CS302-Modulation and Simulation

Lab 2

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Contents

1 Innovation Diffusion Models

Adoption of a new innovation does not happen simultaneously in a social system; rather some people adopt the innovation faster than others.

There are five established adopter categories, the majority of the general population falls in the middle categories.

1. Innovators - First ones to try out the innovation. They are willing to take the risk of developing something new.

2. Early Adopters - They are the first ones to adopt to any new idea. They can be called the trend setters.

3. Early Majority - They get involved once they know from word of mouth about any product. Once they are convinced about it, they start using it.

4. Late Majority - They will adopt only after majority of the people are trying it and the product is well established in the market.

5. Laggards - They are the most difficult of the people, they will only adopt to any new product under extreme conditions.

1.1 Assumptions about the Society

1. We will be considering the net effect of the innovation together and not individually.

2. There exists a good communication channel between the people and there are good socially connected groups present.

3. The interaction between the people is instantaneous.

4. The users adopt new technology to maximize their utility.

5. People who are very far from each other and cut off from communication, who lack awareness about the new product would not be considered.

1.2 Assumptions about the Technology

1. The technology is beneficial to the people and better than existing technology, thus getting accpted by the people.

2. The technology is within the time, i.e. the even though sometimes the product being very innovative it isn't accepted well by the people. E.g. Orkut

3. The competition from other products isn't considered here i.e. we will be looking at the product absolutely.

1.3 Differential Equation Modelling Diffusion Of Innovation

$$\frac{dN}{dt} = \alpha(t)(C - N(t)) \tag{1}$$

1.4 Parameters

$N(t)$ = Total number of people who have adopted the product till time t
$\alpha(t)$ = Diffusion Coefficient
C = Maximum number of potential users of the product
t = Time

1.5 External Influence Model

Here, the initial innovators who adopt the model without any external influence i.e. there is no interaction between any to users. Thus, the probability of a person knowing about a new innovation is dependent only on his awareness about the latest news about the innovations.

Since, the size of population is very large the possibility of knowing about a new innovation is considered to be an average value for all and all the calculations are done based on this value.

For this case, we will consider only the spread of technology using the advertisements and no social interactions. Hence, the diffusion constant has a constant value because it is independent of time.

The differential equation modeling this phenomena is given by:

$$\frac{dN}{dt} = p(C - N(t)) \tag{2}$$

Here, C is the proportionality constant, showing the awareness level due to advertisements hence leading to adoption.

1.5.1 Solution

Solving the Eq. (2) we get,

$$N(t) = C - (C - N_0)e^{-pt} \tag{3}$$

Here, N_0 is the number of initial innovators who adopted the product. The number increases to the size of the population. Due to this, there is an increase in the number of people using the product initially and later on it saturates to a constant i.e. the total population.

1.5.2 Computational Model

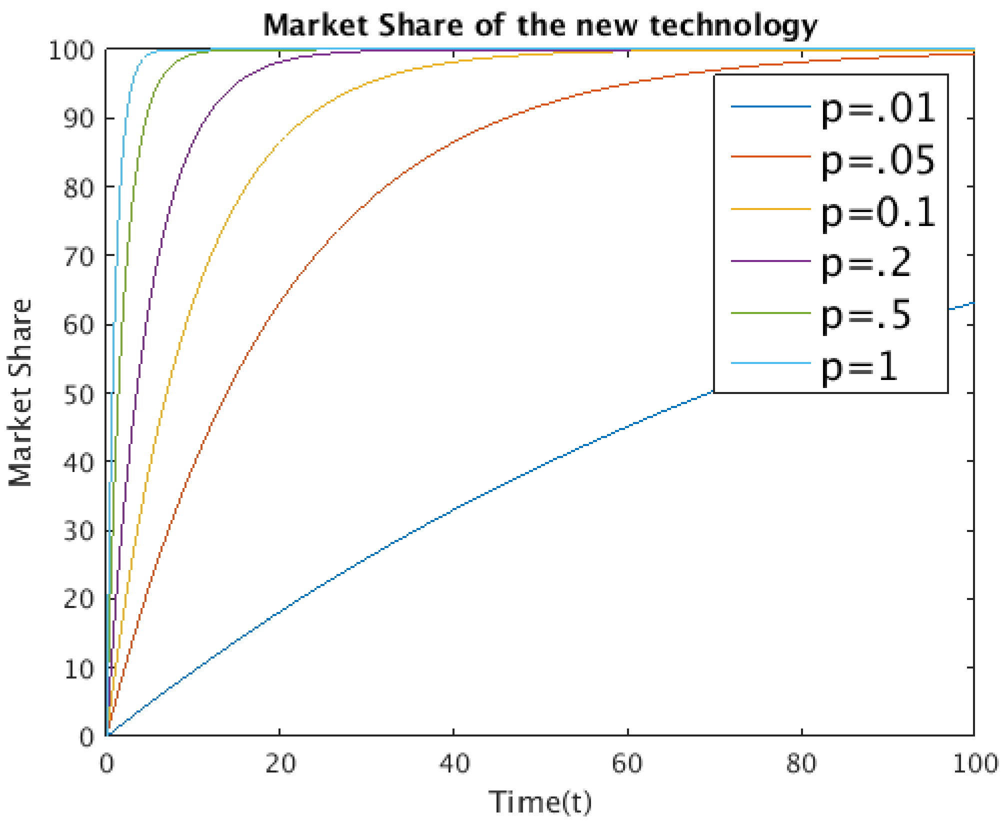

Figure 1: From Eq. (2) we see that Market Share of the product eventually reaches the saturation level

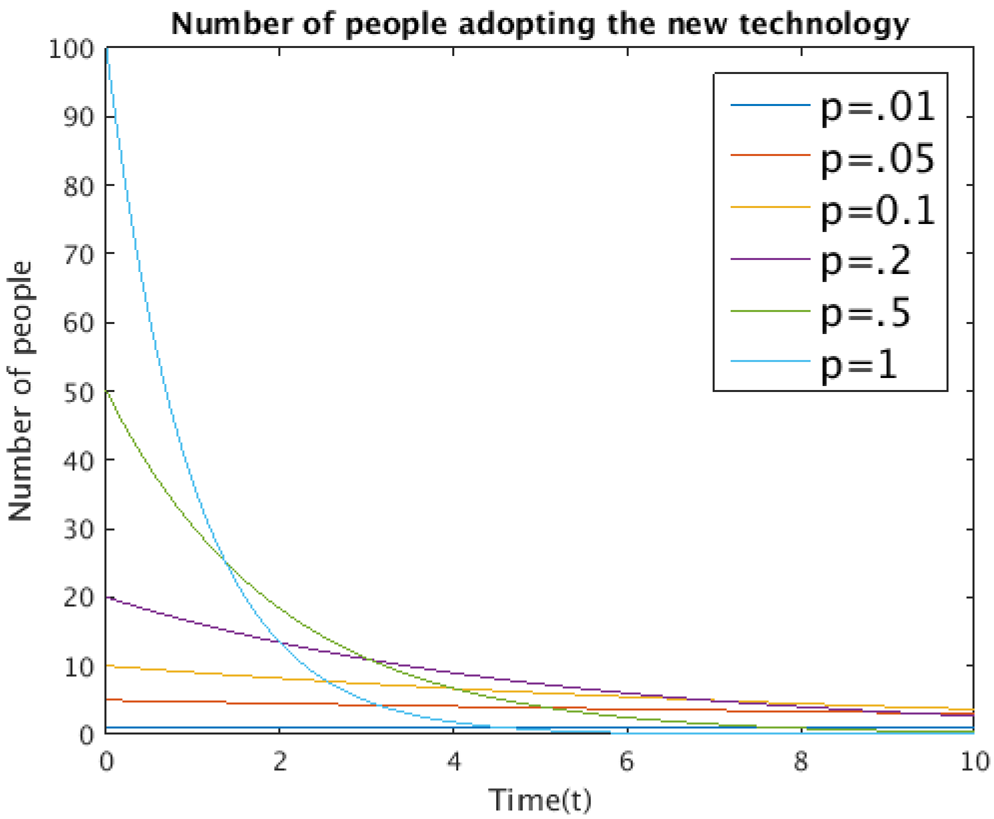

Figure 2: From Eq. (2) the number of users at any particular time will decrease. That is shown in this figure.

On increasing the value of 'p' i.e. the probability of knowing about the new innovation, the saturation is achieved faster. This is obvious because more number of people are aware of the product and hence would adopt to the innovation faster. The maximum saturation value won't change as it is fixed (size of the population).

1.6 Internal Influence Model

Here, the early adopters who adopt the model based on the adoption of other users. Instead of the effect of advertisements and campaigning we will only look at word of mouth propagation. This makes the equation dependent on the number of people who are aware of the innovation. The probability that we will now consider would be the probability of communication between two people. Hence, the diffusion constant is a function that is dependent on the communication between two people instead of people knowing about the new technology.

The diffusion function now would be, $\alpha(t) = \frac{qN(t)}{C}$.

Hence, the differential equation modeling this phenomena is given by:

$$\frac{dN}{dt} = \frac{qN(t)}{C}(C - N(t)) \tag{4}$$

1.6.1 Solution

Solving the Eq. (4) we get,

$$N(t) = \frac{CN_0 e^{qt}}{C + N_0(e^{qt} - 1)} \tag{5}$$

Here, N_0 is the number of initial innovators who adopted the product. The number of users increases exponentially until it reaches the maximum population C.

1.6.2 Computational Model

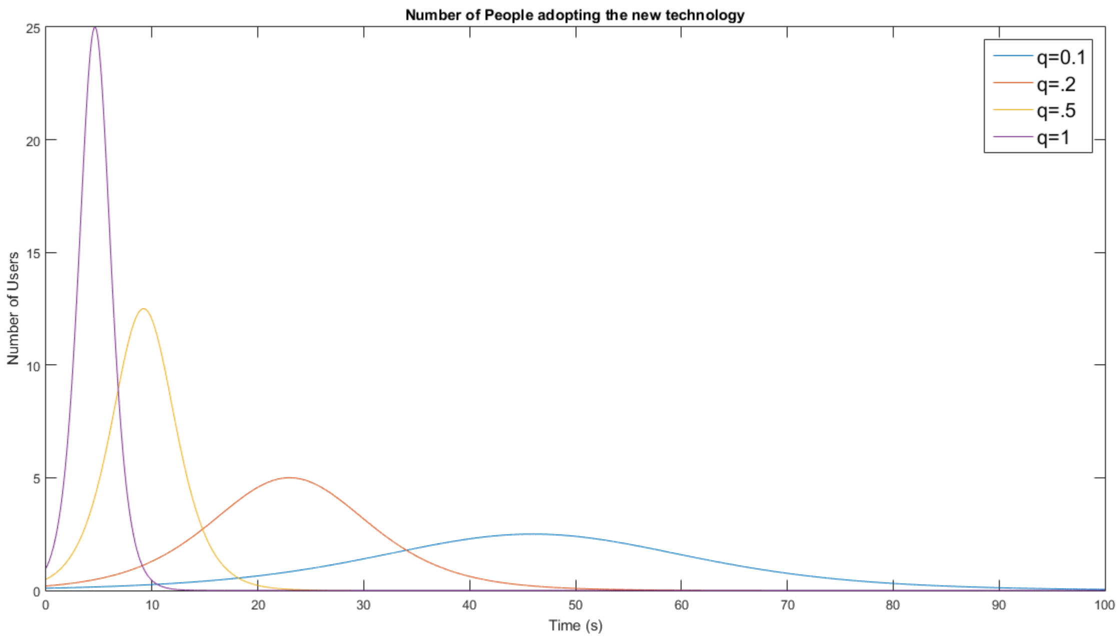

Figure 3: We have plotted the number of people adopting to the product for different values of q.From Eq. (4) we see that the number of people accepting teh product initially increases and then decrease.

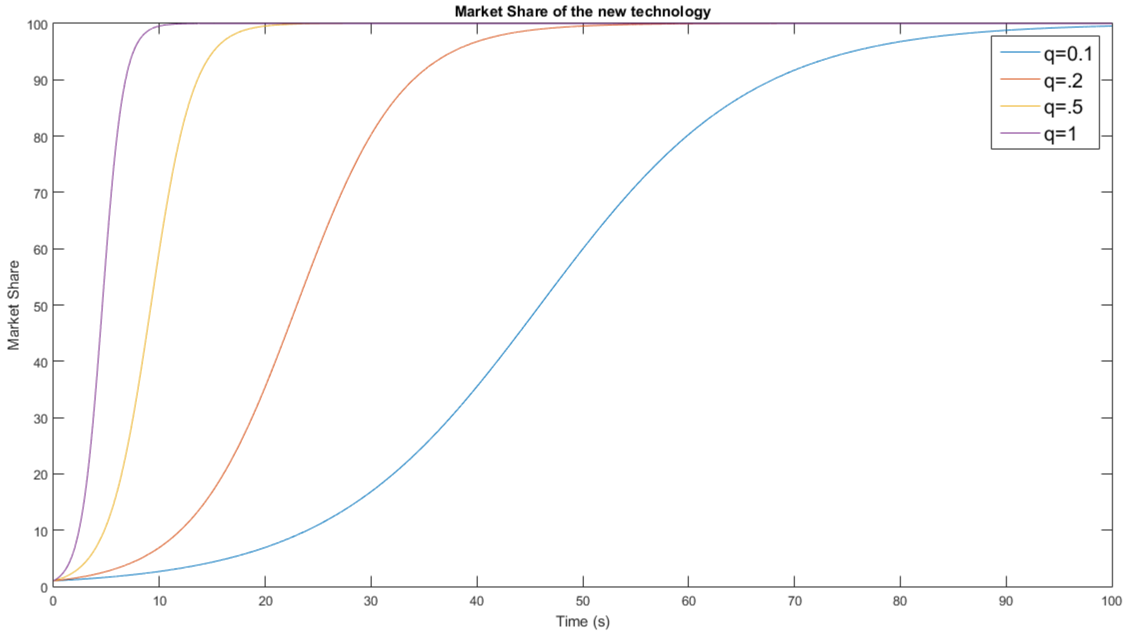

Figure 4: For different values of q the market share varies as shown. From Eq. (4) we see that Market Share of the product increases exponentially until it reaches the saturation level

On increasing the value of 'q' i.e. the probability of people interacting with each other, the saturation is achieved faster. The maximum saturation value won't change as it is fixed (size of the population).

1.7 Mixed Influence Model (Bass Model of DOI)

This model reflects the effects of both the models. This model captures the diffusion by advertisement as well as word of mouth i.e. communication between the people. Thus, the diffusion constant would show the effects of probability of both the cases.

The diffusion constant will have the effect of uninfluenced as well as influenced adoption and can be given as:

$\alpha(t) = p + \frac{qN(t)}{C}$

Thus, we will have the differential model as:

$$\frac{dN}{dt} = p + \frac{qN(t)}{C}(C - N(t)) \tag{6}$$

1.7.1 Solution

Solving the Eq. (6) we get,

$$N(t) = C - (C - N_0)e^{-pt} + \frac{CN_0e^{qt}}{C + N_0(e^{qt} - 1)} \tag{7}$$

This solution gives us the cumulative effect of the previous models and we see that the adoption rates vary accordingly.

1.7.2 Computational Model for different values of p

For the same value of q and different values of p we see that the number of people adopting the technology decrease. This happens since there is no effect of the interaction factor or it remains the same. p and q denote the probability of awareness and interaction respectively, hence they are in the range of 0 and 1 only. Where, 0 denotes that the person is not aware whereas 1 suggests that the person knows.

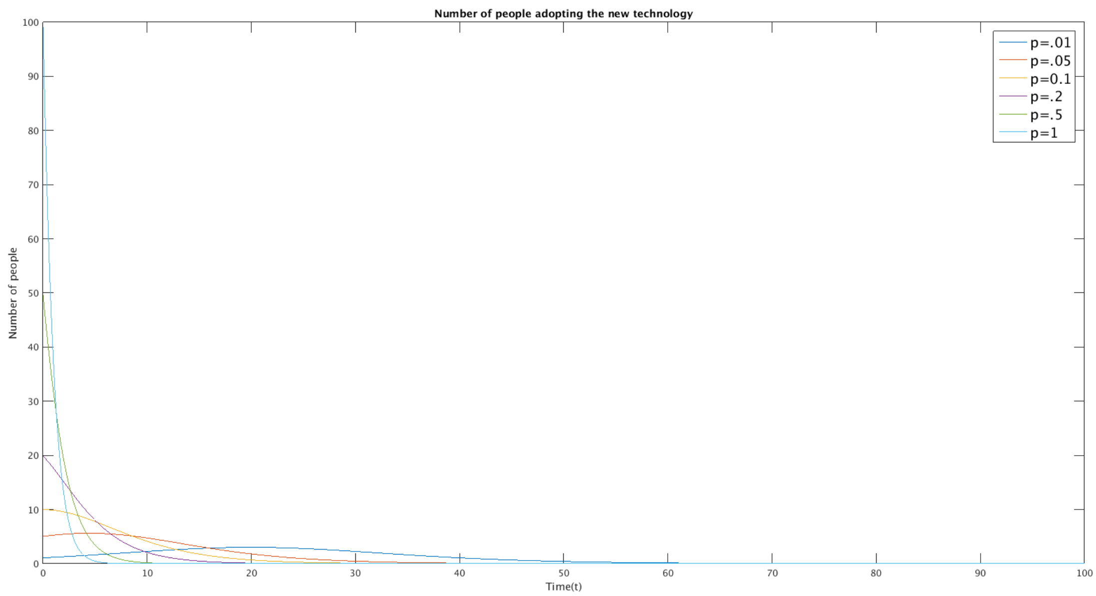

Figure 5: Number of people adopting the new technology for the Bass Model with different 'p' i.e. probability of knowing about a new innovation

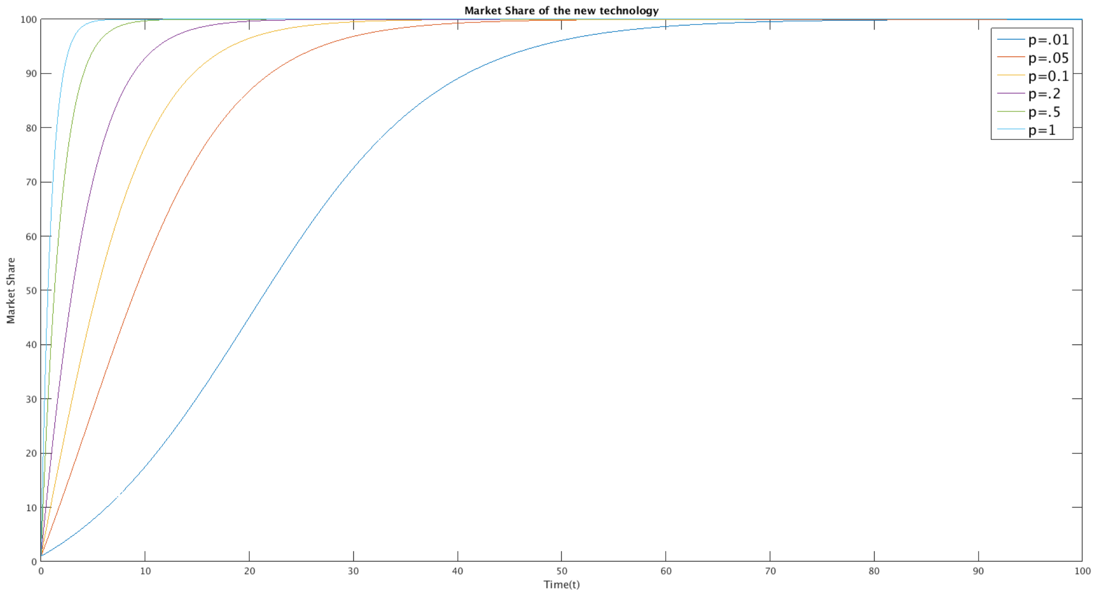

Figure 6: Market share for a new technology for the Bass Model with different 'p' i.e. probability of knowing about a new innovation

1.7.3 Computational Model for different values of q

For the same value of p and different values of q we see that the number of people adopting the technology increase according to q. The graph rises rapidly and is dependent on the value of q. This suggests that the adoption is dependent exponentially to the interaction between people. Here, 0 denotes that two person are not interacting whereas 1 suggests that they do interact.

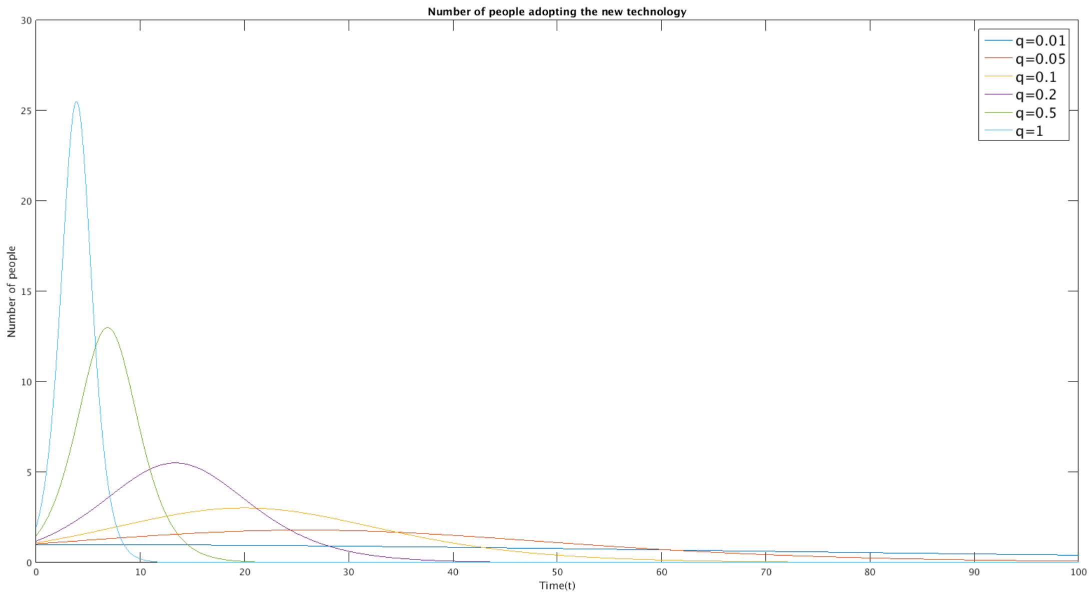

Figure 7: Number of people adopting the new technology for the Bass Model with different 'q' i.e. probability of people interacting with each other

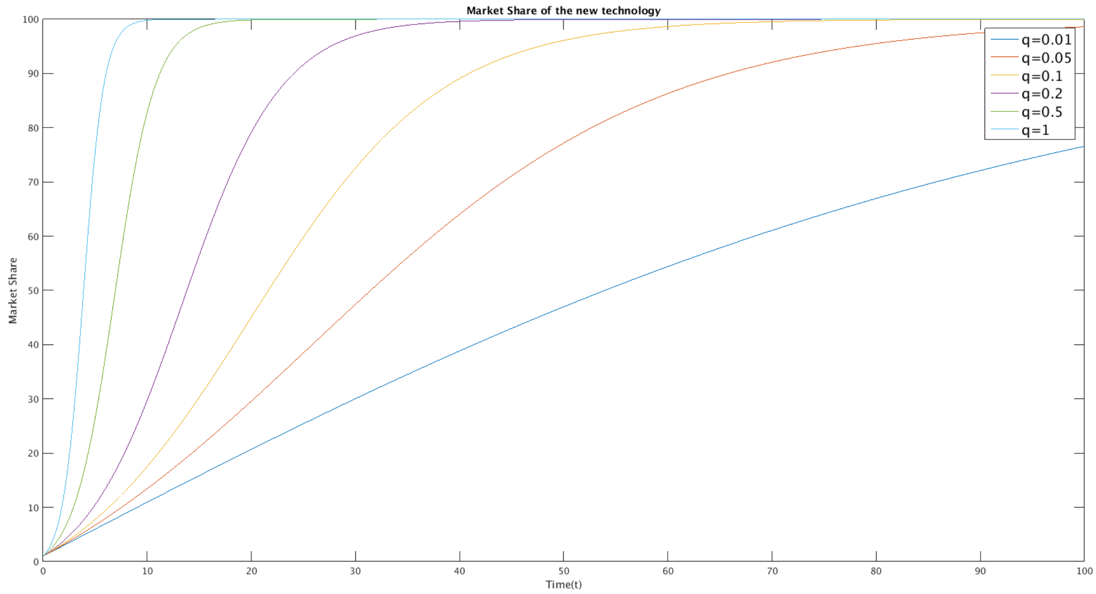

Figure 8: Market share for a new technology for the Bass Model with different 'q' i.e. probability of people interacting with each other

1.7.4 Computational Model for different values of p as well as q

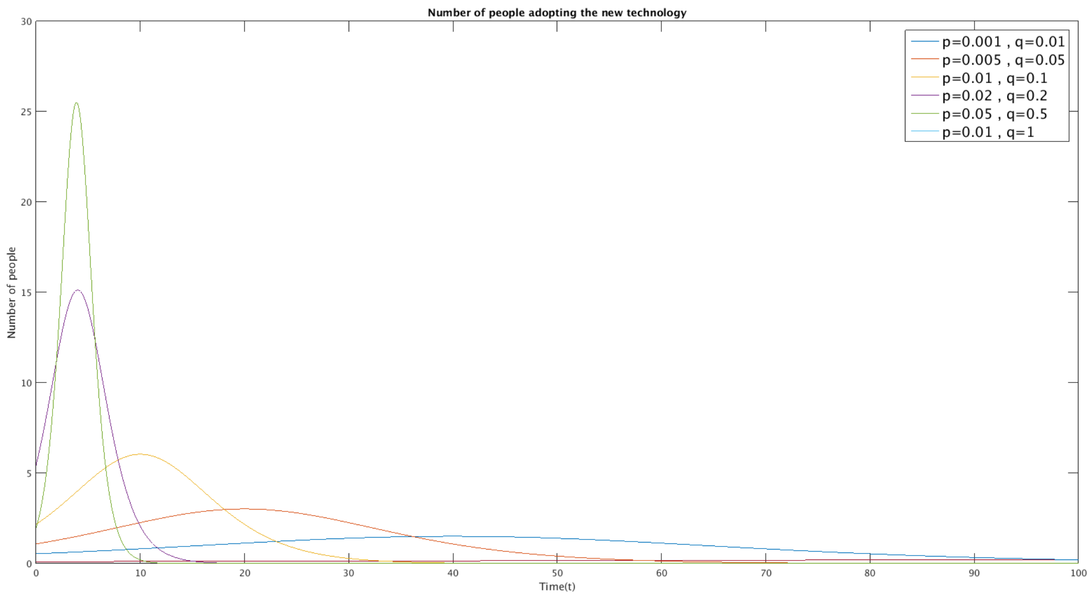

Figure 9: From Eq. (6) we have plotted the number of people adopting a new technology according to the Bass Model. Here, the p' as well as 'q' have been varied

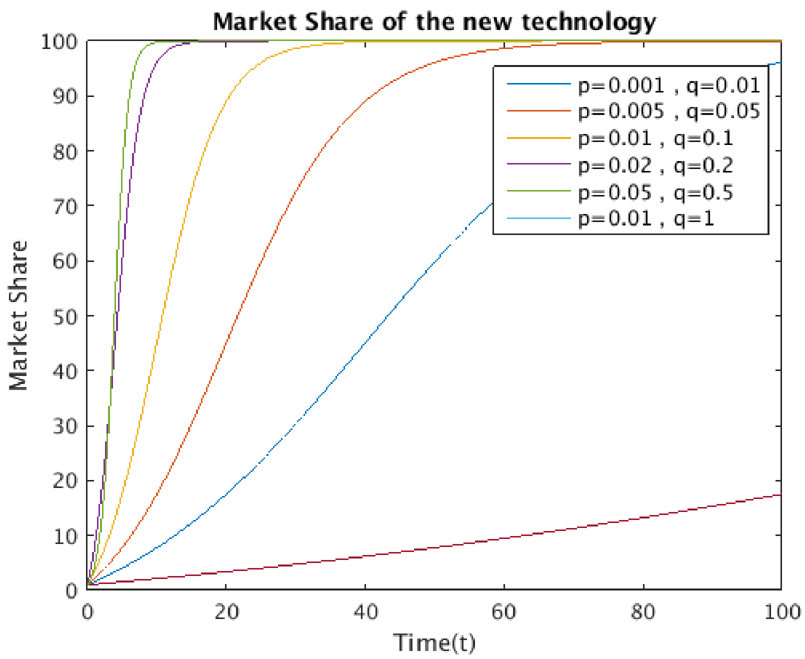

Figure 10: From Eq. (6) we have plotted the market share of a new technology according to the Bass Model. Here, the p' as well as 'q' have been varied

1.8 Advertising Strategy

We need to propose an appropriate advertising strategy for a firm based on our model. This strategy has to be optimal, i.e. we need to get the maximum adoption from this campaign.

The customer may have the needs of maximum outreach or maximum sustenance in the market depending on the type of the product. For each of this we would be suggesting proper plans.

If we want to have the maximum outreach in little time, we need to increase the reach of our product. This can be done by increasing the p value. Thus, we need to increase the advertising of their product. This advertisement campaigns can be done through print on electronic media. By doing so, the consumer will get the knowledge of the product and also promote the product to his/her social networks, thus amounting for the value of q. Apart from campaigns, the client can set up booths at various conferences or exhibitions. This will increase probable consumer interaction. The client can also sponsor some event thus getting his product featured.

Now, if we need to keep the product in the market for a longer time, we have to constrain the value of p. That was done in the case of Facebook where initially only the people studying in Harvard were allowed to make an account. This will not let the product go fast but will have a gradual increase in market share. It is easier to sustain such product too because it is stable.

2 DOI Modeling with varying capacity

Population is generally modeled by the logistic equation, in which the population reaches a state above which it can not have any more number of people. This is known as the carrying capacity, it is dependent on the geography, facilities and resources available, etc.

In some cases, this carrying capacity can vary. The reason for this being the technological advancement of that area which gives a better situation for the development of a particular species, in this case humans. Hence, we need to change our model to suit these requirements.

The new model will have a time dependent function which can change the carrying capacity, and hence our problem would be solved.

2.1 Assumptions

1. The time span is such that we can neglect the normal births and deaths.
2. The new generation that may possibly come in is already a user of the new technology.
3. There is no competition from any other product in the market.
4. People are aware of the new products in the market.

2.2 Differential Equation for Population Growth

$$\frac{dP}{dt} = \alpha P(1 - \frac{P}{K(t)}) \tag{8}$$

2.2.1 Parameters

$P(t)$ = Population at time t
α = Initial concentration of drug in bloodstream at time $t = 0$
$K(t)$ = Time dependent function which changes the carrying capacity of the model
t = Time

2.3 Dynamics of the Carrying Capacity

The differential equation modelling the carrying capaciity is:

$$\frac{dy}{dt} = \beta y(1 - y) \tag{9}$$

Here, β is the rate of change of the carrying capacity.

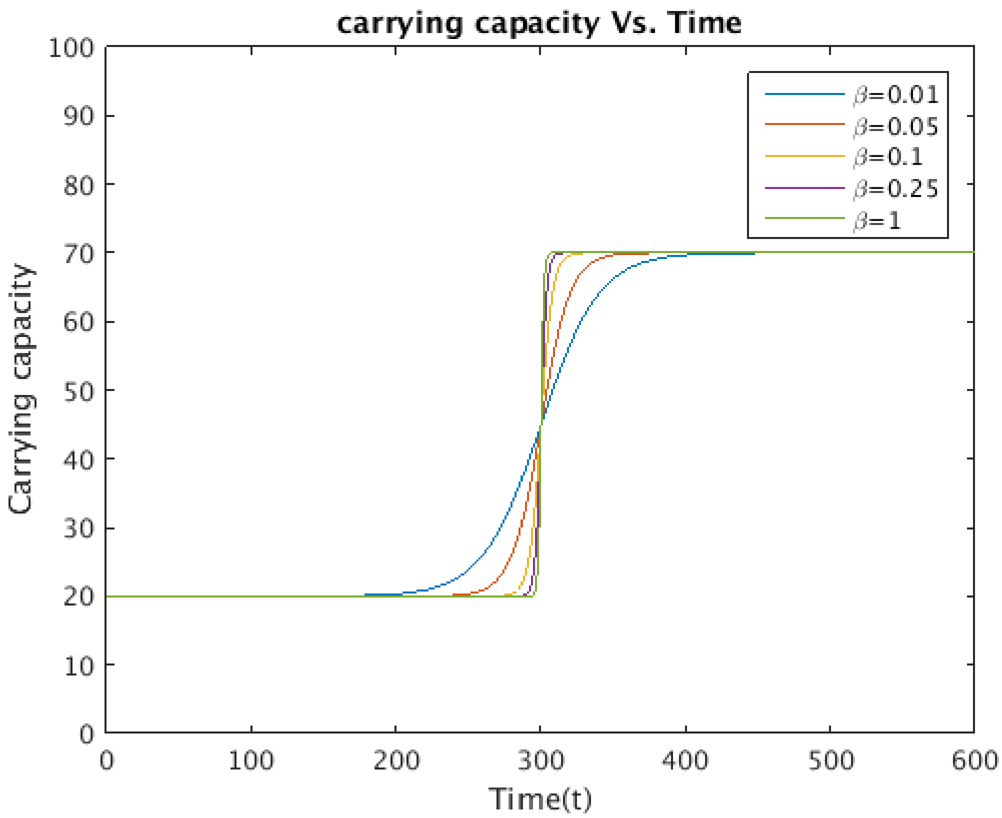

Figure 11: From Eq. (9) the carrying capacity for varying values of β

Here, with the increase in the value of β we see that the carrying capacity is reached at a faster rate.

2.4 Parameters affecting the Modelling

1. α determines the time for which the function would be staying at the lower value, i.e. it will change according to K_1.

2. $\frac{K_1+K_2}{2}$ is the value where the function makes a transition from the lower state to the higher state. This is generally known as y(0).

2.5 Computational Analysis

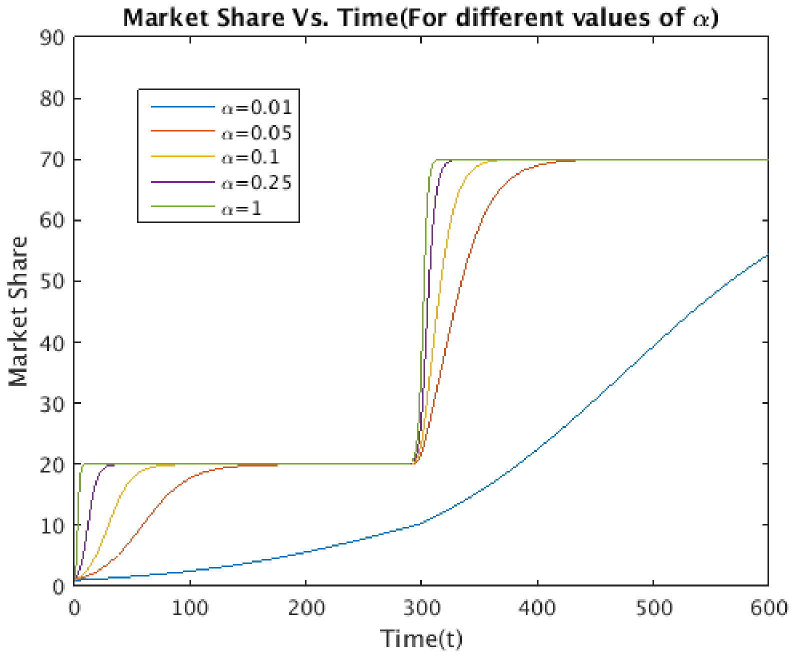

Figure 12: From Eq. (8) the market share of new technology according to the new model

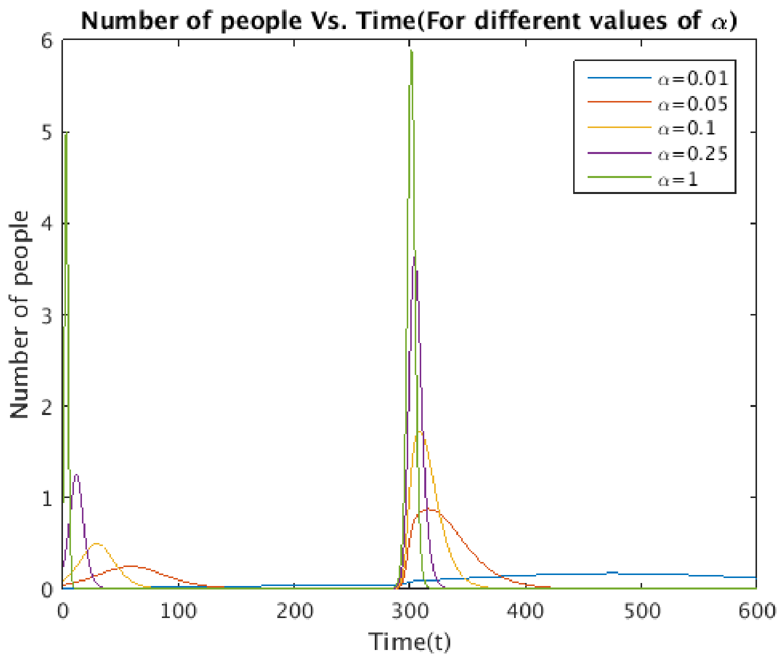

Figure 13: From Eq. (8) number of people adopting the new technology

We see that with the change in α we will get the change in the adoption of the technology.

If the value of α is high then initially the saturation will happen according to the former value of K i.e. K_1. Later, when the value of carrying capacity is changed, the saturation is reached accordingly.

Now, when the value of α is optimal we get a continuous increase in the number of users without saturation. This value will have adoption at a steady rate. The value of α for this to happen is in the range of 0.01.

2.6 Comparison with the previous model

Both the cases are very similar to each other. Initially, we modified p and q to control whether we would like to have longer sustenance or higher adoption, now we modify the value of α to achieve this task.