering of ceiling of f1
     _painting of ceiling of f1
```



REFERENCES

[1] Project Management Institute, "A guide to the project management body of knowledge", Third Edition, PMI Publisher, 2004, pp. 110-117.

[2] D. Z. Milosevic, "Project management toolbox", John Wiley & Sons, 2003, pp.165-167.

[3] P F. Rad "Advocating a deliverable-oriented work breakdown structure." *Cost Engineering (Morgantown, West Virginia)*, v 41, n 12, Dec, 1999, pp 35-39.

[4] A Hashemi Golpayegani, B Emamizadeh." Designing work breakdown structures using modular neural networks". Decision Support Systems 44, 2007, 202–222.

[5] Hosley, W N," The application of artificial intelligence software to project management."1987, Project Management Institute.

[6] C. J. Adedeji B. Badiru." Cost-integrated project network planning using expert systems.", 1988, Project Management Institute.

[7] Kangari, R, Boyer, LeRoy T. "Risk management by expert systems.", 1989. Project Management Institute.

[8] Nordin B Y, Babcock D L, Colin O B, "Development of a knowledge-based schedule planning system. ", 1990, Project Management Institute

[9] G., Kermit H,Lenart,Mihary." PROJCON. An expert system for project controls in construction managemen.t" ,1991,3rd International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems.

[10] A Mango." Expert system concepts for project planning.".,1992, Project Management Institute.

[11] HM Leung, KB Chuah, VM Rao Tummala." A Knowledge-based System for Identifying Potential Project Risks". Omega, volume26, Issue 5, 1998, 623-638.

[12] C Zozaya-Gorostiza, C Hendrickson, D R. Rehak" A knowledge-intensive planner for construction projects." Building and environment. Issue 3. 1990, 269-278.

[13] Schuyler, John R "Expert systems in project management. ".2000, Project Management Institute.

[14] Avots, Ivars," Application of expert systems concepts to schedule control "Project Management Institute.

[15] Nemati H., Todd, D. W. Brown, Paul D," A hybrid intelligent system to facilitate information system project management activities ", 2002, Project Management Institute.

[16] Xiaoqing (Frank) L, Gautam Kane, Monu Bambroo " An intelligent early warning system for software quality improvement and project management",2006,Journal of systems and software, volume 79,Issue 11,1552_1564.

[17] K.C. Lam, D. Wang, Patricia T.K. Lee, Y.T. Tsang. "Modeling risk allocation decision in construction contracts" International Journal of Project Management 25 ,2007, 485–493.

[18] K.C. Iyer, N.B. Chaphalkar, G.A. Joshi. "Understanding time delay disputes in construction contracts". International Journal of Project Management 26 , 2008, 174–184.

[19] M Ingemann, "The power of mind mapping", e-book.

[20] N. Lea Hyer, K. A. Brown,"Whole-brain thinking for project management".

[21] T Akpodiete. "Mind mapping as a Project Management Tool" .Project Management Institute.

[22] D.J. Mullier, M.B. Dixon. "Authoring Educational Hypermedia Using a Semantic Network" Faculty of Information and Engineering Systems, Leeds Metropolitan University.

[23] Wikipedia site_ the free encyclopedia.

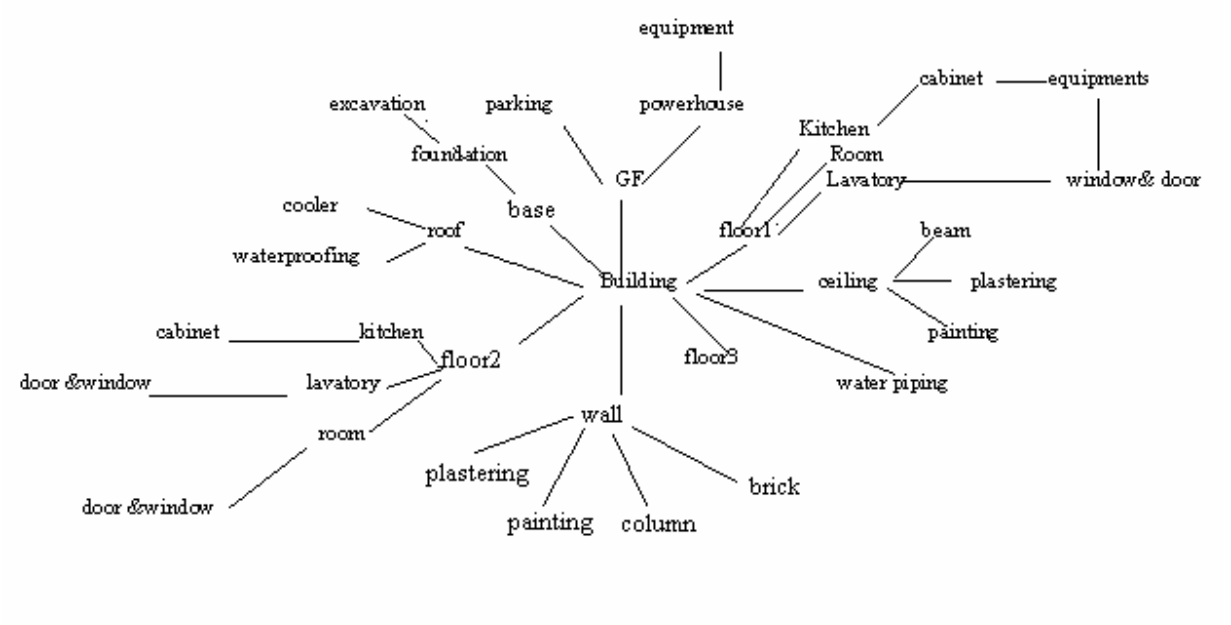


Fig. 8 Part of the mind map of sample building project

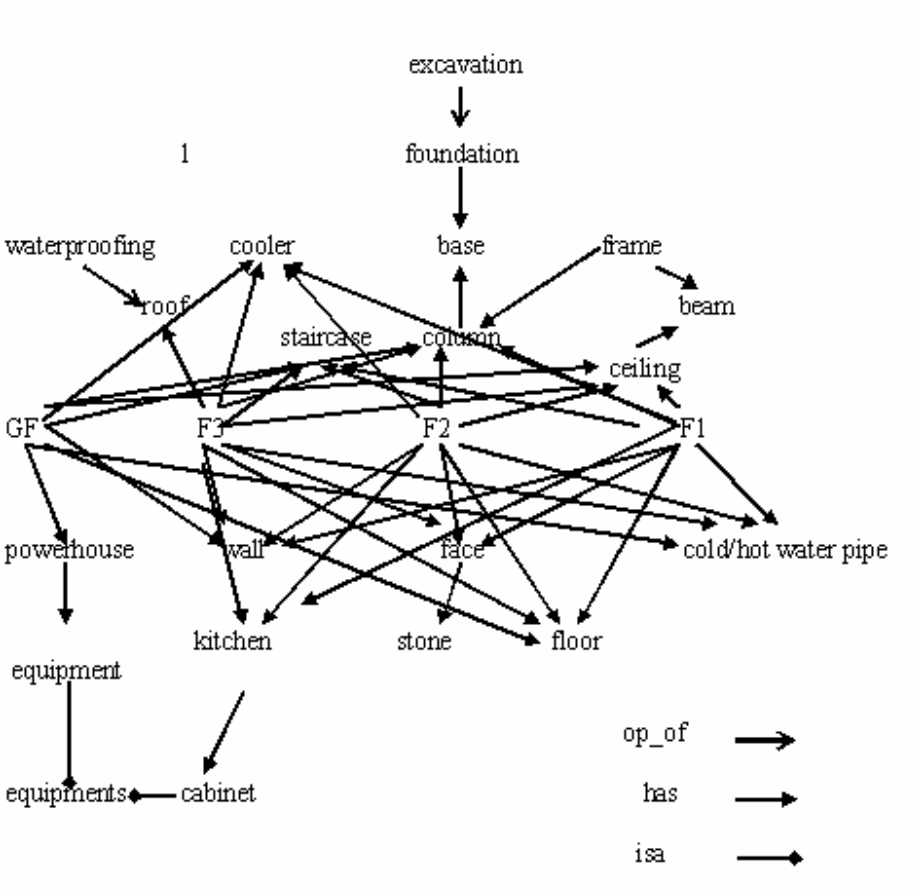


Fig. 9 Part of semantic network of sample building project