Web Based Map Generations of Mobile Robot Movement using Scalable Vector Graphic

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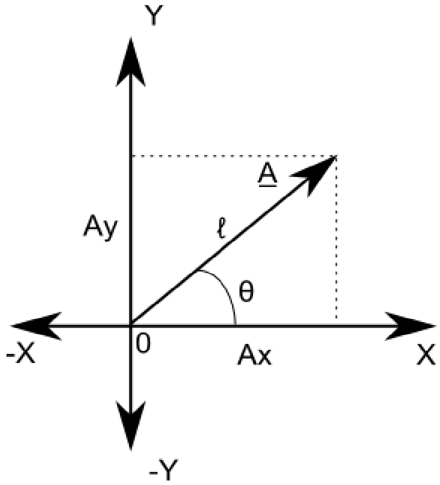
Abstract—**Mobile robot movement carry various valuable information. The mobile robot movement needs to be visualized in order to get understood by human eye. This paper describes the process of movement data composition and conversion to prepare the information required to build a map. The map composed by mapping every movement into polar coordinate area. The map stored into a database for flexible future usage. Commonly used web based interface chosen to display the map via web browser. The map generated by server side script that transforms polar data into full map. For observation purpose, sample robot movement used to test the map generation result.**

Keywords: mapping, web, robot, vector, SVG.

INTRODUCTION

The development of mobile robotics leads human being into a whole new era. Many human doing job and activity being replaced by autonomous robot. These robots are in charge of taking dangerous, heavy lifting and also boring monotone jobs from our daily activity. Some of these robots are stand in one particular place, but some others are continuously moving from one place to another. Mobile robot have a particular job such as bringing materials from one place to another, observing line of progress or as a scout discovering new places or environment. Some of these mobile robots had its own map and movement path, but the scouting robot barely knew the area of observation.

This research would try to develop a mechanism to build map automatically from a mobile robot movement. Movement of a mobile robot can be represented as a vector which contains angle and distance of the movement [3]. A vector itself consists of several components for example vector $\vec{A}$ consists of scalar component l_a and angular component θ_a [3]. These vector components illustrated on the Fig. 1 below.



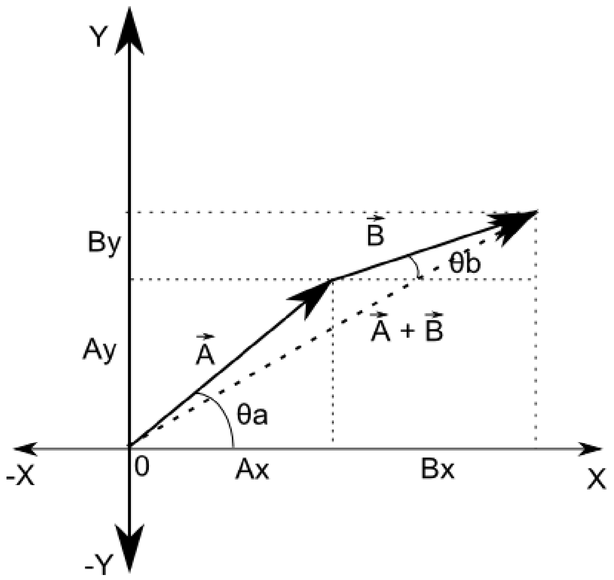
Vector Components

Vector $\vec{A}$ can also be extracted into horizontal component and vertical component. Fig. 1 show us vertical component of vector $\vec{A}$ labeled *Ay* and horizontal component of vector $\vec{A}$ labeled *Ax*. Reference [1] show simple trigonometry used to extract the vertical and horizontal component of a vector described in (1) and (2).

$$A_y = l \sin\theta \tag{1}$$

$$A_x = l \cos\theta \tag{2}$$

The vertical and horizontal components are used to do vector addition operations. To add one vector to another each vector needs to get extracted into their horizontal and vertical components. Each vertical components of every vector added to get the resultant vector vertical components and each horizontal components of every vector added to get the resultant vector horizontal components [3]. Vector addition operations illustrated on Fig. 2 below.



Vector Additions

Fig. 2 above shows us components of vectors being added each other. For vector $\vec{C}$ with scalar component l_c and angular component θ_c as the result of $\vec{A}+\vec{B}$, the addition described in (3) and (4).

$$l_c=\sqrt{(l_a\sin\theta_a+l_b\sin\theta_b)^2+(l_a\cos\theta_a+l_b\cos\theta_b)^2} \quad (3)$$

$$\theta_c=\tan^{-1}\frac{(l_a\sin\theta_a+l_b\sin\theta_b)}{(l_a\cos\theta_a+l_b\cos\theta_b)} \quad (4)$$

Mobile Robot Movement

Calibration

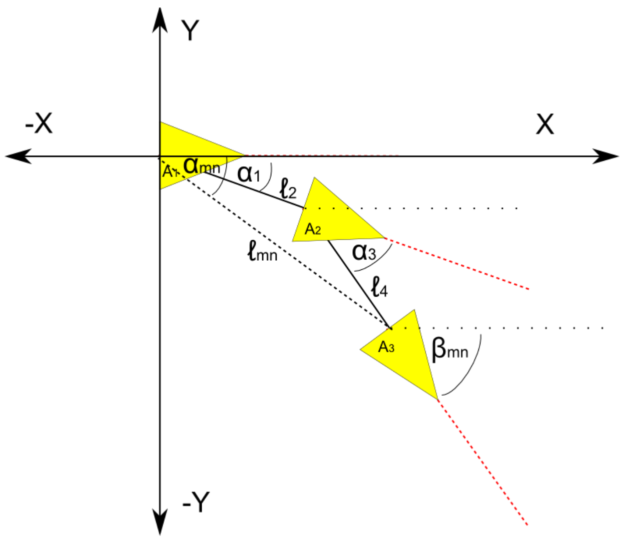
To get the precise information of the movement of the mobile robot, a calibration process needs to be done first. The calibration process compares the data parsed from the robot into the system with the measurement of the movement of the robot. The data parsed from the robot are expressed as a digital integer value, and the measurement of the movement expressed as a scalar value in millimeters for straight movement and angle for the rotating movement. As the result, a coefficient of the movement will be stored in millimeters per step for the straight movement and angle per step for the rotating movement. For s is straight movement coefficient and r is rotating movement coefficient conversion process can be described in (5) and (6).

$$l=s\times l_{parse} \quad (5)$$

$$\theta=r\times\theta_{parse} \quad (6)$$

Movement Data Composition

In order to gather the information of robotic movement, the data parsed need to be composed into standard form and stored into database [4]. The data stored need to carry every important aspects of the movement which is the vector components. To save data storage, only the basic components of the vectors stored, they are the angle and distance of the movement. The movement a mobile robot can be illustrated in Fig. 3.



Robot Movement

Fig. 3 above show the movement of a mobile robot represented in angular and scalar form. The position of robot at A_2 is the movement from A_1 to A_2 and the position of robot at A_3 are resultant of movement from A_1 to A_2 and from A_2 to A_3, therefore we can conclude that a final position of the robot from its initial position are the sum of every movement vector. For $\vec{A}_n$ is the final position of robot on step n with two component l_n and α_n and also β is the angle where the orientation of the robot, using vector addition concept on (3) and (4), movement recapitulations process can be described with (7) and (8) when the final orientation of the robot described in (9).

$$l_n=\sqrt{\left(\sum_{x=1}^{x=n} l_x\sin\theta_x\right)^2+\left(\sum_{x=1}^{x=n} l_x\cos\theta_x\right)^2} \quad (7)$$

$$\theta_n=\tan^{-1}\frac{\left(\sum_{x=1}^{x=n} l_x\sin\theta_x\right)}{\left(\sum_{x=1}^{x=n} l_x\cos\theta_x\right)} \quad (8)$$

$$\beta_n=\sum_{x=1}^{x=n}\theta_x \quad (9)$$

Map Preparation

Scalable Vector Graphics

SVG is a language for describing two-dimensional graphics in XML. Many kinds of objects were capable to be embedded into an SVG such as vector graphic shapes, images and text [2]. At this point map planning required to fulfill the demand of information and the available shapes of an SVG.

The SVG uses Cartesian coordinate system which requires the vertical and horizontal component of a vector in order to be drawn [2]. The Cartesian system of SVG actually flipped vertically compared with the common Cartesian coordinate system. The SVG positive y-axis are pointing down while the y-axis of common coordinate system pointing up. The SVG coordinate also limited on the drawing area which only show the certain area on positive axis both x and y.

Visualization in this research will use standard SVG path using previously defined marker to show the movement direction of the mobile robot. The mobile robot final position showed on the map using triangle shaped SVG polygon. The smallest angle of the triangle show the front end of the robot and the shortest side of the triangle show the rear end of the robot.

Data Preparations

To illustrate every movement vector position, every vector start and end point gathered and plotted into Cartesian area. As mentioned before, every starting point of every vector's is the end point of the previous vector. So the movement information of the mobile robot can be rendered as an SVG path passing through every end point of each vertically flipped vector.

In order to maintain the visibility of the map, several variable need to be declared first such as map height, map width and map margins. These map variables can be set by the program or user input. The actual map needs to be transformed to match the drawing area of SVG. Both vertical and horizontal area must be included on the drawing area. Information comparison between the width and height required to decide will it be horizontally or vertically aligned. Calculation of map height and width required to determine the comparison.

The drawing area need to be reduced by the margin size. Since the margin take place on all four side of the map, the height and the width need to be subtracted by the margin twice.

Before plotting, every point of the data needs to be transformed into Cartesian form. The data then shorted to find the maximum and minimum value of both horizontal and vertical axis to estimate the map size.

For every point available on the map represented as (x,y), the highest and lowest point are on y_{max} and y_{min}, and the most right and left point are on x_{max} and x_{min}, (10) and (11) applies.

$$W_{map} = x_{max} - x_{min} \tag{10}$$

$$H_{map} = y_{max} - y_{min} \tag{11}$$

Map Transformation

The ratio of the map and the drawing area compared to Fig. out which area are wider in perspective ratio. If the map ratio bigger than the drawing area, the map will be horizontally fitted into the drawing area and vertically center aligned, otherwise if the drawing area ratio bigger than the map, the map will be vertically fitted into the drawing area and horizontally center aligned.

For height, width, ratio and transformation coefficient represented as *H, W, R* and *T*, (12) applies.

$$R = \frac{W}{H} \tag{12}$$

If $R_{map} > R_{draw}$, and vertical padding represented as P_y, (13) and (14) applies.

$$T = \frac{W_{draw}}{W_{map}} \tag{13}$$

$$P_y = \frac{[H_{draw} - (T \times H_{map})]}{2} \tag{14}$$

if $Rmap < Rdraw$, and horizontal padding represented as P_x, (15) and (16) applies

$$T = \frac{H_{draw}}{H_{map}} \tag{15}$$

$$P_x = \frac{[W_{draw} - (T \times W_{map})]}{2} \tag{16}$$

The transformation process turn every point of robot position $A_{map}(x_{map},y_{map})$ into $A_{draw}(x_{draw},y_{draw})$. The vertical axis flipped by subtracting the drawing area height with the vertical value. The transformation processes described in (17) and (18).

$$X_{draw} = T(X_{map} - X_{min}) + M + P_x \tag{17}$$

$$Y_{draw} = H_{draw} - T(Y_{map} - Y_{min}) + M - P_y \tag{18}$$

Equations (17) and (18) show minimum value of x and y added into the coordinate as subtraction value of x and y. The subtraction with the minimum value used to make sure all of the point passed by the robot shown on the SVG map. When the minimum value is negative, this subtraction will add the minimum point and move it into zero axis. Otherwise when the minimum value is positive, this subtractions reduce the minimum point and move it into zero axis.

MAP GENERATION

The generations of the map require the data to be processed using the previously described term and equations. After the data processing complete, the map can be plotted into drawing area using SVG tags.

Data Processing

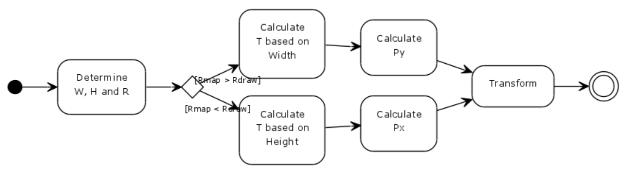
This sub chapter would determine how the data will be treated during the visualization process. The data processing flows step by step according to the previous explanation. The process flows illustrated on the diagram in Fig. 4 below.

Process flow activity diagram

Fig. 4 above shows the three steps of data visualization from the input processing, map transformation and the plotting. The input recapitulations and conversions process can be detailed on the diagram in Fig. 5 below.

Input recap & conversion activity diagram

The transformation process begins with determination of both map and drawing area width, height and ratio. The transformation process also had a conditional check is the ratio of the map larger than the ratio of the drawing area, if so the process then calculating T based on width and also calculate P_y. Otherwise if the ratio of the drawing area larger than the ratio of the map then calculating T based on height and also calculate P_x. Every point on the map then transformed. Transformation processes displayed in Fig. 6 below.



Transformation activity diagram

Data Plotting

The information plotted into the drawing area using SVG tags. As mentioned before, there are several shapes used explained further below.

A triangle shape drawn to the drawing area to represents the robotic position. The triangle encoded using a polygon tag that mentions all the vertex of the triangle. The sides of the triangle drawn in black with 1pixel width and the inner of the triangle filled with yellow color. The triangle can be rotated according to the position of the robot. Important to be noted is that the rotation system in the SVG coordinate is different with the common Cartesian coordinate. The common Cartesian coordinate, positive angle rotate counterclockwise, otherwise the SVG coordinate use clockwise rotation for positive angle. For the robot position in $A_{draw}(x_{draw},y_{draw})$ and the orientation of the robot as βn, the triangle can be plotted using the following code.

```
<polygon points="X-5,Y+7 X,Y-7 X+5,Y+7"
fill="yellow" stroke="black" stroke-width="1"
transform="rotate(-β X,Y)" />
<text x="X+25" y="Y+5" fill="black">Robot</text>
```

A path plotted to illustrate the robot movement. The path had triangle mark to show where the robot moves into. Every single vector data will be represented by each vertex of the whole path. The path plotted with black 1pixel width line using the following code.

```
<path d="M X1 Y1 L X2 Y2 L X3 Y3 ... L Xn Yn"
marker-mid="url(#Triangle)" fill="none"
stroke="black" />
```

The above code show a list of point drawn into the map represented as $An(Xn,Yn)$. The first point will use M prefix to state that it is the first point. The second and following point will use L prefix to state that the line will be drawn between the two points.

Testing

Using a data sample, a trial map can be generated to test the concept and equations of this research. The data input both angle and distance generated randomly and then processed. This research uses two sets of random data for testing purpose. The sets of data used displayed at table 1.

SAMPLE MOVEMENT DATA SET

No	Data Set 1		Data Set 2	
	l	*θ*	*l*	*θ*
1	15	-6	15	77
2	12	-29	19	-41
3	10	-67	13	-57
4	8	-86	12	-83
5	11	23	18	-83
6	5	-77	20	6
7	9	20	3	81
8	5	42	7	-74
9	4	89	14	-6
10	11	-41	20	5

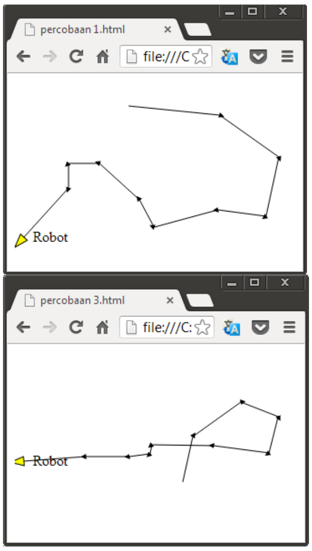
Data set from table 1 being input into the system to generate the map. The system processes the data and generates output script to be displayed by the browser. The output script generated for data set 1 displayed below.

```
<polygon points="10,177 25,172 10,167 "
fill="yellow" stroke="black" stroke-width="1"
transform="rotate(132 10,172)" />
<text x="20" y="177" fill="black">Robot</text>
<path d="M 125 28 L 225 38 L 290 84 L 276 149 L
223 142 L 153 161 L 137 131 L 93 91 L 59 91 L 59
118 L 10 172" marker-mid="url(#Triangle)"
fill="none" stroke="black" />
```

The second data set also got the map generated by the system. The final output of the second dataset displayed below.

```
<polygon points="10,126 25,121 10,116 "
fill="yellow" stroke="black" stroke-width="1"
transform="rotate(175 10,121)" />
<text x="20" y="126" fill="black">Robot</text>
<path d="M 185 144 L 196 94 L 249 56 L 290 72 L
280 112 L 219 104 L 151 103 L 149 113 L 126 116
L 78 116 L 10 121" marker-mid="url(#Triangle)"
fill="none" stroke="black" />
```

The script above displayed on the browser to view the map. Both map displayed using Google Chrome browser. The display captured and displayed in Fig. 7.

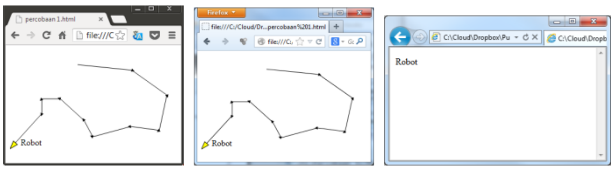


(a) (b)

Map generated from sample data set (a) data set 1, (b) data set 2

A comparison can be done between the map and the data set. A positive angle shown as turning right on the map and a positive angle shown as turning left on the map. The distance of movement displayed as the line length.

The above script also tested using several browsers to check the compatibility. Each browser access the first data set and captured in Fig. 8 below.



(a) (b) (c)

Map generation testing (a) Google Chrome, (b) Mozilla Firefox, (c) Internet Explorer

Fig. 8 shows the map accessed using Google chrome Mozilla Firefox and also Internet Explorer. The Google chrome browser and Mozilla Firefox fully support SVG tags and display the exact same map while the Internet Explorer only display the label of the robot and failed to draw the path and polygon. Several version of Internet Explorer isn't seems to support SVG tags.

Conclusion

Visualization of mobile robot can be generated using simple XML tags. Movement of robot can be considered as several numbers of vectors. Final position of a mobile robot can be calculated by adding all the vector of the entire movement. Several version of Internet Explorer is still having difficulties of displaying SVG image while Mozilla Firefox and Google Chrome had better support of SVG image.

Acknowledgment

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References

Alisa Favinger, Jim Lewis, "The Polar Coordinate System", M.A. thesis, University of Nebraska-Lincoln, Nebraska, 2008.

Erik Dahlstrom, et al. "Scalable Vector Graphics 1.1 Second Edition" W3C Recommendation, August 2011.

John Peacock, Foundation of Mathematical Physics, Topic: "Vector, Tensor and Field", University of Edinburgh, Edinburgh, 2009.

Yang Cao, "Towards Virtual Watersheds: Integrated Data Mining, Management, Mapping and Modeling", AWRA Spring Specialty Conference, Orlando FL, March 2010.