In the following paragraph an introduction to game theory is given based on the work of \citep{leyton2008essentials} and \citep{Coursera}. For a more detailed and full introduction to game theory, the reader is referred to \citep{leyton2008essentials}.

# Intoduction Game Theory

%begin over dat gametheorie handig is in de economie

Game theory studies the interaction between independent and self-interested agents. It is a mathematical way of modelling the interactions between two or more agents where the outcomes depend on what everybody does and how it should be structured to lead to good outcomes. For this reason it is very important for economics and also for politics, biology, computer science, philosophy and a variety of other disciplines.

%Every agent has different levels of happiness for the different outcomes.

%self interested meaning

One of the assumptions underlying game theory is that the players of the game, the agents, are independent and self-interested. This does not necessarily mean that they want to harm other agents or that they only care about themselves.

%utility function meaning

Instead it means that each agent has preferences about the states of the world he likes. These preferences are mapped to natural numbers and are called the utility function. The numbers are interpreted as a mathematical measure to tell you how much an agent likes or dislikes the states of the world. \\

It also explains the impact of uncertainty. When an agent is uncertain about a distribution of outcomes, his utility will describe the expected value of the utility function with respect to the probability of the distribution of the outcomes. For example: with 0.7 probability it will be 7 degrees outside and 0.3 probability it will be 10 degrees. The agent can have a different opinion about that distribution versus another distribution. (\todo{uitleggen aan de hand van een voorbeeld}).

%Cooperative and non cooperative games

In a decision game theoretic approach an agent will try to act in such a way to maximise his expected or average utility function. It becomes more complicated when two or more agents want to maximise their utility and whose actions can affect each other utilities. This kind of games are referred to as non cooperative game theory, where the basic modelling unit is the group of agents. The individualistic approach, where the basic modelling is only one agent, is referred as cooperative game theory.

There are two standard representations for games. The first one is the Normal Form. The second one is the Extensive Form.

In the following list a couple of terms that will be used throughout the paper.

* *Players:* players are referred as the ones who are the decision makers. It can be a person, a company or an animal.
* *Actions:* actions are what the player can do.
* *Outcomes:*
* *Utility function:* the utility function is the mapping of the level of happiness of an agent about the state of the world to natural numbers.
* *Strategies:* A strategy is the combination of different actions. A pure strategy is only one action.

A game in game theory consists of multiple agents and every agent has a set of actions that he can play.

# Extensions on FlipIT

There a various possible ways to extend FlipIt. For instance Laszka et al. extended the basic FlipIt game to multiple resources. The incentive is that for compromising a system in a real case it needs more than just taking over one resource. An example is gaining access to a system and breaking the password. The model is called FlipThem \cite{FlipThem}. Two ways of flipping the resources are used: the AND and the OR control model. In the AND model the attacker only controls the system if he controls all the resources of the system, whereas in the OR model the attacker only needs to compromise one resource to be in control of the entire system. The difference with FlipThem and this paper is that we introduce a Graph Model in the beginning.

Another extension on FlipIt is done by Pham [\todo{citatie needed voor Are We Compromised?}]. Beside the action Flip there is another action Test. The basic idea is to test with an extra action if the resource has been compromised or not. This action involves also an extra cost. This model is useful if somebody wants to know for example if his password has been compromised or wants to assess the periodic security of a system. In \citep{MitigationCovert} \cite{MitigationNonTargeted} Laszka et al. they also consider non targeted attacks by non-strategic players and \todo{verder aanvullen}.

# Intoduction to FlipIt

In this section, we introduce the game FlipIt \cite{FlipIt}. FlipIt is a game introduced by .. .. and Rivest. First we explain the framework of FlipIt and after that the formulas and assumptions that we will make for the game for during the whole paper.

**\section{The First Topic of this Chapter}**

FlipIt is a two-players game with a shared (single) resource that the players want to control as long as possible. The shared resource can be a password, a network or a secret key depending on the setting being modelled. In the rest of the paper we will call the players the Attacker and the Defender. To get the control over the resource, players can flip the resource at any given time. Each move will imply a certain cost.

The unique feature of FlipIt is that the move will happen in a stealthy way, meaning that the other player has no clue that the other player has flipped the resource. For instance, the defender will not find out if the resource has already been compromised by the attacker, but he can only potentially know it after he flips the resource himself.

The goal of the player is to maximize the time that he or she has control over the resource while minimizing total cost of the moves. Players won't move to frequently. A move can also result in a "wasted move", called a flop. It may happen that the resource was already under control by the defender. If the defender moves when he or she has already control over the resource, he or she would have wasted move since it does not result in a change of ownership.

Because the players move in a stealthy way, there are different types of feedback that a player can get while moving:

* Non-adaptive (NA): The player does not receive any feedback while flipping.
* Last move (LM): The player finds out the exact time the opponent played the last time.
* Full History (FH): The player finds out the complete history of the opponents move.

The game can be extended by the amount of information that a player receives. It can also be possible for a player to get information at the start of the game. Both interesting cases are:

* Rate-of-play (RP: The player finds out the exact rate of play of the opponent.
* Knowledge-of-strategy (KS): The player finds out the complete information of the strategy that the opponent is playing.

In our assumption the strategy of both players will be non-adaptive. None of the players has information of the strategy of the opponent.