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Development of Algorithms Under Matlab for the Study of Characteristics Motion Components Associated With Descending Moon Impact Probe (mip) and its Validation From Sequential Photo Images Aquired During the Descend From Chandrayan-1.

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Abstract

The present paper is an attempt to know the motions characteristics associated with descending motion of Moon Impact Probe (MIP), a probe on board Chandrayan -1 designed to impact moon surface at pre decided location for scientific data collection from close range. For this, three independent motions viz.; spinning ,coning and translations were considered for a falling object and algorithms have been developed under MATLAB to simulate the surface trace from assumed parameters. Similar surface traces were generated using the time sequential images acquired by the descending MIP to moon surface without considering the three fundamentals motions as in first case. It has been observed that the two moon surface trace are quite similar which supports our assumptions of three above said independent motions. Such study is expected to provide a basis to choose suitable motion parameters for future MIP release to moon surface.

Keywords : Chandrayan1, Moon Impact Probe, Descending Motion, MATLAB

1. INTRODUCTION

Moon Impact Probe (MIP) is an unique, stand alone micro satellite probe which was released on 14^{th} November 2008 from Chandrayaan-1, a first Moon mission of ISRO launched on Oct 22nd, 2008. The MIP was designed to impact at a pre-decided location on the moon with a purpose of scientific exploration of moon from the close range and to design, develop and demonstrate the technology required for deciding suitable impact site for probing the Moon. This MIP took about 25 min to impact near the south-pole surface of the Moon with a velocity of about 1.6 km/s. After separation, the MIP and the mother space craft Chandaryaan-1 were both in the same line of site so that the data send by the descending MIP could be received by the mother space craft as shown in fig no.1a and the details of instruments on board MIP is given below(Kumar et al 2009,Goswami et al 2009):

- Radar Altimeter – which measured the altitude of the probe during descent and provided information on qualifying technologies for future landing missions. The operating frequency band was 4.3 GHz ± 100 MHz.

- Video Imaging System – acquired close range images of moon's surfaces during descent at defined interval until its impact on moon's surface. The video imaging system consisted of an analog CCD (SONY ,Model XC 555 camera)camera.

- Mass Spectrometer – measured trace constituents of the lunar atmosphere during descent. This instrument was a quadrupole mass spectrometer with a mass resolution of 0.5 amu and sensitivities to partial pressures on the order of 1.3×10^{-11} pascal.

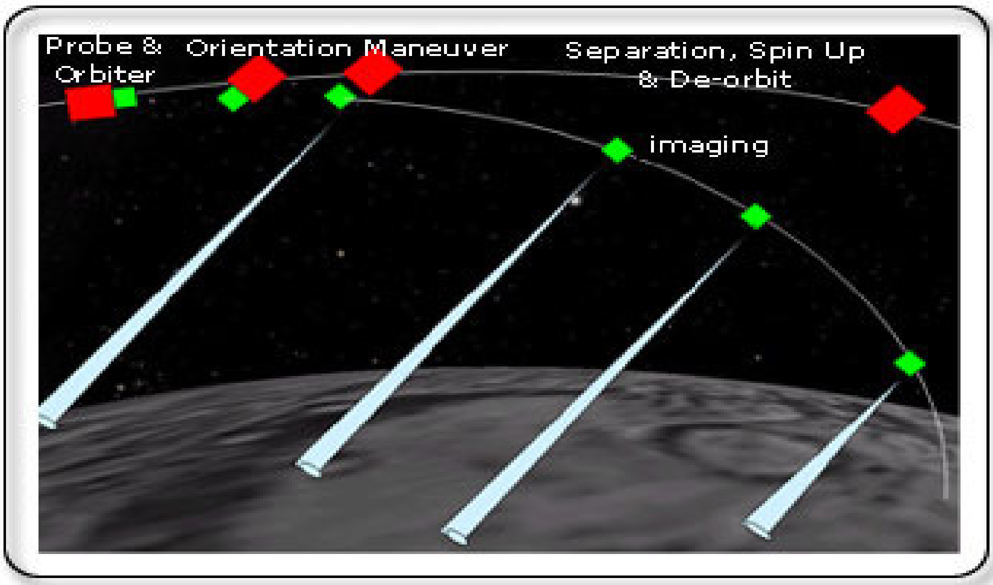


FIGURE 1a: The MIP mission profile

The present work specifically deals with the development of algorithm under MATLAB for simulating the pattern of surface traces assuming three basic independent fundamental motions of a falling body in space viz.; rotating ,coning and translational and comparing the same from the real surface trace patterns on moon derived from time sequential images acquired during the fall from the Chandrayan-1. Such basic understanding of motions could provide a basis for deriving motion parameters as well future landing sites for MIP.

2. METHODOLOGY AND DATA USED

Programs have been written in MATLAB from which surface traces were generated separately for 3-independent basic motions (see fig nos.2 to 4). There after algorithms were developed to generate surface traces due to composite motions of all three by taking some arbitrary values of these. In next stage moon surface traces of motion of descending MIP were mapped from about 3000 time- sequential corrected photo images of dimension 720*576 pixels, acquired after 25 minutes of journey at 20:31 Hrs IST covering the region in and around Shackleton Crater located in south pole region of moon (see fig no1b) and were received on 14th November 2008 by the Chandrayaan-1. This crater Shackleton has been the subject of intense study which is coincident with the south pole and is an unremarkable crater whose interior is almost completely in permanent shadows (Bussey et al 1999).The time interval between the two subsequent odd-even frames has been 20 m sec where as it is 1.72 m sec in between two subsequent even-odd frames ie time interval between each odd-odd pair is 1.72 sec. (these sets of data were provided by the Space Application Center of ISRO, Ahmedabad, India to junior author during his training program). Finally the surface traces of two motions , one from assumed motion data and the other from mapped real MIP motions have been generated and were then compared for verifying the nature of associated motions with descending MIP.

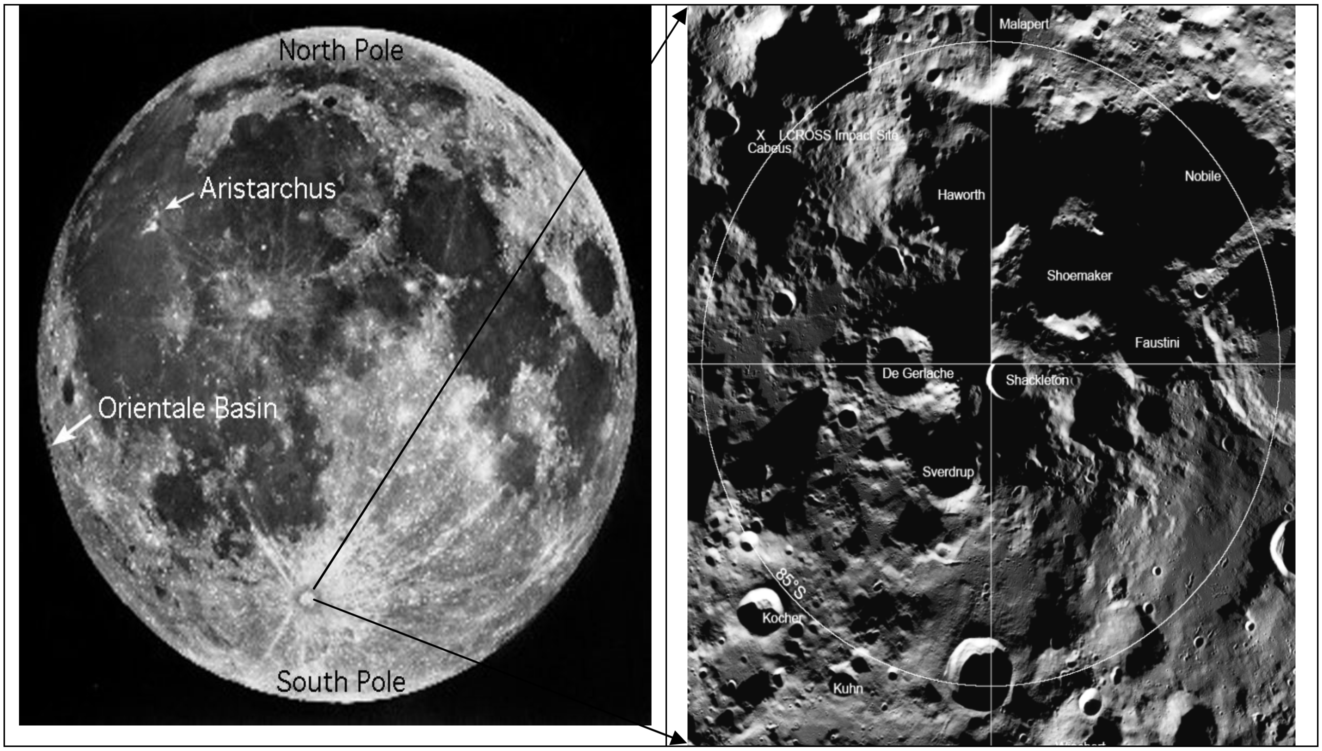


FIGURE 1b: LROC Wide Angle Mosaic of Lunar South Pole showing locations of major craters and Shackleton (modified after NASA/ GSFC/Arizona State University).

3. DEVELOPMENT OF ALGORITHM UNDER MATLAB ASSUMING THREE BASIC MOTIONS ASSOCIATED WITH ANY FALLING OBJECT UNDER GRAVITY VIZ.; SPINNING (ROTATION), CONING AND FORWARD TRANSLATION MOTION.

The following paragraphs discusses step by step the concept and algorithm for above mentioned three independent motions:

a. Spinning (rotation)
In rotation the each particle of the body moves in a circle and their center on a straight line, called axis of rotation and the perpendicular line to the axis of rotation from a point will sweep equal angle in equal time interval.

Let us consider a particle P rotating in 2D (x-y) plane with angular velocity w r p s (see fig 2a and 2b). The initial position of the particle is P(x0,y0), and after a certain time t the position is P'(x1,y1). The particle is rotating along a circular path having a radius

$$R = \mathrm{sqrt}(x0^2 + y0^2) = \mathrm{sqrt}(x1^2 + y1^2)$$

And the initial angle is $a = \tan - 1\left(\frac{y0}{x0}\right)$.

The particle sweep an angle b=w*t.

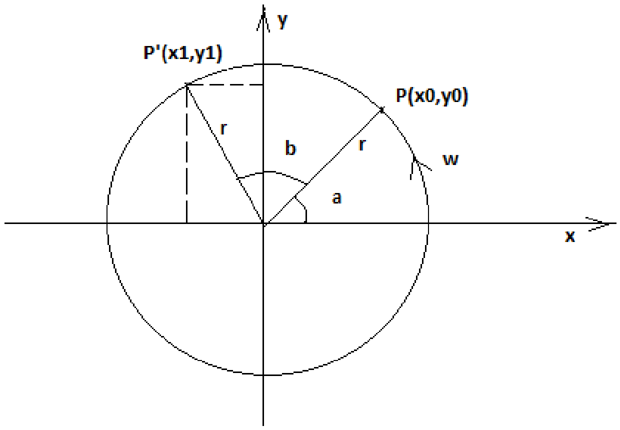


FIGURE 2a: Shows basic spining motion.

MATLAB program

```
t=0:.5:50;
x0=2;
y0=5;
w=72;
p=sin(w*t+atan(y0/x0));
q=cos(w*t+atan(y0/x0));
y1=sqrt(x0^2+y0^2)*q;
x1=sqrt(x0^2+y0^2)*p;
plot(x1,y1),grid;
```

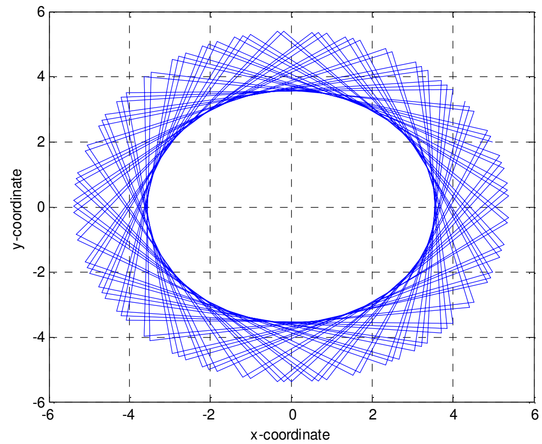
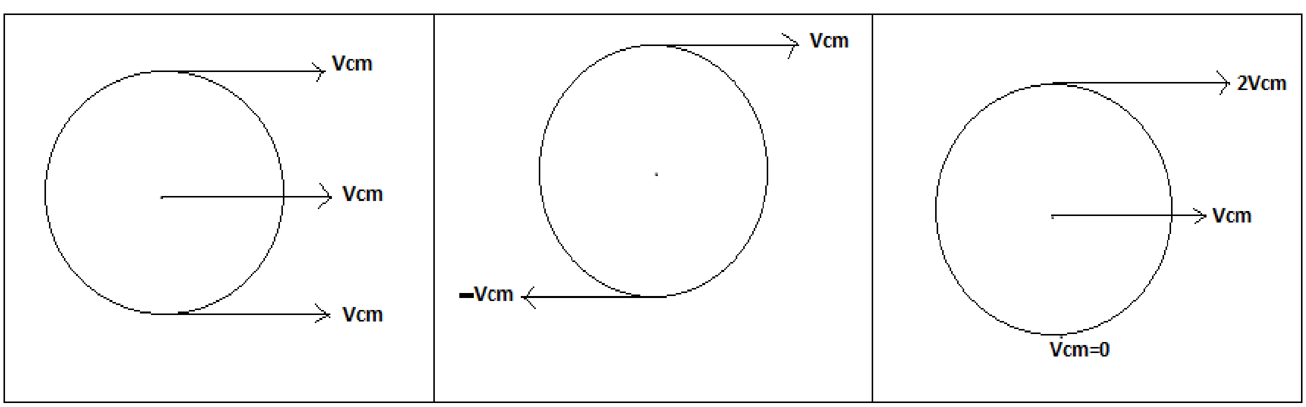


FIGURE 2b: MATLAB plot for a body which is rotating about a fixed axis (spinning).

b. Spinning (rotation) Along With Translation Motion (see FIGURES 3a and 3b)

If the rotating body is translating with the velocity V at an angle θ with respect to the horizontal then the composite motion shall be as shown below.



Pure translation Pure rotation Rotation with translation

FIGURE 3a: Shows the basic spinning, rotational as well as combined rotational and translation motions.

MATLAB program

```
t=0:.5:50;
x0=4;
y0=5;
v=30;
w=500;
theta=pi/6;
p=sin(w*t+atan(y0/x0));
q=cos(w*t+atan(y0/x0));
y1=sqrt(x0^2+y0^2)*q+(v*sin(theta)*t);
x1=sqrt(x0^2+y0^2)*p+(v*cos(theta)*t);
plot(x1,y1),grid
```

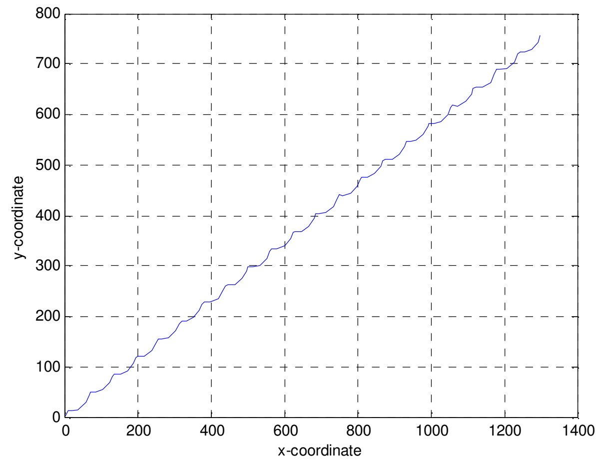
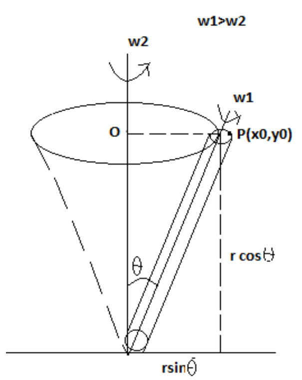


FIGURE 3b: MATLAB plot describing the composite motion of rotation, and translation.

c. Rotation (spinning) Along With Coning



Here,
w1 is the spinning rate.
w2 is the coning rate.
r is the height of the camera.
θ is the inclination angle of the camera with the vertical

FIGURE 4a: This figure demonstrate the concept of coning motion along with spinning motion.

MATLAB program:

```
t=0:.005:2000;
x0=4;
y0=5;
h=30;
w1=100;
w2=10;
theta1=pi/6;
p=sin(w1*t+atan(y0/x0));
q=cos(w1*t+atan(y0/x0));
y1=sqrt(x0^2+y0^2)*q+(h*tan(theta1)*cos(w2*t)
);
x1=sqrt(x0^2+y0^2)*p+(h*tan(theta1)*sin(w2*t))
;
plot(x1,y1),grid;
```

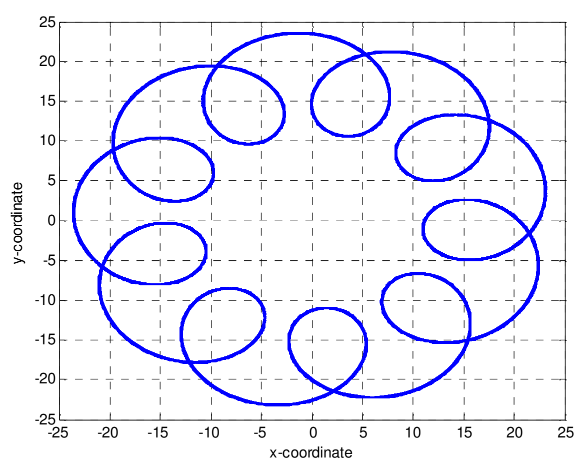


FIGURE 4b: The MATLAB lab plot describing the composite motion of rotation along with coning.

Algorithm for Combined Spinning, Coning and Translation Motions of MIP (see FIGURE 5).

In this case we see the above in some modified way, i.e. we can see the effect of the above case along with the translation motion.

MATLAB Program

```
t=0:.25:80;
x0=4;
y0=5;
h=30;
v=10;
w1=600;
w2=300;
theta1=pi/4;
theta=pi/6;
p=sin(w1*t+atan(y0/x0));
q=cos(w1*t+atan(y0/x0));
y1=sqrt(x0^2+y0^2)*q+(h*tan(theta1)*cos(w2*t))+(v*sin(theta)*t);
x1=sqrt(x0^2+y0^2)*p+(h*tan(theta1)*sin(w2*t))+(v*cos(theta)*t);
plot(x1,y1),grid;
```

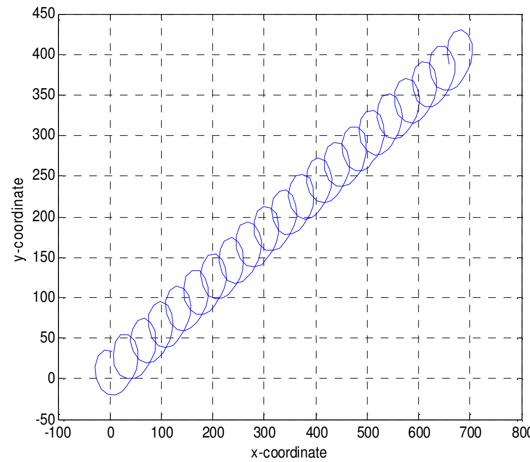


FIGURE 5: The MATLAB plot for the composite motions of rotation, coning and translation.

4. RESULTS AND DISCUSSIONS

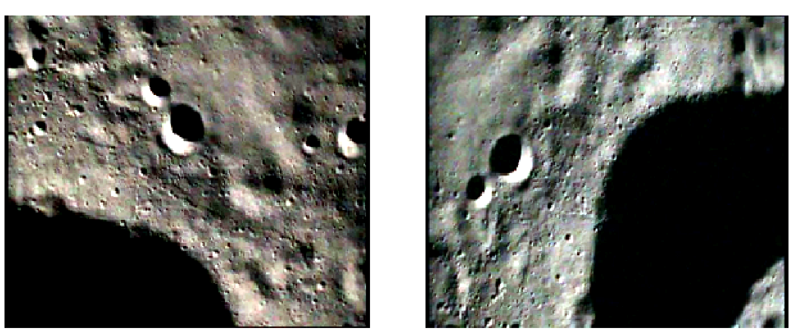
Using assumed parameters and the algorithm developed under MATLAB the surface motion traces were generated without any consideration to real data. We have chosen some arbitrary values of the motion parameters and then computed the final position from the initial point. Thereafter we plotted the surface traces of the descending MIP having composite motions viz.; spinning, coning and forward translation motion.

Later similar ground motion traces were derived using the parameters derived from space sequential images acquired by the descending MIP of the Chandrayan -1 and on comparision with simulated one it is observed that both the traces are similar. This fact supports our basic consideration that the motion of descending MIP has three motion components as discussed and stated below.
The fig no.6 shows consecutive images of two frames of MIP which shows the features/objects are rotating and indicates the spinning motion of MIP about its axis.

In FIGURE 7, it is observed that the objects in the images are rotating and certainly they go away from the frame and after a certain time the objects are reappearing in the frames. So we can easily conclude that the MIP is spinning and also coning with respect to a certain axis.

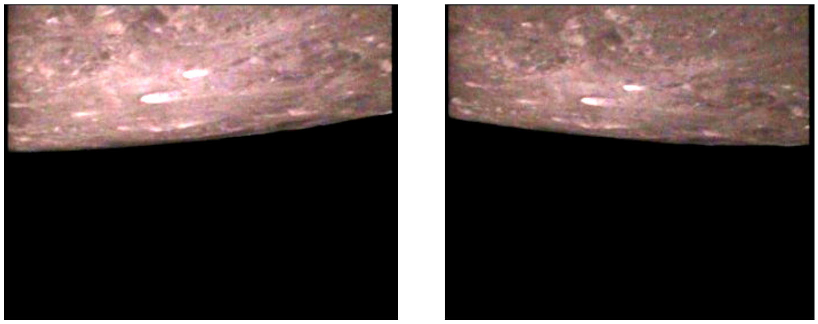
In FIGURE 8, it is seen that besides rotation, the features in the images are moving in a certain direction which is opposite to the direction of the camera movement from which it is concluded that the camera is translating with a certain velocity.

So it has been possible to verify three basic motions of descending MIP from traces as mapped from developed algorithms as well as from acquired images of MIP.



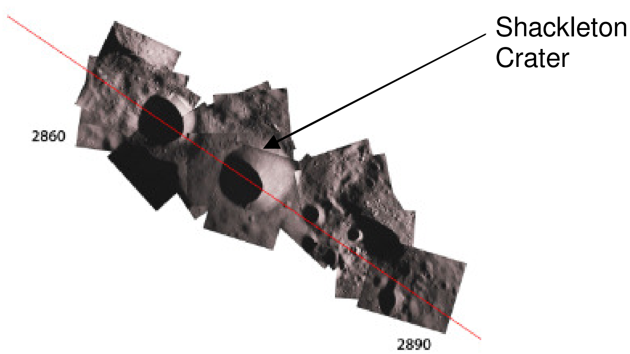
Frame # 2768 Frame # 2769

FIGURE 6: From these consecutive two frames (Frames # 2768 & 2769) we can get the idea of spinning of MIP



Frame # 1405 Frame # 1425

FIGURE 7: Almost after 20 frames the large crater reappears in these frames (Frames # 1405 & 1425) with small residual angle which support the motion due to coning.



Space sequential frames from #2860 to2890

FIGURE 8: From these space sequential frames (Frames # 2860 & 2890) we can observe that the MIP is moving in a certain direction and which support the forward translation motion.

5. CONCLUSIONS

From two final moon surface traces, one obtained from developed algorithm using arbitrary motion parameters of descending MIP (see FIGURE 9a) and other from real space sequential images acquired on 14^{th} November 2008 by the descending MIP from Chandrayan-1(see FIGURE 9b) it is concluded that the descending motion of the MIP is composite of three independent fundamental motions viz.; Spinning, Conning and Forward translational. This is verifiable from the trace path along which the MIP has travelled during the descend to moon surface and if we see in the real de-rotated space sequential images we get the almost same traces followed by the MIP and is comparable to surface trace as simulated using developed algorithm by taking assumed motion parameters as well as considering the above mentioned three fundamental motion in space for a descending MIP on moon surface.

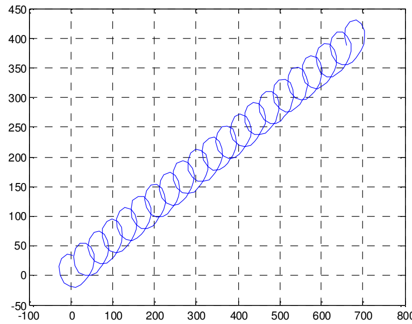


FIGURE 9a: Plot showing calculated moon surface trace of MIP motion derived from algorithms developed under MATLAB

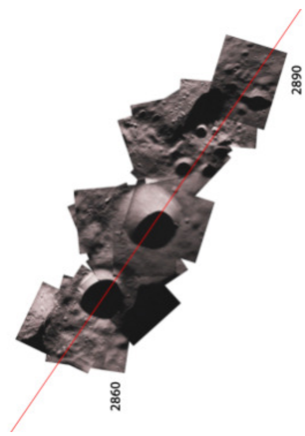


FIGURE 9b: The moon surface trace of path derived from the MIP space sequential Images.

From the developed algorithm it is possible to derive characteristics motion parameters of descending MIP from spacecraft in deciding the future impact site on moon surface. However it has not been possible to compare and verify the results further as very few number of publications are available on this aspect.

6. ACKNOWLEDGEMENT

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Role Model of Graph Coloring Application in Labelled 2D Line Drawing Object

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Abstract

Several researches had worked on the development of sketch interpreters. However, very few of them gave a complete cycle of the sketch interpreter which can be used to transform an engineering sketch to a valid solid object. In this paper, a framework of the complete cycle of the sketch interpreter is presented. The discussion in this paper will stress out on the usage of line labelling and graph coloring application in the validation of two dimensional (2D) line drawing phase. Both applications are needed to determine whether the given 2D line drawing represent possible or impossible object. In 2008, previous work by Matondang et al., has used line labelling algorithm to validate several 2D line drawings. However, the result shows that line labelling algorithm itself, is not adequate, as the algorithm does not have a validation technique for the result. Therefore, in this research study, it is going to be shown that if a 2D line drawing is valid as a possible object by using the line labelling algorithm, then it can be colored using graph coloring concept with a determine-able minimum numbers of color needed. This is equal in vice versa. By that way, it is said that the 2D line drawings is valid. The expected output from this phase is a valid-labeled of 2D line drawing with different colors at each edge and ready for the reconstruction phase. As a preliminary result, a high programming language MATLAB R2009a and several primitive 2D line drawings has been used and presented in this paper to test the graph coloring concept in labeled 2D line drawing.

Keywords: Engineering Sketch, Line Labelling, Graph Coloring.

1. INTRODUCTION

Sketching generally means freehand drawing. An engineering sketch is a preliminary design in the life cycle of an engineering product design namely in the conceptual stage [9]. A process flow in engineering design such as transformation of two-dimensional (2D) drawing from its engineering sketch into three-dimensional (3D) object is known as a sketch interpreter. One of a complete cycle of the sketch interpreter has been presented in the year

2008 by Matondang et al., [16]. The framework shows exactly the complete cycle of the transformation of an object from an engineering sketch 2D line drawing to a valid solid 3D solid object. The framework consists of five phases. First is the interpretation of engineering sketch which is also known as the image processing part, second is the representation of the regular line drawing, third is the validation of the 2D line drawing, fourth is the reconstruction of the validated 2D line drawing into three-dimensional (3D) solid object, and the final phase is representation of the reconstructed 3D solid object. Five methods have been used to carry out all processes for each phase inside. They are thinning algorithm, chain-code scheme, line labelling concept, neural network and mathematical modeling. In this paper, the authors will stress out the discussion on the usage of line labelling and graph coloring application that will be used in the validation phase of the framework. Both methods are used to determine whether the given 2D line drawing represent possible or impossible object. The discussion point out that this research is need to be done because the uses of line labelling concept itself [16] is not enough to determine whether the given 2D line drawing is representing possible or impossible object. Furthermore, the line labelling concept itself does not have any validation method for its own result. Hence, by adding the graph coloring application in the validation phase, the authors expecting the result as a valid-labelled of 2D line drawing with different colors at each edge and ready for the reconstruction phase as the newly enhanced output of the framework, specifically to the validation phase. Also it is expected that the result of this research study could be used as a reference for any further researches on line labelling, precisely the graph coloring. These problem backgrounds and reasons motivate the requirement to undertake the research. The discussion in this paper is managed as follow. The next Section 2 and 3 discuss some literatures and related issues on line labelling and graph coloring concept. Section 4 presents the discussions of the proposed idea and the preliminary results, while Section 5 gives the conclusion and suggestion for future researches.

2. LINE LABELLING

A brief introduction to line labelling is presented in this section. By definition, line labelling is a method for interpreting 3D structure of a 2D line drawing, in which labels are placed on lines to indicate their relative position in space and their convexity [7]. The works on line labelling have been carry out since the early70's, started by Huffman [10], known as the first who worked on the related study concerning the impossible object as nonsense sentences. Initially, it is used to interpret trihedral of planar objects as highlighted by Huffman [10] and Clowes [2]. The years after, the convention has already been extended by Waltz [26] and it is known as Huffman-Clowes-Waltz line labelling. Figure 1 shows the Huffman-Clowes-Waltz line labelling scheme. The convention has four types of line labelling scheme, known as L-type, W-type, Y-type, and T-type and it is limited to a junction with three maximum line incidents. However, it has great impact on the research interpreting and reconstructing of 3D object from a single projection of line drawing.

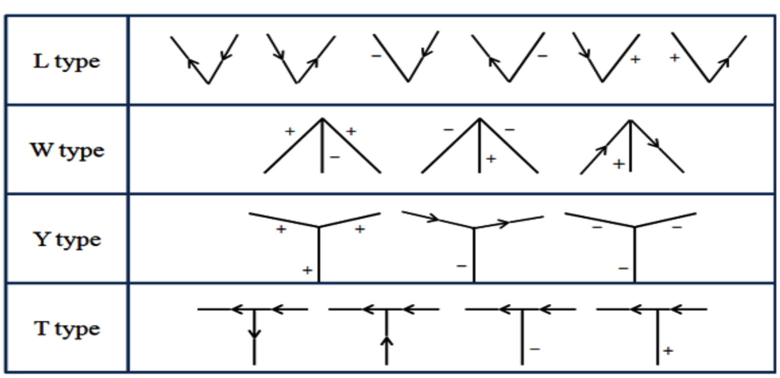


FIGURE 1: Huffman-Clowes-Waltz line labelling scheme.

The growth of line labelling makes the researchers intense to use the method in their works and enhance the ability. Line labelling has been used with vertices more complex than trihedral such as curved surface by Malik [14], transparent solids by Sugihara [22] and drawings with shadows by Waltz [26], Grimstead and Martin [8], Salem and Young [21]).

Some previous works show the uses of line labelling in various applications. Jenkins and Martin [12] showed the uses of line labelling in reconstructing a 3D object from 2D line drawing. Varley and Martin ([24], [25]) also worked on the same issues. They converted a 2D sketch with hidden lines removed from a single polyhedral object into a boundary representation by improving Grimstead's system [7]. Also, Varley and Martin [23] have used the line labelling together with other reconstruction methods like line parallelism, corner orthogonality and a new function, junction label pair (JLP). They estimated the depth value and inflate the drawing 3D space. Cooper [3] introduced novel constraints between unconnected lines or junctions, based on parallel lines, cycles of lines or co-linearity. Other researchers such as Salem and Young [21] and Myers and Hancock [18] had attempted to use soft computing approaches in line labelling representation. Salem and Young [21] tried to adopt the Hopfield and the Tank model in representing 2D sketch with higher order neural network. They assumed that each type of label is represented by neuron. Meanwhile, Myers and Hancock [18] used genetic algorithm to find the optimal set of algorithm control parameters for line labelling.

Apart of those works, Varley et al., [25] have studied different issues. They are explaining that the original purpose of line labelling was as a method of identifying and rejecting impossible drawings. Impossible object can be represented by a regular 2D line drawing, as it cannot be reconstructed into a valid 3D object because the object does not exist. However, the impossible object is designed uniquely to test mind and previous works such as the work by Cowan [4] which has been done in picture interpretation to indentify the correctness of this type of line drawing. Figure 2 shows two examples of the impossible objects.

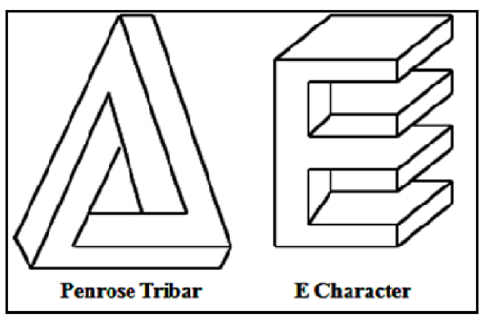
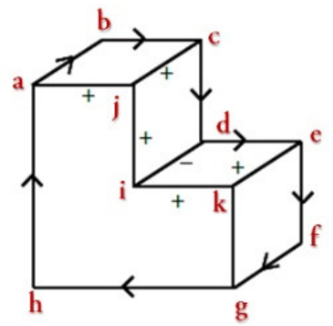


FIGURE 2: Impossible objects (redrawn from [10]).

Back to the issues discuss in this research study, the line labelling concept has been used to represent 2D and 3D object. Line labelling concept has also been used to validate whether the 3D object which has been represented by a 2D line drawing is a possible or impossible object. Table 1 shows the line labelling scheme on a 2D line drawing which represent a 3D solid object L-block.

TABLE 1: Example of line labelling on a 3D solid object L-bock.

<table>
<tr><th>2D line drawing for a 3D solid object L-block</th><th>Line labelling scheme</th><th>Example of the labelled line</th></tr>
<tr><td rowspan="4">
</td><td>L-type</td><td>$\{(abc),(bcd),(fgh)\}$</td></tr>
<tr><td>W-type</td><td>$\{(hbj,a),(dfk,e),(jkd,i)\}$</td></tr>
<tr><td>Y-type</td><td>$\{(ice,d),(ica,j),(gie,k)\}$</td></tr>
<tr><td>T-type</td><td>-</td></tr>
</table>

The data gathered above have been fed into worksheets to perform statistical analysis on the results in group-projects, project's individual reports, and exams. In addition, the results of students' attainment in the assignment and the exam have been compared, and particularly in similar subject areas, for example requirements analysis and software architecture. Also, students' and tutors' feedback have been analyzed.

3. GRAPH COLORING

A brief discussion to graph coloring literatures is presented in this section. By definition, graph coloring is a special case of graph labelling, with color used as the label. By the means, there are no two adjacent vertices, or edge, or face are assigned by the same color. Therefore, there are three kinds of graph coloring, known as vertex coloring, edge coloring and face coloring. Given a graph $G(V,E)$ with $V=\{v_1,v_2,\ldots,v_n\}$ is the set of vertices in *G* and $E=\{e_1,e_2,\ldots,e_m\}$ is the set of edge in *G*, then the chromatic numbers $\chi(G)=k$ is defined as the minimum numbers of colors needed to color graph $G(V,E)$. The property: assumed $G(V,E)$ is a graph and $G^*=(V,C)$ is a mapping function $f:v\rightarrow c$ with $c\in C$ is a finite set of colors, such that if $(v_1v_2)\in E$ then $f(v_1)\neq f(v_2)$. This implies that the adjacent vertices are not assigned the same color [1].

In this paper, the discussion is been concentrated on the edge coloring. By definition, edge coloring of a graph $G(V,E)$ is a color assignment to each edge in $G(V,E)$ so that for each two adjacent edges e_j and e_k to a vertices v_i, they do not share the same color. For details discussion about the graph coloring properties, readers are referred to Jensen and Toft [13], as the authoritative reference on graph coloring.

In many cases, graph coloring is used to solve problems that may involve conflicts, or items that need to be separated [20]. Several applications previously done include separating chemicals in a lab work, separating animals in zoo, scheduling classes or exams, and the most common applications is coloring maps in order to separate distinct countries. Iturriaga-Velazquez [11] shows that the originated problems involving the four-color problem that is four colors enough to color the countries on world map without two countries with common boundary are assigned the same color. However, since the time, graph coloring is applied to many various fields of researches. Marx [15] explained in his paper about the applications of graph coloring in scheduling problem while Gaceb et al., [6] carried out physical layout segmentation for postal sorting system using the graph coloring application. Redl [19] used graph coloring approach for university timetabling in University of Houston, and Dobrolowski et al., [5] have developed Koala Graph Coloring Library, which is an open graph coloring library for real world applications. However, in this research study, it is attempted to use the concept of graph coloring to develop a role model as the validation of 2D line drawing which is representing 3D object. The validation will determine the represented 3D object as possible or impossible object. The result of this research study is expected to give a better validation compare to the previous work by Matondang et al., [16] which only used line labelling algorithm to perform the validation. It is because the line labelling algorithm itself cannot be used as the validation tool or method to validate its labeled 2D line drawing. Therefore, the combination of both line labelling algorithm and graph coloring application can be useful in order to speed up or enhance the validation of 2D line drawing. It is also proposed as the performance of the graph coloring in many fields and gave the motivation to adapt in validating 2D line drawing.

4. ROLE MODEL OF GRAPH COLORING APPLICATION IN LABELED 2D LINE DRAWING OBJECT: A PRELIMINARY RESULT

This section discusses the framework for the complete cycle of the sketch interpreter ([16], [17]). Interested readers could refer to the related references for details discussions of the framework. It is because the discussions in this paper, only focus on the validation phase as a part of the framework, which is about the role model of graph coloring application in labeled 2D line drawing. Figure 3 shows the framework for the complete cycle of the sketch interpreter.

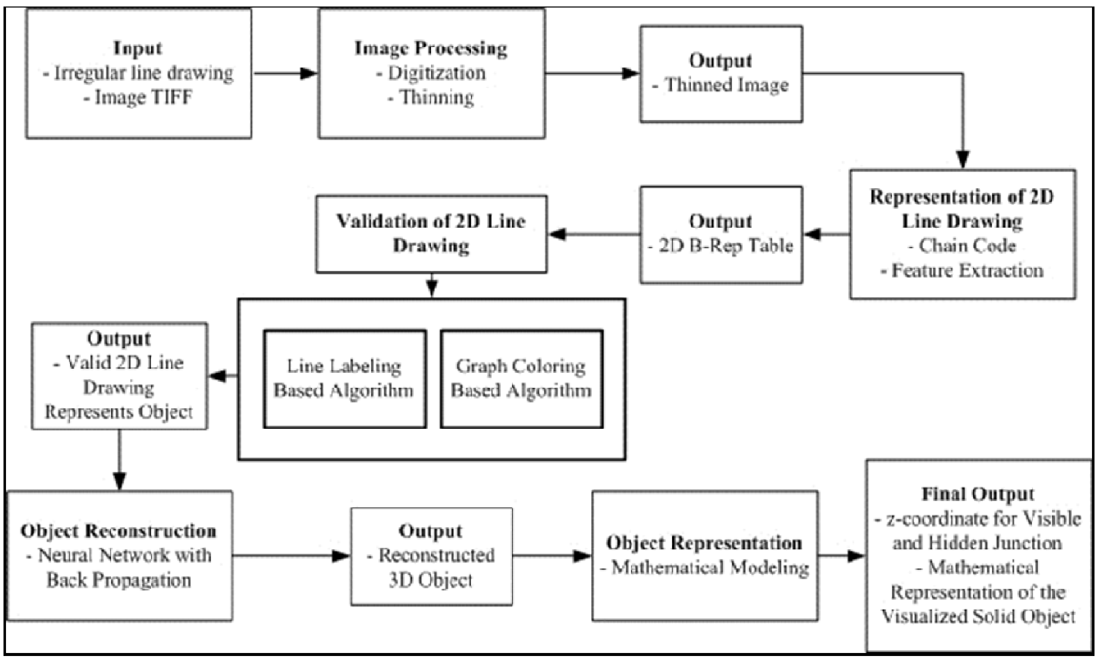


FIGURE 3: Complete cycle of the sketch interpreter (Redrawn [17]).

The following Theorem 1 gives a property to the graph coloring characteristic in terms of the numbers of color and the degree of vertices in a graph *G*.

Theorem 1: *Given $G(V,E)$ is a graph G with a set of vertices V and a set of edge E in G. The number of colors $\hat{k}$ needed to color each edge in G is equal to or greater than the maximum degree of the vertices in G*

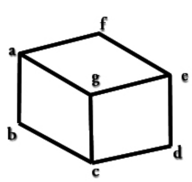
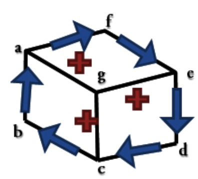
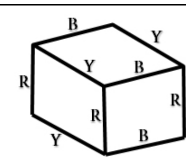
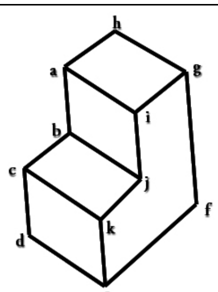
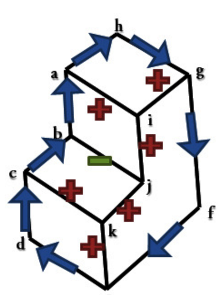
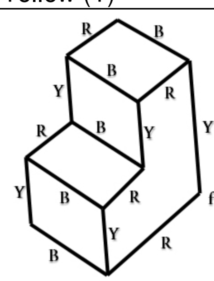
$$\hat{k} \geq \max\{\deg(v), v \in V\}.$$

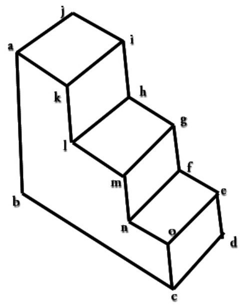
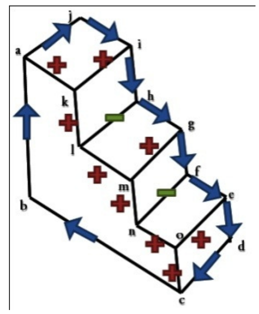
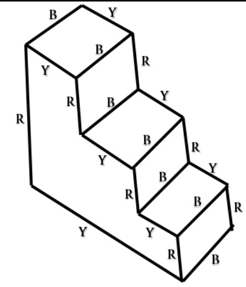
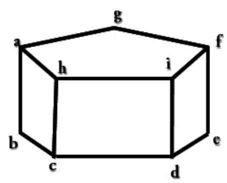
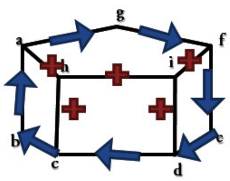
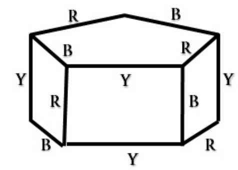
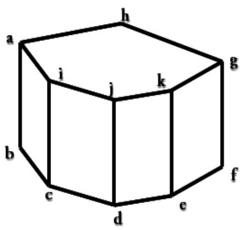
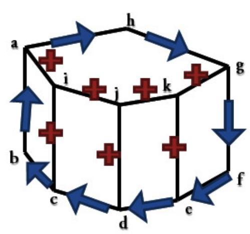
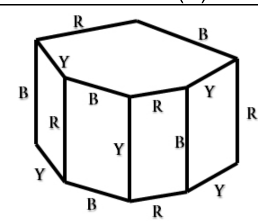
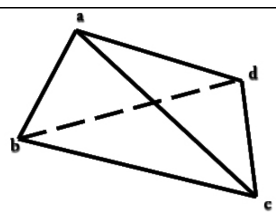
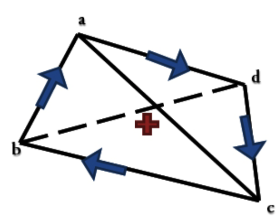
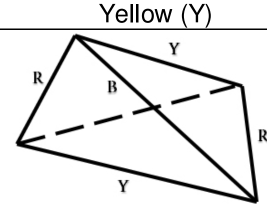
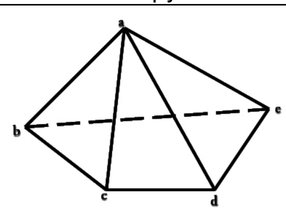
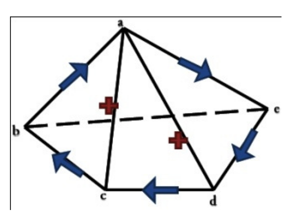
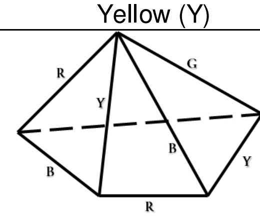
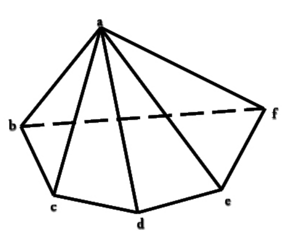
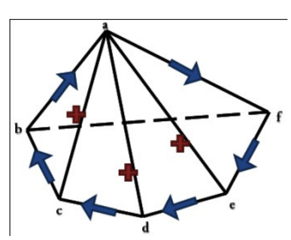
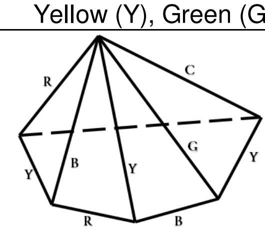
Proof: Assumed vertex $v \in V$ incident to m edges in E. Hence $\deg(v) = m$. Then there must be at least m number of colors needed to color every incident edge in vertex v. It is because for each edge which is incident to a vertex v cannot assign by the same color.

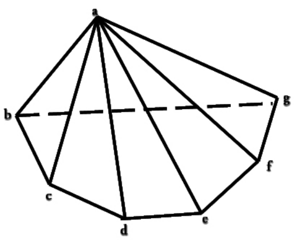
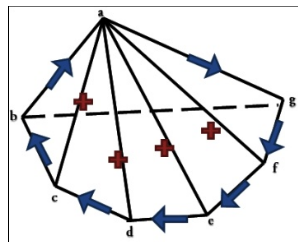
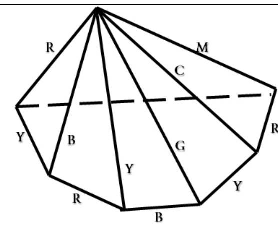
Hence, $\hat{k} \geq \max\{\deg(v), v \in V\}$ with $\hat{k}$ is the numbers of color needed to color each edge *E* in *G*.

In this research study, few assumptions have been made to simplify the implementation of the research work and its contributions. First, the tested 2D line drawings are assumed as an engineering sketch in a form of 2D line drawing that represent solid model. Second, the 2D line drawing is assumed to represent a valid solid model where all unwanted points or lines have been removed and there are no unconnected points or lines. Third, the solid model is assumed as a 2D line drawing with all informative lines shown. Fourth, there is only a maximum of one hidden point in the backside of the solid model. These assumptions make the proposed model more logical or otherwise the engineering sketch is not seen as solid models because the projection is parallel to the other faces of the object. In this case, it is impossible to interpret, reconstruct and represent the sketches as solid model and hence the analysis of the accuracy of the results will become simpler. Table 2 shows our preliminary result in this research study. There are four columns in the Table, with the first column shows the 2D line drawings and the second column shows the validation of the 2D line drawings using line labelling algorithm. Interested readers could refer to Matondang et al., ([16], [17]) for details discussion on the line labelling algorithm. The third column shows the labeled 2D line drawings are colored based on the graph coloring concept and the fourth column present some note. From the result showed in Table 2, our expected output which is a valid-labeled of 2D line drawing with different colors at each edge and ready for the reconstruction phase has been achieved. However, in further research, we are going to extend the research by proving that for any given 2D line drawing, if it is can be validated as possible object by using line labelling algorithm, then it can be colored with the minimum numbers of color needed *k* by using graph coloring concept. The objects use to implement the concept of graph coloring given, also will be extended to more complex structures of 2D line drawings (not primitive).

TABLE 2: Preliminary Result.

2D line drawing	Labeled 2D line drawing using line labelling algorithm	Valid-labeled of 2D line drawing with different colors at each edge	Role Model
 Cube		 • Red (R), Blue (B), Yellow (Y)	• Number of visible vertices = 7 • Number of visible edge = 8 • Numbers of color needed *k* = 3
 L-block		 • Red (R), Blue (B), Yellow (Y)	• Number of visible vertices = 11 • Number of visible edge = 15 • Numbers of color needed *k* = 3

 Stairs		 • Red (R), Blue (B), Yellow (Y)	• Number of visible vertices = 15 • Number of visible edge = 21 • Numbers of color needed k = 3
 pentahedral-prism		 • Red (R), Blue (B), Yellow (Y)	• Number of visible vertices = 9 • Number of visible edge = 12 • Numbers of color needed k = 3
 hexahedral-prism		 • Red (R), Blue (B), Yellow (Y)	• Number of visible vertices = 11 • Number of visible edge = 15 • Numbers of color needed k = 3
 trihedral-pyramid		 • Red (R), Blue (B), Yellow (Y)	• Number of visible vertices = 4 • Number of visible edge = 5 • Numbers of color needed k = 3
 kwartahedral-pyramid		 • Red (R), Blue (B), Yellow (Y), Green (G)	• Number of visible vertices = 5 • Number of visible edge = 7 • Numbers of color needed k = 4
 pentahedral-pyramid		 • Red (R), Blue (B), Yellow (Y), Green (G), Cyan (C)	• Number of visible vertices = 6 • Number of visible edge = 9 • Numbers of color needed k = 5

 hexahedral-pyramid		 • Red (R), Blue (B), Yellow (Y), Green (G), Cyan (C), Magenta (M)	• Number of visible vertices = 7 • Number of visible edge = 11 • Numbers of color needed k = 6

5. CONCLUSION AND FUTURE WORK

This paper has presented a framework for the complete cycle of the sketch interpreter. However, the discussion in this paper stresses out on the usage of line labelling algorithm and graph coloring application in the validation of 2D line drawing phase only. It is needed to determine whether the given 2D line drawing represent possible or impossible object, before it is proceed to the next phase, namely reconstruction. However it is, in 2008, a previous work by Matondang et al., [16], has used line labelling algorithm to validate the 2D line drawing. But, the result shows that line labelling algorithm is not enough, because the algorithm does not have a validation technique for its own result. Therefore, in this research study, it is shown that if a 2D line drawing is valid as a possible object by the line labelling algorithm, then it can be colored using graph coloring concept with the minimum numbers of color needed is equal to k. The output from this phase is a valid-labeled of 2D line drawing with different colors at each edge and ready for the reconstruction phase. In general, the inputs for the framework are points, lines and junctions of the engineering sketches which are irregular line drawings. Meanwhile, the output may vary up to the direction of the input. As the preliminary result, a high programming language MATLAB R2009a and several primitive 2D line drawings have been used to test the graph coloring concept in labeled 2D line drawing.

The authors believed that this paper has presented an extended result of a series research paper which focuses on the validation of 2D line drawing based on line labelling algorithm and graph coloring concept only. In the next research paper, the discussion will going to prove the hypothesis which is: *For any given 2D line drawing by an engineering sketch, if the 2D line drawing is determined as a possible object by the line labelling algorithm, then there are k colors that are the minimum numbers of color needed to color the 2D line drawing*.

Apart of that, it is realized some weaknesses of this series of research study. One of them is the line labelling algorithm which is still only covered for the trihedral pyramid but not for tetrahedral, pentahedral, hexahedral pyramid and so on. In future, the 2D line drawing used to implement this research will be extended to a more complex object instead of the primitive ones used in this paper. However, as a general conclusion, the combination of the methods use in the framework; thinning algorithm, chain-code scheme, line labelling, graph coloring, neural network, and mathematical modeling, has generated new invention in the development of sketch interpreter.

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