1. INRODUCTION

1.1 Background

Squad Game, is a research game which is developed by the researcher, delivered in Game Design category of Imagine Cup 2010. This game has faced a failure when researcher tried to implement a computer-player, which consists of several characters with different tasks and sub-goals. This computer-player should be able to provide the cooperation between characters.

On the other hand, Agent Based Modeling (ABM) (also sometimes related to the term **multi-agent system** or **multi-agent simulation**) is a class of computational models for simulating the actions and interactions of autonomous agents (both individual and collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole. It combines elements of game theory, complex systems, emergence, computational sociology, multi-agent systems, and evolutionary programming. This model enables agents to be autonomous, i.e. they are capable of adapting and modifying their own behavior. Besides, Q-Learning is a widely used learning method in ABM that has succeed in solving several problems in any kinds of Dynamic Environments [15].

Even though this model widely uses in simulations, it is not impossible to be implemented in a game. In fact, it has been implemented in several research games, such as BattleCity.net that adopted original BattleCity [10] video game, and First-person Shooter game which carried out soldier simulation for Naval Postgraduate School in Monterey, California [2].

Based on previous research, the researcher believes that this model can be implemented in a real-time strategy game that will be our concern in this research, Squad Game. It is possible that real-time strategy game is an analogy paralleling a real world (environment) for the agents. Besides, this game's genre may us to develop an environment that can be changed by the action taken by all entities in the game system.

1.2 Problems Formulation

The research will answer the following questions:

1. How to develop a Squad Game, as real-time strategy game's representation.
2. How to implement an Agent Based Modeling with Q-Learning for each characters in Squad Game.

1.3 Constraints

The constraints of the research are laid out as follows:

1. The gameplay of Squad Game is featured as the research's evaluation.
2. The changes of environment consists of the position goal's changes.
3. Prometheus Methodology as the design-method for Multi-agent System.
4. Q-Learning as the learning-method for the agent, divided as with and without sharing knowledge between agents.

1.4 Objective

The objective of the research is:

To develop a Squad Game, as a Dynamic Environment representatives, implements Agent Based Model with Q-Learning.

1.5 Methodology

1. Problem Definition

   Squad Game is a real-time strategy game, which has two main characters: *carrier* and *executor*. One character has a tied relationship to another whereas each goal could not be solved without a team work between them. In the other hand, most game theories and artificial intelligences provide each entity in the system as an individual, not a team. To build the characters which work together in the game, researcher used Agent Based Model. Moreover, the learning method for each agent is Q-Learning.
2. Literature Studies

   The literature studies consist of lecture notes and references about the following:

   a. Real-time strategy game,

   b. Agent Based Modeling (ABM), and

   c. Learning alghoritm for the agents.
3. Research Design

   a. Functional Design of Game Model [6]

      i. What is Squad Game?

      Squad is a game adopted chess' strategy when the player receives a responsibility to control all resources he has, to reach the game's goal.

      ii. Game's Objective

      The soldier (agent) receives a responsibility to work together as a squad solving problems.

      iii. How to Play?

      Frequently, aids are dropped to the terrain. When one problem comes up, squad has to distribute the aids to it. How? *Carrier* just needs to load the aids and bring them to the square where problems come up.

      Next, the *executor* has to unpack the aids. Simply said, the *executor* has to move to where problems come up, and then it unpacks the aids there.

   b. Design Model Agent

      The agents are eventually divided into two types characters in Squad Game: *carrier* and *executor*. Those agents are designed as equal agents in communication, means none of them inferior from another.

      i. Agent's Hierarchy

      In Squad Game, all of the agents don't communicate and negotiate each other directly. Even interact with environment (*terrain*), the agents will never send information directly to it. Besides, for supporting all interaction's features, researches states a supervisor entity (*monitors*) in the middle. It means all communication and negotiaten between agents, and interaction with environment, are provided by *monitors*.

ii. Agent's Learning

For learning skill in each agent, the researcher proposes to use Q-Learning as the algorithm. Q-Learning, is a reinforcement learning technique that works by learning an action-value function that gives the expected utility of taking a given action in a given state and following a fixed policy thereafter. One of the strengths of Q-Learning is that it is able to compare the expected utility of the available actions without requiring a model of the environment.

As the representative of human naive thoughts, Q-Learning has a capability to solve any kind of problems in a Dynamic Environment. In another research game, Sachiyo Arai and Katia Sycara in *Multi-agent Reinforcement Learning in Dynamic Environment* [1], developed a classic-game "Pursuit" which implemented Q-Learning. That experiment concludes that Q-Learning is available to be embedded in Multi-agent System with dynamic environment included.

c. Implementation

With common form of Agent Based Model, another question appears to make sure if the research that researcher developed is an agent system. For agent's modelling, researcher designed Squad Game based on the Prometheus Methodology. This methodology itself has been improved by RMIT, Melbourne with developing Prometheus Design Tool (PDT). PDT itself is a visual-design tools for designing multy-agent system. [13]

For implementing this model, researcher used C# programming language. Eventhough originally PDT is developed in Java, and has a capability to generate JACK code which is based on Java. There is no boundaries to transform this model into another object-oriented programming language.

d. Testing

The goal of testing are to measure the learning feature of Q-Learning in Dynamic Environment, and the adaptability between agents. For testing the first goal, researcher developed two types of Q-Learning (two scenarios). Those learning-features differ based on information shared between agents. In one learning-feature, all agents frequently merge and share their knowledge (*Q(x, a)*) and another they don't.

For the second one, researcher developed two conditions. In one condition, researcher uses two agents with different types of agents (both *carrier* and *executor*). Besides, in another one, researcher uses four agents with different types of agents.

For both scenarios, researcher will calculate the improvement of total time taken for each problems solved, and total steps taken by agents for each goals. Then, researcher wil determine the learning and adaptable performance based on those scenarios.

4. Hypothesis

Agent Based Modeling enables each agent in the system to adapt with its behavior and to modify its states based on the environment changed. It is suitable with the characteristic of Squad Game as real-time strategy game's representation, where agents' capabilities are changed based on the environment condition and the acts taken by all agents. Besides, Q-Learning enables each agent to learn the environment (by excluding another agent) by deciding what steps taken next in order to reach the goal, based on the value it gets in the past. Even the agents face dynamic environment, Q-Learning should be able to solve the problems appeared.

With all scenarios, we have in this research; we can predict that the Q-Learning's feature and agents' number will impact agents' performance. For Q-Learning's feature with share and merge knowledge, we can predict agents' will take more time than another feature, beside this may increase the probability to success the agents' reaching the goals. Because by sharing and merging knowledge makes the agents spend longer time to communicate in merging their Q-Matrix. Moreover, this scenario helps the agents to determine the optimum value based on all agents' experiences. On the other hand, the increasing of agents' number will affect to reduce the total steps taken for agents to reach the goals, but will spend more time at the same time. This condition creates a possibility for agents to stop their works if other agent has solved the problem. Nevertheless it makes the agents spend more time because of all communication happens between more agents in this system.

1.6 Systematic Writing

The research systematic writing is as follows:

1. INTRODUCTION
   Describes research's background for the same perception around this research.
2. BASIC THEORY
   Research in various areas is similar to Squad Game Project, either through gaming, agent-related work, or Reinforcement Learning. Description of existing and past research, which areas were complementary, and inapplicable. In the other hand, recaps all theories related to the research.
3. DESIGN
   Describes the underlying methodology and structure of the agent system and its learning, and discusses the decision and trade-offs made to tailor the design to implement the game and reach research's goal.
4. IMPLEMENTATION AND TESTING
   Describes the basic structure of Squad Game's engine and the data structures on which it is built. Then details the modules created for this research and what results where derived.
5. CONCLUSION AND FUTURE WORK
   Discusses the strong and weak points of the system currently implemented, and suggestes directions for future research and development.