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Deploying Natural Language with Topological Relations for Robotics Behavior

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Abstract: Topological descriptions and maps are key prerequisite to any autonomous machine for successful navigation in unpredictable behavior of environment. It is necessary to consider topological map with metric refines of 9-intersaction model for the movement of the robot and react its environment accurately. The aim of present study was to identify the robotics movement and its behavior using natural language spatial relations to process information for robot without computation failures and communication errors. The similarity measure of geometric interpretation is considered for computation for the movement of robot. The splitting metric concepts are used for robotics movement to determine the appropriate way to divide by line in a region. The 16 different metric parameters for natural-language spatial term are considered to find out the appropriate direction for the robotic movement. So that robot will react with behavior of environment with natural language spatial term. There are 32 natural language spatial terms are found for robotic movement from present study found and finally these natural languages with spatial relationship are deployed for robotics movement. All these natural language spatial terms could be used in any research related to spatial technology especially where autonomous machine is used.

Key words: Behavior based robot, spatial relationship, autonomous machine, geometric interpretation

INTRODUCTION

When considering deploying robots into the agricultural environment we have to deal with the complexity of the robot as well as the complexity of the growing environment. This level of interacting systems is often too difficult for a single person to deal with. In the past engineers had tried to simplify the environment to allow autonomous tractors to function. It is now felt that the opposite view should be taken, where the machine should have enough intelligence embedded within it to be able to deal with the real-world complexity. The enhancement of robotics and its application has grown tremendous since the mid-eighties. For every application there are requirements of accuracy, versatility and the lowest cost (Poplawski and Sultan, 2007). On the scientific side, the novel branch of the so-called behaviour-oriented robotics emerged (Birk *et al*., 2002). A key prerequisite for a truly autonomous robot is that it can simultaneous localizes itself and accurately map its surroundings (Cai *et al*., 2008).

The behaviour based robots become more acceptable by the scientists to work with the reactive task. Recently, Pratomo *et al*. (2011) utilized behaviour based robot and use obstacle avoiding strategy. The enhancement of robotics and its application has grown tremendously since mid-eighties. The novel branch of robotic technology emerged by introducing behaviour oriented robotics (Birk *et al*., 2002; Brooks, 2002; Mataric, 1998; Schmidt *et al*., 2006) experimented behavior based robotics and defined the behavior based system reacts its environment autonomously and performs concurrent process of behavior. Blackmore *et al*. (2004) defined robotics behaviour is same as with human behaviours context. Most of the reactive robotic actions tend to be spatially defined and have limited relationships with other spatial objects (point, Line and polygon). There is potential of using robotics in agricultural application with spatial technology. Many organizations' activities are based on spatial information (Poorazizi *et al*., 2008). Shariff *et al*. (1998) introduced natural language spatial relationship model. Most of the mobile robotic actions tend to be spatially defined and have limited relationships with other spatial objects. The relationships between these objects and other objects can be defined in structured English and are proposed by Egenhofer and Shariff (1998) and Egenhofer and Dube (2009). These relationships, or syntax, take the generic form of Object1, Spatial term, Object2. For example the road crosses the field. 'Road' is a linear object, 'field' is an area object and 'crosses' is the spatial term.

The following algorithm considered for the movement of the robot by taking the instruction based on Object1, Spatial Term and Object2. The Algorithm describe with

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the natural language spatial term Cross. The behaviour of the robot will follow the syntax like Robot Crosses the Field. First of all Robot take the actual scenario of the field and road, then follow the natural language spatial term, here is Cross. It will start moving by following the boundary of the field and move strait until the end of the field. Finally, it will follow the other end of boundary and stop movement just after the boundary of the field. When a robot reaches an unknown place two basic questions it has to answer: Where am I? And Where to go? (Yuan *et al.*, 2010).

- Cover the scenario of object1 (road which is the way of robotic movement) and object2 (field)
- Take the natural language spatial term for the movement of the robot
- Start movement from the outside of the field
- Follow the boundary of the field and Minimize the distance covered
- Maximize driving in a straight line
- Find out the boundary of the field to cross
- Minimize duplicate coverage
- Avoid and map new obstacles
- Follow the boundary of the field and Stop movement outside of the field

Behaviour based systems typically consist of a collection of simple computations running in parallel (Horswill, 2000). It could be the appropriate tools to utilize the semantic of spatial relations in natural language. This research provides the possible solutions to increase the productive use of reactive robot in agricultural environment. This study measures the robotics movement and its behavior with natural language spatial relations to process information for robot without computation failures and communication errors. The Spatial objects are considered for the movement of reactive robots. The English structured natural language is used to represents the spatial relationship for the robots control mechanism. Finally, it identified an action and a condition when that action should be taken place.

MATERIALS AND METHODS

The research was conducted from July 2008 until June 2010 at spatial laboratory in the university Putra Malaysia. This research used mainly the 9-intersection topological model Eq. 1 is a comprehensive model for spatial relations and applied to objects of type area, line and point. This research mainly used the topological relation t between two point sets, A and B by the set intersections of A's interior (A^0), boundary (∂A) and exterior (A^-) with the interior, boundary and exterior of B; (B^0), (∂B) and (B^-) represented by a 3 × 3 matrix. After that 19 possible line-region relations (Fig. 2) from 9-intersection is considered for the use natural language spatial term. Finally The splitting intersection of the region's and line's interiors, boundaries and exteriors considered for the robotic movement using natural language spatial terms.

$$I(A,B) = \begin{pmatrix} A^0 \cap B^0 & A^0 \cap \partial B & A^0 \cap B^- \\ \partial A \cap B^0 & \partial A \cap \partial B & \partial A \cap B^- \\ A^- \cap B^0 & A^- \cap \partial B & A^- \cap B^- \end{pmatrix} \quad (1)$$

Figure 1 is stated the Exterior, Boundary and Interior of the Line and Area. A robot's movement is considered as Line and Field considered as area.

The research mainly considering the relationship between the line and the area, they are 19 possible line-region relations (Fig. 2) from 9-intersection by Egenhofer and Herring (1991).

In order to obtain the Line-Region (LR) number, we use the sum of the first row (0 1 1) on binary representation scale is 3, the sum of the second row (0 0 1) on binary representation scale is 1 and the bottom row is ignored since it always produces three 1's for LR relations in R^2. So, the LR Number is 31.

$$\begin{pmatrix} 0 & 1 & 1 \\ 0 & 0 & 1 \\ 1 & 1 & 1 \end{pmatrix} \quad (2)$$

The line region topological relations on plotted in the form of a conceptual neighborhood graph (Fig. 3). For the horizontal changes, represented by A-B, the LR 44 on the Extreme left because the LR 11 on the extreme right. In natural language, this is the representation "S"th line that is inside (LR 44, LR 46 and LR42), because the line that is outside (LR 11, LR 13 and LR 12). For the horizontal changes, represented by the movement C-D, the LR 46 on the Extreme left because the

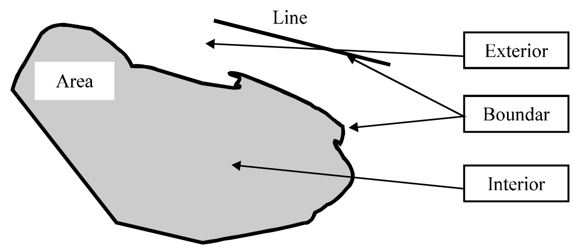


Fig. 1: Exterior, Interior, and boundary of the area and the line

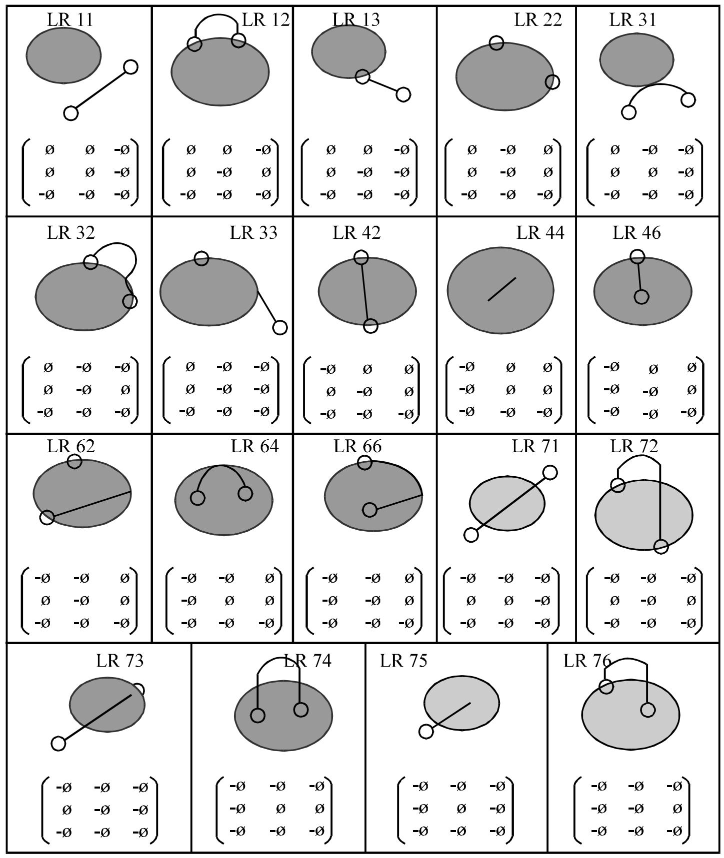


Fig. 2: The geometric interpretations of the 19 line-region relations from 9-intersection by Egenhofer and Herring (1991) where ∅ is represented empty (0) and ¬∅ represented non-empty (1)

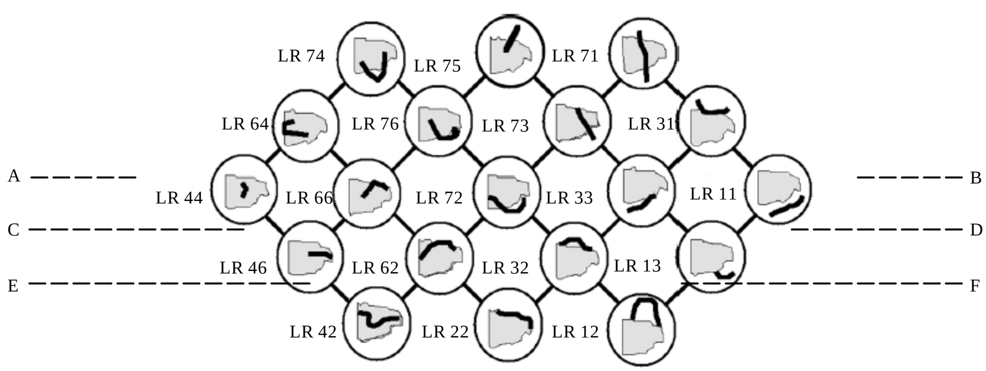


Fig. 3: The conceptual neighborhood graph of topological relationship model between line and region (Egenhofer and Herring, 1991)

LR 13 on the extreme right. This is a line to the internal line that touches the boundary on the inside because/becoming the extreme line that touches the boundary on the outside.

Topological relations in itself are inadequate to represent the robotic movement. Robotic movement creates an imaginary path that can be represented by line, the line and surrounding area can be represented by a region and semantic properties of which relation can be determined. These properties are described in and useful to represent robotic movements. The splitting and nearness determines the followings:

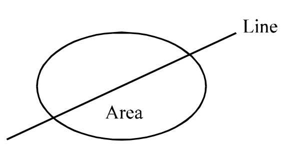
- The Splitting determines the intersection of the region's and line's interiors, boundaries and exteriors
- The Closeness determines how far apart region's boundary and the parts of the line are

The appropriate range of metric parameters for natural-language spatial term is considered to find out the appropriate natural language term for the robotic movement. After computing all these metric parameters and topological parameters, the correct term of natural language can be determined. This allows a foundation for the use of natural language term to describe spatial relationship deployed robotics movement.

Deploying the natural language spatial relations to capture the robot's interaction with the environment, this research used the topologic and 16 different metric properties Shariff (1996). The first property describes the topologic relation between the region and the line. The 15 different metric properties are represented on separate dimensions: seven for splitting, four for closeness and four for alongness. The topologic properties of natural language spatial relations are described by different values on this dimension. While most qualities are described on a linear dimension, this quality dimension has a network structure. This paper uses the seven metric properties for splitting.

The splitting:

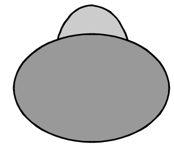
$$\text{Inner Area Splitting (IAS)} = \frac{\min(\text{Left area}(L^{-} \cap R^{0}), \text{Right area}(L^{-} \cap R^{0}))}{\text{Area}(R)} \quad (3)$$



The line's Interior divides the region's interior into two areas.

The Eq. 3 is stated that the range of IAS is $0 < \text{IAS} \leq 0.5$. It would reach 0 if the interior-interior intersection between the line and the region was empty, and is 0.5 if the line separated the region's interior into same size:

$$\text{Exterior Area Splitting (EAS)} = \frac{\text{Area (bounded Exterior}(\partial R, L^{0}))}{\text{Area (R)}} \quad (4)$$



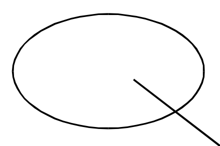
Metric measure of this property is the exterior area splitting ratio (EAS) as the area of the exterior boundary area, over the area of the region:

$$\text{Interior Traversal Splitting (ITS)} = \frac{\text{Lenght}(L^{0} \cap R^{0})}{\text{Lenght (L)}} \quad (5)$$

Metric measure of this property is the interior traversal splitting ratio (ITS) between the length of the inner line and length of the total line.

The range of ITS is $0 < \text{ITS} \leq 1$. The highest value is reached if the line is completely contained in the closure of the region:

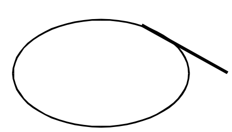
$$\text{Exterior Traversal Splitting (ETS)} = \frac{\text{Lenght}(L^{0} \cap R^{-})}{\text{Lenght (L)}} \quad (6)$$



Metric measure of this property is the exterior traversal splitting ratio (ETS) between the length of the outer parts of the line and length of the total line.

The range of ITS is $0 < \text{ETS} \leq 1$ ad would be 0 if the interior-exterior intersection between the line and the region was empty. The highest value is reached if the line interior is completely contained in the region exterior:

$$\text{Line Alongness (AL)} = \frac{\text{Lenght}(L^{0} \cap \partial R)}{\text{Lenght (L)}} \quad (7)$$



The range of the line alongness ration is $0 \leq \text{LA} \leq 1$. LA is 0 if the line intersects the region's boundary exclusively in 0-dimensional components and it reaches 1 if:

$$\text{Perimeter Alongness (PA)} = \frac{\text{Lenght}(L^0 \cap \partial R)}{\text{Lenght }(\partial R)} \quad (8)$$

The range of the perimeter alongness ration is $0 \leq PA \leq 1$.

$$\text{Region Boundary Splitting (RBS)} = \frac{\text{Min (Lenght}(\partial R \cap \partial L)}{\text{Lenght}(\partial R)} \quad (9)$$

The range of the Region Boundary Splitting (RBS) ration is $0 \leq RBS \leq 0.5$. RBS reaches the maximum value of 0.5 if the line's boundary separates the region's boundary into two parts of equal lengths.

Capturing robotic behavior: The semantic similarity measure serves as a computational model to describe the semantics of natural language spatial relations for robotic movement. The distance similarity measure is considered in the robotics decision making process. The following table shows the decision making process of robotic behavior.

The topological parameters and its metric refinements can be used to determine the best natural language spatial term to describe the path taken by a robot and to determine the natural language spatial term to be used in giving instruction to the robot.

The natural language spatial terms Bisects, Comes, Cuts, Cuts Through, Cuts Across, Divides, Goes Across, Goes through, Intersects, Runs across, Splits, and spans are used for Interior Area Splitting which is showed in Table 1. The robotic movement follows these spatial terms.

In Table 2 describes the natural language spatial terms Connects, Ends at, Starts and Ends in are used for External Area Splitting. These spatial terms are followed by the robotic movement.

The natural language spatial terms Comes from, Comes into, Comes out of, End just inside, Ends at, Ends in, Ends outside, Enters, Exits, Goes into, Goes out of, Goes to, Leaves, Run into, Is connected, Start in, Start just outside, Start just inside, Start outside are used for Interior Traversal Splitting which is showed in Table 3. The robotic movement follows these spatial terms.

Table 4 describes the natural language spatial terms Comes from, Comes into, Comes out of, End just inside, Ends at, Ends in, Ends outside, Enters, Exits, Goes into, Goes out of, Goes to, Leaves, Run into, Is connected, Start in, Start just outside, Start just inside, Start outside

Table 1: Natural language spatial term for Interior Area Splitting (IAS)

Interior Area Splitting (IAS)

Natural Language Spatial Term: Bisects, Comes, Cuts, Cuts Through, Cuts Across, Divides, Goes Across, Goes through, Intersects, Runs across, Splits and spans

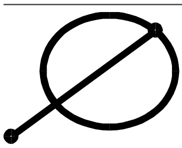
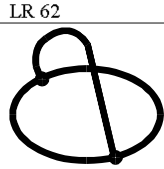
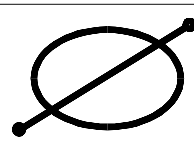
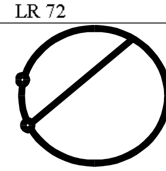
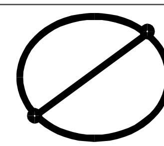
LR 42	LR 62	LR 71	LR 72	LR 73
				
$\begin{pmatrix}1&1&0\\0&1&0\\0&1&1\end{pmatrix}$	$\begin{pmatrix}1&0&0\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\0&0&1\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\0&1&1\\1&1&1\end{pmatrix}$

Table 2: Natural Language spatial term for External Area Splitting

Exterior Area Splitting (EAS)

Natural Language Spatial Term: Connects, Ends at, Starts and Ends in

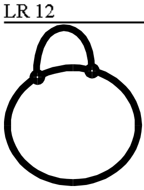
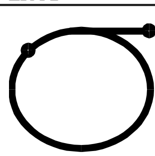
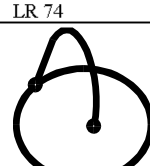
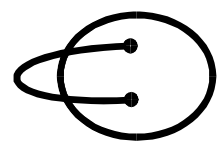
LR 12	LR 32	LR 74	LR 76
			
$\begin{pmatrix}0&0&1\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}0&1&1\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\1&0&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\1&1&0\\1&1&1\end{pmatrix}$

Table 3: Natural language spatial term for interior traversal splitting

Interior Traversal Splitting (ITS)

Natural Language Spatial Term : Comes from, Comes into, Comes out of, End just inside, Ends at, Ends in, Ends outside, Enters, Exits, Goes into, Goes out of, Goes to, Leaves, Run into, Is connected, Start in, Start just outside, Start just inside, Start outside

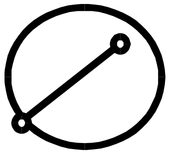
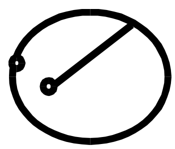
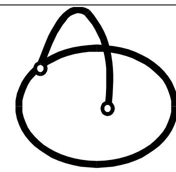
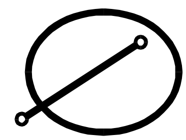
LR 12	LR 32	LR 74	LR 76
			
$\begin{pmatrix}1&0&0\\1&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&0\\1&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\1&0&1\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\1&1&0\\1&1&1\end{pmatrix}$

Table 4: Natural language spatial term for exterior traversal splitting

Exterior Traversal Splitting (ETS)

Natural Language Spatial Term : Comes from, Comes into, Comes out of, End just inside, Ends at, Ends in, Ends outside, Enters, Exits, Goes into, Goes out of, Goes to, Leaves, Run into, Is connected, Start in, Start just outside, Start just inside, Start outside

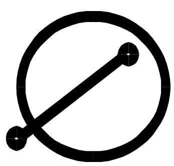
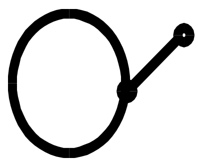
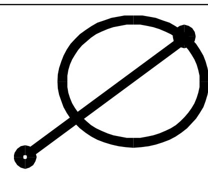
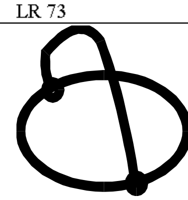
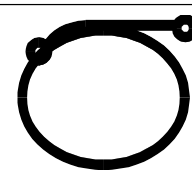
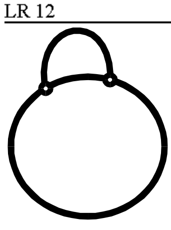
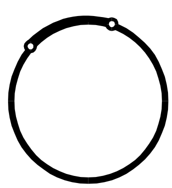
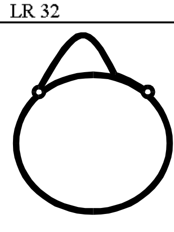
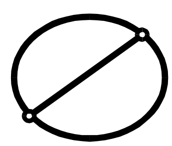
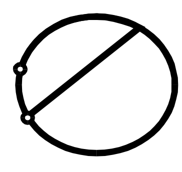
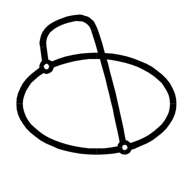
LR 13	LR 33	LR 72	LR 73	LR 75
				
$\begin{pmatrix}0&0&1\\0&1&1\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\0&1&1\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\0&1&1\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\1&0&1\\1&1&1\end{pmatrix}$

Table 5: Natural language spatial term for region boundary splitting

Region boundary splitting

Natural Language Spatial Term: Cuts, Cuts across, Goes through, Runs across, Bisects, Contained in edge, Spans

LR 12	LR 22	LR 32	LR 42	LR 62	LR 72
					
$\begin{pmatrix}0&0&1\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}0&1&0\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}0&1&1\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&0&0\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&0\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\0&1&0\\1&1&1\end{pmatrix}$

are used for Exterior Traversal Splitting for the robotic movement.

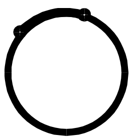
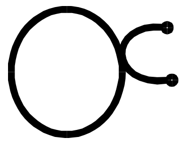
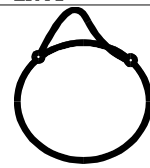
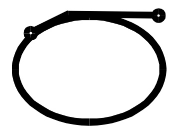
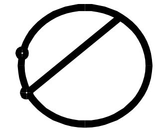
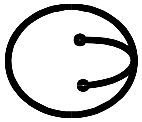
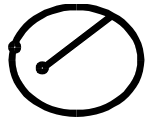
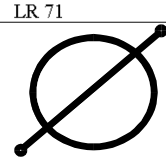
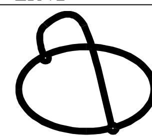
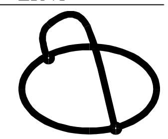
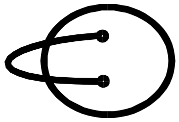
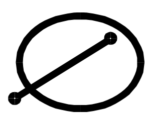
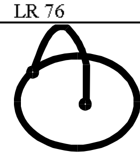
The natural language spatial terms Cuts, Cuts across, Goes through, Runs across, Bisects, Contained in edge, Spans are used for Region Boundary Splitting which is stated in Table 5. These spatial terms are followed by the robotic movement.

In the Table 6 the natural language spatial terms Bisects, Comes, Cuts, Cuts Through, Cuts Across, Divides, Goes Across, Goes through, Intersects, Runs across, Splits, Spans, Comes from, Comes into, Comes out of, End just inside, Ends at, Ends in, Ends outside, Enters, Exits, Goes into, Goes out of, Goes to, Leaves, Run into, Is connected, Start in, Start just outside, Start just inside, Start outside are used for Line Alongness and Perimeter Alongness. These spatial terms are followed by the robotic movement.

Table 6: Natural language spatial term for line alongness (LA) and perimeter alongness (PA)

Line Alongness (LA) and Perimeter Alongness (PA)

Natural language spatial term : Bisects, Comes, Cuts, Cuts through, Cuts, Across, Divides, Goes across, Goes through, Intersects, Runs across, Splits, Spans, Comes from, Comes into, Comes out of, End just inside, Ends at, Ends in, Ends outside, Enters, Exits, Goes into, Goes out of, Goes to, Leaves, Run into, Is connected, Start in, Start just outside, Start just inside, Start outside

LR 22	LR 31	LR 32	LR 33	LR 62
				
$\begin{pmatrix}0&1&0\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}0&1&1\\0&0&1\\1&1&1\end{pmatrix}$	$\begin{pmatrix}0&1&1\\0&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}0&1&1\\0&1&1\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&0&0&1&0\\1&1&1&&&\end{pmatrix}$
LR 64	LR 66	LR 71	LR 72	LR 73
				
$\begin{pmatrix}1&1&0\\1&0&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&0\\1&1&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\0&0&1\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\0&1&0\\1&1&1\end{pmatrix}$	
LR 74	LR 75	LR 76		
				
$\begin{pmatrix}1&1&1\\1&0&0\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\1&0&1\\1&1&1\end{pmatrix}$	$\begin{pmatrix}1&1&1\\1&0&0\\1&1&1\end{pmatrix}$		

CONCLUSION

This study described similarity measure for robotic behaviour and natural language spatial relationship objects. This paper used 16 different metric properties described. The first property describes the topologic relation between the region and the line. The 15 different metric properties are represented on separate dimensions: seven for *splitting*, four for *closeness* and four for *alongness*. This study focused on *Splitting* Properties of topological relationship 32 natural language spatial terms identified to represent 7 different splitting metric properties. The range values of each metric parameter were considered for determining natural language term for robotic behaviour. This structured natural language could be used to represents the spatial relationship for the robots control mechanism. This paper demonstrated that it is possible to define the actions and interactions of robots based on a near natural language with a recognized set of key words. Once defined, it can be shared between developers, modified by users and replace the need to define the same tasks and operations over and over again. Finally, it identifies an action and a condition when that action should take place.

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