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Using Autonomous Robots for the Formation of Alpha Numerals and Symbols

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Abstract: The present research proposed an interactive way of teaching using robots by making synergistic formations. The robots could arrange themselves on walls or ceiling of a room and make words or sentences or symbols with different or same colors. This kind of interactive teaching is especially helpful for kids. They could also be used for the actions like spreading on the ceiling making it looks like a sky full of stars or making an event viewer or reminder. The robot formation problems have never been studied for educational purpose before. The assembling and making of those characters as well as other interactive formations mentioned here are not available in the literature. The robots considered here are mini robots with volume of almost seven cubic centimeters with minimal burden of communication and having the capabilities of wall climbing. We are not available with these robots in our lab so we tested and verified our algorithm on simulation.

Key words: Mobile robots, intelligent robots, autonomous robots formations

INTRODUCTION

Robots are in use in almost all fields of science. With the increase in their production and reduction of cost, they are available with different sizes. This has increased their use in many diverse applications. Researchers are doing work on multi robot problems as compare to single robot problems. The multi-robot coordination and cooperation techniques have gone advanced and more intelligent in the areas of robotics. People are now looking for the different applications of multiple robots working in diverse, dynamic and complex environment and explore the new ways of the use of coordination and cooperation among them.

Multi-robot formation is also a part of multi robot research problems and is discussed in detail by different researchers with respect to different fields, including but not limited to schooling[1], herding[2], pray capturing[2], autonomous traffic[3], formation flight[4], etc. Most of the time people consider formation as making of geometrical patterns or shapes like column, line, wedge[3] etc.

In our literature review on robot formation, we did not come across any reference having research on the use of robot formation for educational purpose although they are used as a research tool. There are some researchers[3,5], who just mention the formation of big words as an example but did not implement. We have done some work on the formation of alphabets and numerals using multiple robots. And this could be extended to further applications.

As no one in literature claims about the making of alphabets and numerals, using multiple robots, so we can claim that we had proposed this idea and this could be implemented for teaching letters and words to youngsters. The motivation behind making those characters is the rapid decrease of their physical size[6] and lower cost, as well as teaching youngsters in an attractive way without harming them the hazardous radiations of computer monitors, or displays. The immobility of the respected displays is also one of the factors and we can see that youngsters are highly attentive to moving objects.

One can imagine making colorful characters on wall or ceiling of ones room by tiny robots and it is easy for a child to get educated even when he is on bed. Also the benefits of using these mini robots could be making other useful things, like spreading themselves on ceiling making stars or other shapes or even a clock at any place where it could be watched without lifting one's head from the bed. These robots could have multi color lights on their tops for making different colorful objects or pictures.

The smallest available micro robot is of the size of sugar cube[6], we hope in near future there will be smaller robots in the market and there would be many applications of them not limited to making alphabets alone. The availability of wall climbing mini robots assures us that these would be in use very soon.

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We will be using the term making character only, but with more robots we can also make words. For the sake of simplicity in this paper, we keep ourselves in making alpha numerals alone.

Theory: We suppose a group of robots gathered at some location on wall or ceiling. To make alphabets autonomously by these tiny robots, they must be arranged in a particular formation. For our case we take them collected on one side (Assembly area) and moving in a particular formation to make characters nearby (Field area). The robots, (Fig.1) are assembled on the right side and making the required characters on the left side. It is our convention, having assembly zone on left side and the field zone on right side; however one could define assembly zone at the top, bottom or right side of the field area.

The making of alphabets on a wall or ceiling is same as making (small circular objects) ASCII (American Standard Code for Information Interchange) characters on computer screen or on Dot Matrix display[7]. The Dot Matrix display is a block of LEDs (Light Emitting Diodes) arranged in a matrix form and used to display characters, by turning ON or OFF the respective LEDs. Figure 2 shows a 7×5 dot matrix[8]. The character 'A' displayed on dot matrix in Fig. 2 may not exactly be displayed similar by other people, it is just our convention.

The making of characters by using robots is almost the same as in dot matrix or computer screen but in this case the robots are not permanently arranged at fixed locations as that LEDs in a dot matrix, or pixels as in a computer screen, hence making it more complex to arrange them in a proper understandable form of alphanumeric character. One thing should be noted that in a dot matrix or screen the exact location of the required LED or pixel is known exactly and accurately before turning on or off that LED or pixel.

The arrangement of robots for making different characters is done by arranging the robots at the locations similar to displaying characters on a Dot Matrix. But the only difference is that on a Dot matrix the

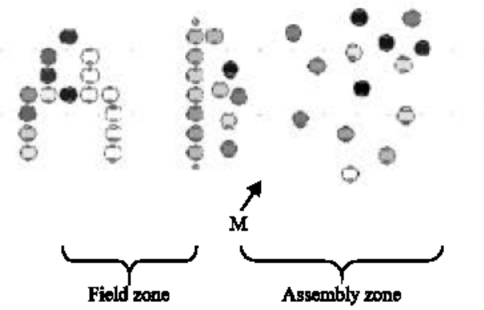

Fig. 1: The arrangement of seven robots on the right side between two markers and on the left side the robots making a character "A" with white/hollow robot areas still to be filled up

respective LEDs are turned on/off while here the robots move and arrange themselves in a fashion to make understandable characters, while keeping the unallocated space empty. Figure 3 shows the character set for ASCII. We have used a part of it skipping the non-visible characters or control characters[7], which are not used here. Each dot represents the placement of a robot for making a character. The character set could be changed for making other characters or characters with different fonts.

The character map is very important for the display of any character because of the location of a robot. This could also be done for making of non-English characters or symbols with an appropriate character map for them. Figure 4 shows the making of a Chinese character "λ" (Meanings Human or People).

Character map (robot positions) for alphabets 'A', "i" numeral '1' and a Chinese character, which we used to make these alpha numerals (Fig. 5). 'O' shows the expected position of the robot.

The algorithm: To validate our idea, we have simulated our algorithm, as these micro robots are not available to us. We needed at least 35 robots for making all 7×5 characters, i.e. if we have to completely fill every space

Fig. 2: (From Left) first showing a 7×5 dot matrix display, second shows the probable display of character "A" in one font, third shows the display of character "A" in another font and (right) shows the character "B" on the same module

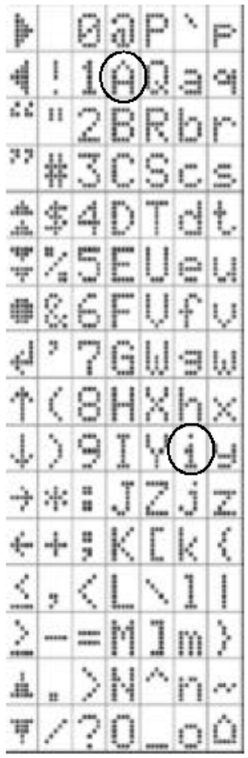

Fig. 3: A part of ASCII Character Map, showing the placement of robots for making understandable characters

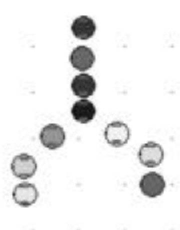

Fig. 4: The Chinese character "λ" made by autonomous robots

of the area, or minimum 7 robots to make a single alphabet "i" (The character using minimum number of robots). Also the robots we have are of bigger size and they are not capable of climbing the wall either.

For our simulation, we have defined two areas, one is known as Assembly zone where all the robots try to assemble and move towards the field zone, the second area, to make understandable alpha numerals.

In assembly zone each robot:

- Organize (make a line) between the two markers (if there is any empty space)
  - i): The robots between markers should make their position identification by starting from the lower or left Marker or Robot till the top or second marker.
- If no space between the markers then make another backup line behind the first one
- When the first line is assembled,
  - i) Tell the robots (in the line) the shape to be made and their column position
  - ii) Move to the Left side for some distance (Field zone), according to their supposed position in making the shape of the character and stop.

In Field zone, the robots remain in their position until ordered by the supervisor robot to come back to the assembly area. Restart all robots for a new job. Furthermore we needed the markers for the following reasons:

Making a legible character: For making an understandable character, we must know the position of a reader, it is same as hanging a picture on a wall, it may be upside down or oriented differently. For our case we must have the line passing through the markers and projected to the floor, be making an angle of 90 degrees. Or if on ceiling then the line should be aligned in such a way so that the character made, must be easily readable while viewing from floor, i.e. we must know which characters we are reading (Fig. 6). It is also obvious from this Fig. 6 that a single marker is not enough for our case so we used two markers.

	1	2	3	4	5
1			O		
2		O		O	
3		O		O	
4	O	O	O	O	O
5	O				O
6	O				O
7	O				O

	1	2	3	4	5
1			O		
2		O	O		
3			O		
4			O		
5			O		
6			O		
7		O	O	O	

	1	2	3	4	5
1			O		
2			O		
3			O		
4			O		
5		O		O	
6	O				O
7	O				O

	1	2	3	4	5
1					
2			O		
3					
4			O		
5			O		
6			O		
7			O		

Fig. 5: Robots "O" at different positions (character map) making characters "A" and "1", "i" and "λ"

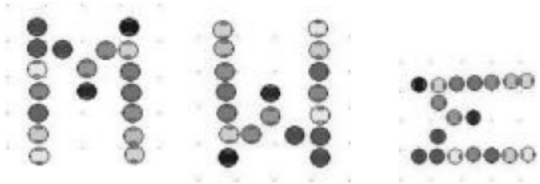

Fig. 6: It is the same character but with different orientations. It is “M” if it is oriented in the direction as we are reading now. But if we see it rotating this page by 180° it appears to be “W” but not “M” and something like Σ (sigma) when rotated this page by 90° to left. Hence the orientation is very important for making the character. That is why we needed the line to be 90° with respect to the floor, if, made on a wall

Defining the zones: The assembly zone is necessary to collect the robots for sending them in a formation to the field area. The field area is only reserved for the robots who are taking part in making the characters

Note that no robot should cross the virtual line made by two markers. It could be checked, if its direction is away towards the field area, the angle made by two markers and the robot (as a vertex) is obtuse, whereas if it is behind that virtual line then the angle is always acute. And if it is on the virtual line made by the two markers then the angle is 180 degree.

To make a line between the two markers, each robot should try to find any of the markers and by the identification of the color on each marker it can easily understand the confined area, i.e. assembly zone. When one finds the marker, it tries to find a blank space between the two, making a line. If an empty space is found try to take it otherwise make another line behind the first one.

Assigning position to each robot passing through them: For every character there is a position table defined with each entry indicating the presence of a robot at the location.

There is no predefined exact position of each robot in the formation as opposed to Jakob and Maja[3], so we can say the system is autonomous and the allocation of their position is dynamic. Each robot can see any other robot on its front, back, left and right. Te robot near to one marker allocates it position as two order pair (x, y), where, x is its column number and y is its row number. The column number is defined when the first column of robots is ordered to move for making the first column of the required character.

The row position is determined as follows:

The robot adjacent to the lower (Predefined color) marker on the virtual line, made by two markers, is given y = 1.

Table 1: In order to make a character, for our case alphabet ‘A’ the robots that pass through the two markers

	1	2	3	4	5
1	44	44	44	17	17
2	50	50	22	22	08
3	27	27	13	13	48
4	35	41	41	41	41
5	03	39	39	39	39
6	07	29	29	29	29
7	02	06	06	06	06

The robot next to it see the position table and identifies that the robot to its left or right has the ‘y’ value identified against its color or the number on the robot (Table 1).

Table 1 is used to make a character ‘A’ as shown in Fig. 1, that robot (ID 44) at position (1,1), gets its position in making the character as (1,1) but it does not move because it has no place in the making of the character. It remains there until a new line is formed and this time it has position (1, 2) but still remains there. When it gets the position (1, 3), it had to move to complete the part of making alphabet in the field area. Similarly the robot with ID 39 takes place between the two markers at location (5, 2) when the robot in front goes to the field area. This robot with ID = 39 remains there till it gets the position allocation of (5, 5) and it moves ahead. Also note that some of the robots with ID’s 17, 08, 48 do not move because they have no position in making the given character.

Note that there is no inter communication among peer robots. The information is available for all robots as a broadcast message.

The completion of making of a character or symbol: When all the required robots are passed between the markers with their respective positions, we suppose the character is formed.

Evaluation criterion: A perfect robot formation means that all relative inter-robot position vectors are fixed over time and a character is formed of a perfect shape. A perfect character formation would be if the inter robot distances for all is an integer multiple of a defined unit. This defined unit is the minimum distance between two neighboring robots when they are placed adjacent to each other (in a row or a column) while forming an alpha numeral.

Mathematically we define these as by observing the Fig. 7:

- If two robots R_i and R_j are in the same column; where $i \neq j$ then
  For all pairs of immediate neighbors (R_i, R_j), with distance dist (R_i, R_j),

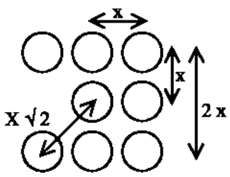

Fig. 7: The inner distances between two neighboring robots for the evaluation of convergence

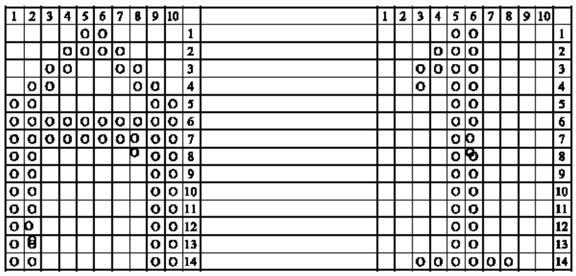

Fig. 8: The character A and numeral 1 with higher resolution, i.e, more robots

Table 2: For making a character, in our case alphabet 'A', the robots that pass through the two markers are shown in the Table 1; this table shows the real number of robots columns used to make the same character

	1	2
1	44	44
2	50	22
3	27	13
4	35	41
5	03	39
6	07	29
7	02	06

$|R_i\text{-}R_j| = m*x$; where, 'm' is a positive integer and 'x' is the minimum distance robots should have between each other.

- If two robots R_a and R_b are in the same row; where, $a \neq b$ then
  For all pairs of immediate neighbors (R_a, R_b), with distance dist (R_a, R_b),
  $|R_a\text{-}R_b| = n*x$; where, 'n' is a positive integer and 'x' is the minimum distance robots should have between each other.
- If two robots R_l and R_g are in the same diagonal; where $l \neq g$ then
  For all pairs of immediate neighbors (R_l, R_g), with distance dist (R_g, R_l),
  $|R_l\text{-}R_g| = k*x*\sqrt{2}$; where, 'k' is a positive integer and 'x' is the minimum distance robots should have between each other.

In any case m, n or k may or may not be equal.

CONCLUSION AND FUTURE WORK

We have done the alpha numerals of English alone but the non-English characters and symbols could also be implemented. This is possible with a good character map. Similarly different fronts could also be implemented in the same way. We have made one Chinese character for this case (Fig. 4).

Still we believe the currently available size of smallest robots is not very good for visualization of the characters if the viewing distance is too small particularly if any of the two robots are making a diagonal line. It is due to the fact that resolution is very low and the characters appear to be jagged. This could be improved with higher resolution i.e. use of more robots of smaller size for a same character (Fig. 8).

We can see from Table 1, the number of robots making the character appears to be too many. But if we have a closer look this list could be reduced to only two columns or even less number of robots. The important fact is that only two columns of robots are enough for making the same character (Table 2). The number of robot lines may not be same for all the characters.

The algorithm has to be further investigated for the cases when there is no need of a full column of robots. For example, for making the numeral '1' (Fig. 5) the robot at position (7,4) should be passed as soon as it is available. This should not wait for the whole column to be formed between the markers. Especially the case when the robot is in the somewhere in the middle of the markers.

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