**Introduction:** Hi everyone, I'm Tugcem. Today i'll talk about my thesis topic. Currently i am working on multi-objective path planning in virtual environments with Faruk Polat.

**Outline:** Before beginning, i'd like to introduce the outline of presentation. First of all, i will give the motivation and the definition of the thesis that why we are getting deal with this problem. Then, I will give some related studies about this area. After, I will get into dynamics of the topic and elaborate the problem. I will consider about the boundaries and concepts of thesis. Then, I'll give what we have done so far, in which phase we are, and further to-do list.

**The Basic Concepts:** First of all, I want to give the basic concepts we are dealing with on this study. The path planning is basically a process that an agent or an intelligent structure finds a way out from initial location to a target one. We can diverse path planning into two main categories. The first one is offline planning, which is not bounded by a time period. The planning process is executed and the optimal paths are generated on offline time. After one or more optimal paths are found, the path is used to reach to the target. This method could be used on static environments. However, if we want to have a more realistic solution, we must consider real-time dynamics. The online path planning provides this constraint that the planned path changes on runtime according to evironment dynamics.

The other concept we are thinking over on this study is multi-objectivity. Single-objectivity oriented path planning considers only one constraint that could be the shortest or the easiest path. But this concept is again could not provide a realistic modeling of real-life problems. Actually, almost all of the real world problems contains more than one constraint. Thus, we consider more than one constraints while finding a path. The comparison between two solituons can be done via domination of these solutions to each other. The formulisation of this domination is another issue. Some constraints could conflict, so we need to think about all of them at the same time.

The third concept is thinking about a target which moves intelligently or unintelligently. This brings the pursuit operation into domain. The agent should re-generate its path according to target's movements.

**The Problem Definition:** So far, we have seen the basic concepts of this study. The general problem can be simplified such that we must find valid paths through a moving target with several constraints in a dynamic environment. Of course, environmental properties and restrictions matter on finding the solution for this problem. When we try to organize all of these aspects in the same problem, it is inevitable to encounter with some issues like complexity of algorithm, consumed time to find the solution and the resources that consumed. Actually, time complexity could be the most significant issue among all of these problems (issues). Thus, we are trying to come up to a new algorithm that covers all of these aspects and considers the time manner at the same time. That means our algorithm should run fast - according to existing solutions- **Note:** Should be extended.

**Related Studies:** So, lets look into some related work around this research area. Actually, we could seperate these studies into 3 main captions. The first one centers on multi-objectivity concept while finding optimal paths. The second one centers on pursuit and chasing of a moving target. The third one simulates alternative scenarios and solutions around similar concepts. I wont give into details of these studies but just explain their methods briefly.

**Multiobjective-based:** Guo and others handles multi-objective path planning (MOPP) for the ball and plate system. The environment is represented by distance map (the euclidean distances between initial and target cells) and hazard map (which represents possible collisions between the ball and the obstacles). They use entropy method to calculate weights of objectives for each grid node. Simply, Dijkstra algorithm is employed as a solution. In simulation results, the path obtained by multi-objective method is much safer compared with single-objective A* algorithm.

Tarapata presents selected multi-objective approaches to shortest path problems in his paper. He gives a classification of multi-objective shortest path (MOSP) problems. and discuss different models of them. He uses terrain based grid network and use modified Dijkstra's algorithm.

Mitchell and his team examine the problem of planning a path through a low dimensional continuous state space subject to upper bounds on several additive cost metrics. They propose an auxiliary partial differential equation with which they evaluate multiple additive cost metrics for paths which are generated. The paper has heavy mathematical notations hard to follow.

**Moving-target:** Goldberg and others use multi-agent systems to pursue and capture the moving target in a virtual environment. Agents are allowed to communicate with each other if they are within their sight-area. Environment is a $m$ $x$ $n$ grid with randomly-placed obstacles, all agents and the target knows the topology of the world. They target is positioned at the middle of the grid and all the agents are placed at the lower left corner of the grid at initial. At least one of the agents can *see* the target. The objective is catching the target in the minimum number of movement.

Hollinger et al. concentrate on finding a moving, non-adversarial, known motion modelled target using multiple agents. non-adversarial, known motion modeled target using multiple agents (robotic searchers) in a closed virtual environment. They define this as Multi-robot Efficient Search Path Planning (MESPP) problem. These typical problems are NP-hard and number of searchers increase the solution space exponentially.

In moving target context, Koneig and his team publish several papers after 2009. They extend A* by covering moving targets and they present D* and D*lite algorithms. They are really efficient incremental search algorithms. Actually, we will go through these algorithms on our study.

**Other Methods:** There are also several other methods center on multiobjective path planning problem. These methods are generally evolutinary methods.

Pangilinan and others introduce an evolutionary algorithm for multi-objective shortest path problem. Their algorithm is based on Strength Pareto Evolutionary Algorithm (SPEA2).

Castillo and others define a genetic *offline* point-to-point agent path planner to find valid paths towards target. They concentrate on two constraints which are path length and difficulty and use a 2D environment.

Nasrollahy proposes a particle swarm optimization algorithm as a multi-agent search technique for a dynamic fully observable environment to minimize total path planning time while avoiding the local optimums. They try to optimize global best path through the goal position.

**Aim of Thesis:** If we turn back into our study, I'd like to give the details of thesis topic.

First of all, i try to give the boundaries and tradeoffs. In this thesis, we are trying come up with a Multi-objective real-time path planning algorithm. As multiobjectivity, this algorithm should accept not only two constraints but also n constraints. That means the formulation of constraints should be independent from constraint number. Also, the multiobjectivity brings the domination concept between solutions, which is used to determine which one is better. We also should formulate it well. On the other hand, we are dealing with a dynamic environment, so we time is an important issue for us. The algorithm should run fast and catch the target as soon as possible. Also, the dynamic environment brings the synchronization issue of domain concepts that this is another issue to handle.

Right now, we are studying on the properties of virtual environment to develop the algorithm. First of all, we are using a 2D grid environment. This environment is partially observable to agent and of course, dynamic. That means other concepts should also be mobile or stationary. We assume that we know the initial location of target. **(the target is stationary in a known location. As we progress, we will mobilize the target as well.)** And as all you predict, we have several obstacles and threads to harden the planning process.

As obstacles, we think that they can be both stationary and mobile. Some of these obstacles are transitive that we can refer rivers or hills from real-world model. But of course they consumes much more energy. We also have intransitive obstacles, too.

We can simply say that threads in environment try to prevent the agent to catch the target. Each thread could be stationary, mobile, or both. Threads have zones and each zone has a probabity to shoot agent - *shot risk percent.*

Basically, the thread is more probable to shoot the agent if it is closer to the center point of thread. Threads neighter try to catch the agent nor pursuits it. They have a sight area and if they observe agent within this, they gain a probability to shoot agent. Mobile agents have a movement schedule and moves accordinly.

The agent enacts the path planner role to navigate towards the target. It has a sight area that it can only observes the environment within this area. It only knows the observations within its sight area and the target location. Thus, it should re-plan its path in every time step if these information is updated. When it enters to a thread zone, it identifies the thread and gets the properties of it such as shot risk percent and movement schedule. The agent has a predefined life, so when a thread shoots the agent, its life decreases until reaches to zero. So the agent should try to find a riskless, shortest path with minimum life loss in a highly dynamic changing environment.

**What we have done, what are we doing and todo list:** So what have we done so far? First of all, we initialized our motivation. Then we examined related studies around this research topic and this helps to define the boundaries of working area. We formulate our problem and construct the basic structure of the algorithm. We reduce the problem into more simpler problems. Up to now, we are studying on a partially observable static environment. Then, we will try to evolve the algorithm with considering moving threads and finally we will include the mobilization of target to pursuit it. Also, all of the formal documentation of these steps are done.

In the next milestone, we are planning to start to the implementation of simulation environment. While implementing, the core structures within algorithm will also develop. Also, environmental and conceptual properties will be defined more precisely.

Actually, we are at the very beginning of everything and we have a lot of work to do. First of all, we did not decide on a specific domain for test environment. Algorithm will grow by simulation environment. As we start with are reduced problem, we should also include the mobilization of threads and target as well. And also the formal documentation should be generated.

This is what i have done and will do for my thesis, thank you for listening.

—We must formulate the definitions and dynamics of the thesis.