Route Optimization with Q-learning

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Abstract: Due to increasing energy requirement the consideration of route determination is becoming important. The aim of this project is to find optimum result considering its important criteria. In this work, Geographic Information System (GIS) based energy transmission route optimization had been performed. In this optimization, using Multiagent Systems which is subdirectory of Distributed Artificial Intelligence the criteria affecting energy transmission line had been severally analyzed. The application had been actualized on the Selcuk University Campus Area. Therefore the digital map of the campus area particularly had been composed containing of relevant criteria. Using Q-learning Algorithm of Multiagent System the optimum route had been determined.

Key-Words: Route Analysis, Q-learning, Optimization, GIS

1 Introduction

Nowadays the establishment of Energy transmission lines are becoming important, in order to meet increasing energy requirement. Particularly, increasing urbanization and electrical power lost, decreasing fertile agricultural land and electric waste makes the optimum route very important when energy transmission lines are established.

In light of the criteria, we aimed to install a system to find the optimum route. If we think each criterion as an agent, the system will be established with multiagent architecture. Taking advantage of this cohering we used Multiagent Systems (MAS) to find optimum route.

Multiagent System (MAS) is one of the sub-disciplines of Distributed Artificial Intelligence (DAI). Distributed Artificial Intelligence (DAI) is examined according to two disciplines [1];

1. Distributed Problem Solving (DPS)
2. Multiagent Systems (MAS)
3. Reinforcement Learning (RL)

DPS, focus on the information management taking place in the systems consisting of subsystem solving different problems and MAS is also interested in behavior management of agent or object that is working together and independent agent [2].

An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors. Also an agent is a computing system that is capable of autonomous action in this environment in order to meet its design objectives [3].

An intelligent agent can react for the goal that is chosen for it. Also an intelligent agent communicates with the other agent in the same environment [3].

Agents had been used to resolve many problems with their features. However, with the problems in real life usually more than one agents influence each other. If more agents come together for same aim, multiple agent systems are formed. So using MAS more realistic and easy solutions can be found. By this way MAS is formed and solutions are more realistic and easy. In our work every criterion thought as an agent. The criteria are dynamic and some times related each other.

Finding optimum route is a complex problem. It doesn’t mean the shortest path problem. It is important to find the best way under the criterion that is determined by experts. This problem solved using with Q-learning Algorithm which is an algorithm of Reinforcement Learning (RL). Next section Q-Learning Algorithm is described.
2 Q-Learning Algorithm

When intelligent agents are planning these learning methods are used:
1. Planning Learning (PL)
2. Supervised Learning (SL)
3. Reinforcement Learning (RL)

Reinforcement Learning is the problem faced by an agent that must learn behavior through trial-and-error interaction with a dynamic environment [4].

Q-Learning is an algorithm of RL that can be applied areas to be modeled to Markov Decision Process (MDP). Problem of RL can be modeled as MDP. MDP is described the variables below [5]:

\[
\begin{align*}
S, & \text{ set of possible states} \\
A, & \text{ set of actions} \\
s, & \text{ state} \\
a, & \text{ action} \\
r, & \text{ reward} \\
\pi: & \rightarrow S \times A \text{ is state transaction function}
\end{align*}
\]

An agent is interacting with its environment (Fig.2). The agent exists in an environment described by some set of possible states $S$. It can perform any of set of possible actions $A$. Each time it performs an action $a_i$ in some state $s_i$, the agent receives a real-valued reward $r_i$ that indicates immediate value of this state action transition. This produces a sequence of states $s_i$, actions $a_i$, and immediate rewards $r_i$ as shown in Fig.2. The agent’s task is to learn a control policy, $\pi: \rightarrow S \times A$, that maximizes the expected sum of these rewards, with future rewards discounted exponentially by their delay[6].

**Algorithm of Q-Learning:**
1. For each $s$, $a$ initialize the table entry $Q'(s,a)$ to zero
2. Observe the current state $s$
3. Do forever:
   3.1. Select an action $a$ and execute it
   3.2. Receive immediate reward $r$
   3.3. Observe the new state $s'$
   3.4 Update the table entry for $Q'(s,a)$ as follows [5]:

\[
\hat{Q}(s,a) = r + \gamma \max_a \hat{Q}(s',a')
\]  

In our work we used Q-learning Algorithm to find the optimum route. We applied the algorithm at the Selcuk University Campus area to test it. At the next section it will be described that how the Q-Learning were used and according to which criteria.

3 Finding Optimum Route

The use of Geographic Information System (GIS) has become necessary tool as a consequence of variation in technology, from data to information, especially in activities associated with cities, community and environment. Over the word, electrical energy is a need for basic necessity of cities for the heating, lighting, communication, etc. The electrical energy produced in power plants is transmitted to the consumption area via the electrical transmission lines. The feasibility of the lines' route is very important. In this feasibility, there are many restricts. Engineering based points, geographical information, environment and social advantages lies as the basic of restricts. Using these restrictions, the route of electrical transmission line must be determined resulting in the least cost, shortest path and going through infertile land without harmful effects on natural environment. During the feasibility of the route, use of GIS provides many advantageous points considering these restrictions and submits alternative routes [8].

It is complicated to find the optimum route of electrical transmission line. The important thinks to find the route are indicated as below [7]:
1. Engineering requirement perspective
2. Built environment perspective
3. Natural environment
4. Avoidance Areas

With these agents some criteria are emphasis and these are:
1. Angle of refraction
2. Altitude
3. Wind state
4. Land efficiency
5. Proximity main route
6. Displacement of petrol and natural gas line
7. Proximity buildings
8. Forest and Parks
9. Avoidances areas

Algorithm tested at Selcuk University Campus Area (Fig.3). The routes are shown red lines. Start point is A and final is B.
We used digital map of Selcuk University Campus Area and take some coordinates on it. These points are fixed with Global Positioning System (GPS). Criterion of each point is determined. In this work 3 criteria which is existing on the digital map, is used to run the algorithm. These criteria are angle of refraction, altitude and distance. The angle of refraction and distance are surveyed. Each point is numbered starting with 2 to 53. As shown in the Fig. 4, our starting number is 2 and finish is 45.

All criterion has different measurement unit. So we normalized all values to 0-1 space. Then each criterion values are multiplied with a digit (between 1-0) according to importance of criterion. The result value is transferred to algorithm as instant reward.

Values of Q-table are 0.05 at first. During the algorithm Q values are updated according to Equ.1. The selection of next point Boltzman Distribution is used (Equ.2). k variable of Boltzman Distribution is chosen small values at the beginning and during the iterations it is made bigger.

\[ P(a_i | s) = \frac{k^{Q(s,a_i)}}{\sum_{j \in A} k^{Q(s,a_j)}} \]  

After 1000 iteration we achieved the route with this number: 2, 3, 4, 22, 23, 24, 26, 27, 50, 28, 29, 30, 31, 32, 33, 34, 35, 45.

4 Conclusion

Nowadays, It is important to use the knowledge direct, actual and fast. GIS helps us to reach the actual knowledge faster and low-cost.

In this work, we have found the optimum route on the map with specified criteria. Along the program Q-learning is used. To make this application more effective depend on GIS knowledge. While the information increasing belongs to the criteria of the each point, more optimum data will be obtained. Hence determination the criteria affecting electrical transmission line route, selection with the GIS method, will be easy our work in cost, labor force and time.

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