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Fuzzy Controlled Routing in a Swarm Robotic Network

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ABSTRACT

Swarm Robotics originated in the research inspired by biology. It is the usual sense of the multi-robot systems which have been given the emerging attributes of swarm intelligence. In nature, ants, termites, wasps, bees and other social insects have inspired surprisingly inspiration of human. These groups of organisms show how to interact with a large number of simple individuals and generate the collective intelligence of systems to cope with complicated tasks. Swarm Robotics is a special robot system which is composed of a group of indiscriminate robots and so it is a typical distributed system. If a task is for only one robot and the robot will be very complex and expensive inefficiently. But if it is for the swarm robotics, the complex task can be done by many more simple robots efficiently. For the Routing problem, the quality of a potential route is determined by the length of the route (i.e. number of links) and the congestion along the route. It is desired to balance the traffic load among links in the network so it is desirable to select routes with a low obstacle rate. In addition, shorter routes are preferred over longer routes because they use fewer network resources.

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1. INTRODUCTION

In an indoor system where a swarm of robots are assigned different tasks and are to communicate with each other and divide the task among themselves. The main idea in our approach is to use a routing algorithm to set up a route between the event and the robot that wants to serve it over the network maintained between the robots using their communication system using which robots can calculate relative position of each other. We assume that each event is represented by a robot that remains static at the event location and does all the communication for the event. This is a realistic assumption, as the need to perform a task will be identified by one of the robots of the Swarmanoid.

For the Routing problem, the quality of a potential route is determined by the length of the route (i.e. number of links) and the congestion along the route. It is desired to balance the traffic load among links in the network so it is desirable to select routes with a low obstacle rate. In addition, shorter routes are preferred over longer routes because they use fewer network resources. In other words, the preferred route is one with a "small" route length and "light" congestion. Thus, the two fuzzy input variables for the fuzzy controller are Route_Length and Congestion. These variables may be represented as continuous or discrete fuzzy variables since each input value is an integer. The output variable of the fuzzy controller is a rating for the path. The fuzzy output variable Rating is expressed as a continuous fuzzy variable. Both fuzzy input variables, Route_Length and Congestion, have three fuzzy values resulting in nine different potential combinations of input values.

2. PATH NAVIGATION

In an indoor system where a swarm of robots are assigned different tasks and are to communicate with each other and divide the task among themselves. The main idea in our approach is to use a routing algorithm to set up a route between the event and the robot that wants to serve it over the network maintained between the robots using their communication system using which robots can calculate relative position of each other. We assume that each event is represented by a robot that remains static at the event location and does all the communication for the event. This is a realistic assumption, as the need to perform a task will be identified by one of the robots of the Swarmanoid.

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Theconsequent of each rule is chosen to reflect the desired route and wavelength preferences. A diagram of the proposed fuzzy controller is shown in Figure 1.

Table1. FuzzyIf-then Rules

If Route Length is small and Congestion is less the Rating is excellent
If Route Leng this small and Congestionis medium the Ratingis good
If Route Lengthis small and Congestion is heavy the Rating is poor
If Route Leng this medium and Congestion is less the Rating is good
If Route Leng this medium and Congestion is medium the Rating is average
If Route Leng this medium and Congestion is heavy the Ratingis poor
If Route Length is large and Congestion is less the Rating is average
If Route Leng this large and Congestion is medium the Rating is poor
If Route Lengthis large and Congestion is heavy the Rating is poor

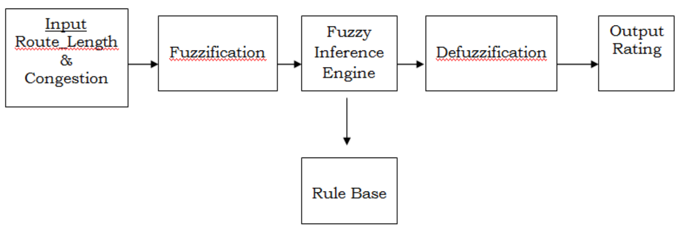

Figure 1. Fuzzy Controller

3. FUZZY CONTROLLED ROUTING ALGORITHM

Fuzzy-controlled adaptive Routing algorithm is basedona set of fuzzyif-then rules that guides the selection of a physical route eachevent requestbased on the current state of the network. In a network with N nodes, L links, and O obstacles perlink, each source nodes maintain sits own routing table RT^S(s =1, 2...N) that contains a list of all paths from the source nodes to all destination nodesd≠s. For larger networks, the size of the routing table can be reduced by limiting the number of alternate routes for each destination. For simulation purpose, limited the routing is limited to 5 routesper (s, d). Table 2 shows an example of a routing table for the simple network shown in figure 2.
The network maintains a L ×O l i n k -Obstacle status matrix S where

Sl0 =
1, if Routewis in useon linkl,
0, otherwise

Table 2. Routing Table

Destination	Route
2	(1,2)
	(1,6,5,2)
	(1,6,5,4,3,2)
3	(1,2,3)
	(1,6,5,2,3) (1,6,5,4,3) (1,2,5,4,3)
4	(1,2,3,4)
	(1,6,5,4)
	(1,2,5,4) (1,6,5,2,3,4)
5	(1,6,5)
	(1,2,5)
	(1,2,3,4,5)
6	(1,6)
	(1,2,3,4,5,6)

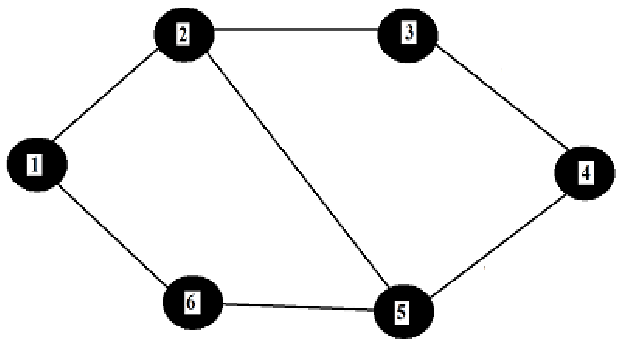

Figure 2. Network

This matrix is used by the fuzzy controller to determine the number of available wavelengths on a route. There is two types of requests used in the algorithm. Connection requests arriveat individual nodes and contain the source nodes, destination noded, and holding time h for the connection. Termination requests are setup by each node once a path has been established.

Algorithm: FC- based Routing algorithm

```
Initialize: RTs=[empty table] for s=1,…, N.
       S=L*O zero matrix.
       T=[empty table].
              While (termination criterion not fulfilled)
              Wait for a request to arrive (connection or termination).
                     If request is a connection request (s, d, h)
                     Let Rsd be the set of routes in routing table RTs to destination d.
                     For each route ri∈Rsd, i=1,….,| Rsd|
                     Let Li be the set of links that compose route ri.
                     Let Routelength*=| Li|.
                     Let Congestion*=| Oi |.
              Invoke fuzzy controller
                     For each fuzzy rule
                     Fuzzify Route Length* and Congestion* from the membership function
                     after fuzzification
```

```
                End
        For each fuzzy rule
                Calculate fuzzy output from Mamdani’s rule
        End
        Aggregate the fuzzy outputs
                Defuzzify to yield a crisp rating

                Let Rating; be the output of the fuzzy controller for
                routeri
                        Exit fuzzy controller.
                End
        Let i* be the index of the route with the highest rating.
                If Oi * is full
                        request is blocked.
                Else
                        Set Li *=L
                        Route request on route ri*.
                        Update T by adding termination request (L*,t + h)
                End
                Else

                        If request is a termination request (L*,O*)
                End
        End
End
```

4. RESULTS AND ANALYSIS

The Performances is evaluated for the FC-based routing algorithm on the network shown in Figure 2. A traffic model in which connection requests arrive at each node according to a Poisson process with network-wide arrival rate λ is used for simulations. An arriving session is equally likely to be destined to any node in the network. The session holding time is exponentially distributed with mean 1/μ. The load per source destination node pair is λ/N (N-1) μ A node may engage in multiple sessions and parallel sessions may be conducted between a source-destination node. In each case FC-Based algorithm is found to be superior compared to Fixed-SP and Alternate Routing methods. Table 3 shows the average blocking rate over all network loads for each algorithm. It is observed that average Blocking Rate decreased by using FC-Based algorithm. The Table 3 show the Average blocking rate of all 3 routing methods.

Table 3. Average Blocking Rate

Routing Method	RouteAssignmentPolicy Average BlockingRate			
	Least-Used	Most-Used	Exhaustive	Random
FC	0.0039	0.0031	0.0038	0.0023
Fixed	0.2827	0.2763	0.2850	0.2740
Alternate	0.2600	0.2542	0.2605	0.2596

5. CONCLUSION

Inspired by swarm intelligence, we have introduced an alternative approach to solving the multicast routing problem in mobilead hoc networks. Multicasting with multiple cores by adopting swarm intelligenceis an ondemand multicast routing protocol that creates a multicast mesh shared by all the members with in each group with other members. Ant agents are used to select multiple cores and the secores use ant agents to establish connectivity with group members. Multicast with multiple cores will support the large scale Distributed Virtual environment (DVE) applications used within mobile ad hoc networks. Multicasting with multiple cores by using swarm intelligence can be applied with other objectives such as load balancing, energy conservation, and security as future work.

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