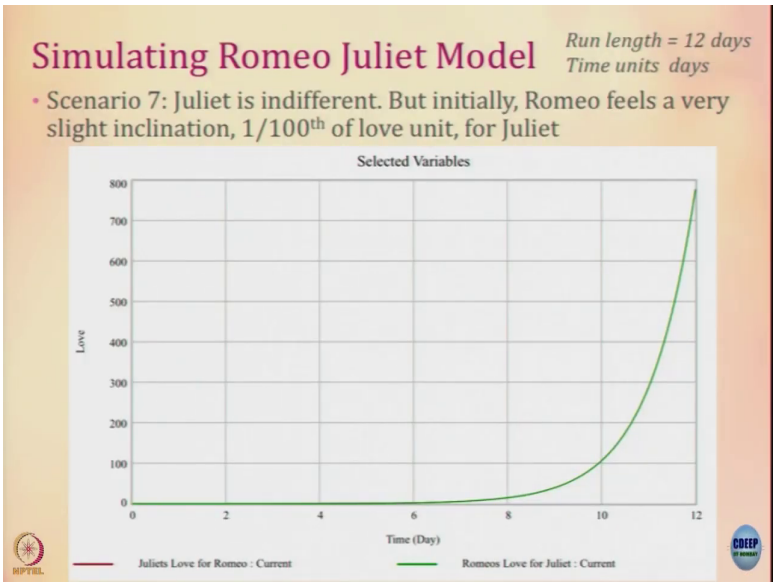
Introduction to System Dynamics Modeling
Prof. Jayendran Venkateswaran
Department of Industrial Engineering and Operations Research
Indian Institute of Technology, Bombay

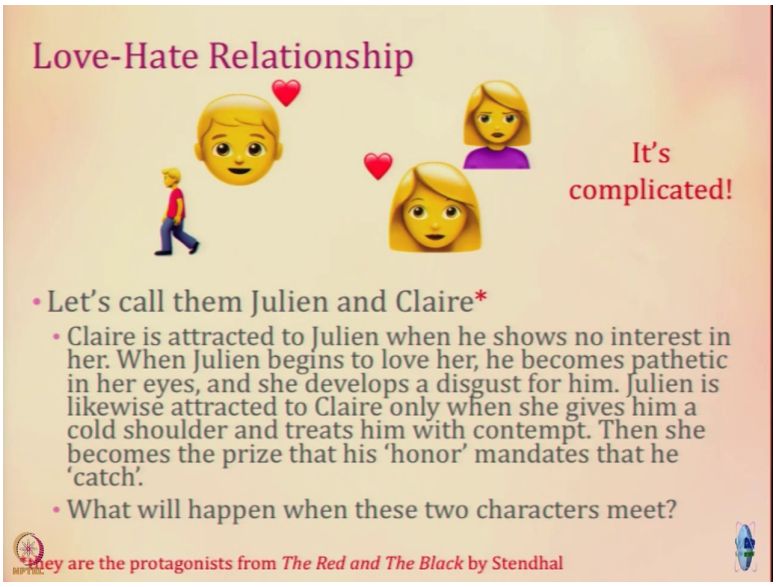
Lecture – 16.2
Second Order Systems
The Red & The Black, Gone with the Wind

(Refer Slide Time: 00:16)



So, we have nicely seen for the model for Romeo and Juliet how things exponential growth because of positive feedback system both like each other and they reinforce of each other's behaviour, if one partner loves the other more than other person reciprocates the love. So, we model that, but still we found that some initial settings resulted in asymptotic behaviour, ok.

(Refer Slide Time: 00:46)

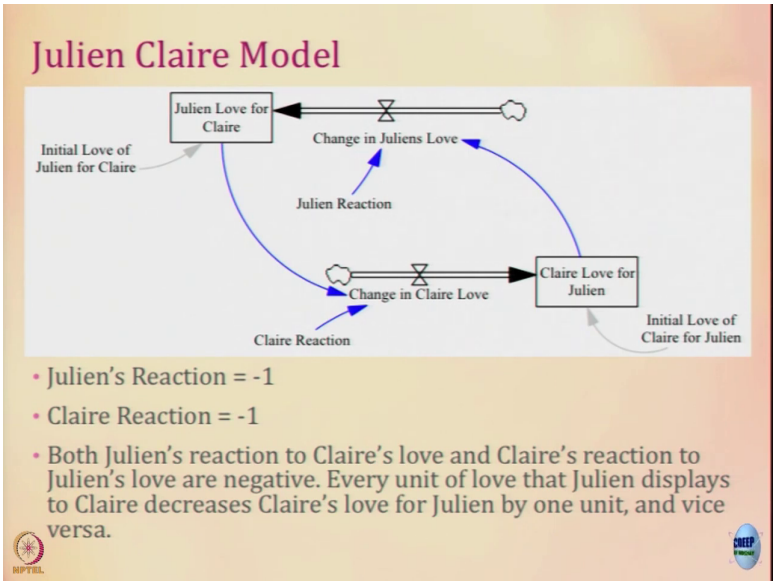


Now, let us take up another setting love hate relationship, things are not as it seems. Perhaps, when the boy is disinterested and does not know does not pay attention maybe she loves her; I mean, she loves him when the boy starts to reciprocate his love, she starts to spurn him or does not like him. And, the same way more she spurns he is he loves her more, but then when she starts to reciprocate her love he walks away it is all very complicated; so, right.

So, let us call them Julien and Claire after the protagonist from The Red and The Black by Stendhal, it is a French book translated in English and setting of many Hollywood movies or Bollywood, any language movies. So, let us take this scenario Claire is attracted to Julien when he shows no interest in her. When Julien begins to love her, he becomes pathetic in her eyes and develops disgust for him. Julien is like is attracted to Claire only if she gives him is cold shoulder, then she becomes the prize for his honor mandates that he catch.

What will happen when these two characters meet; so, how do we model this? Similarly, we will define stock of love for each other and we will see if we can just capture the personalities using the parameter settings.

(Refer Slide Time: 02:28)



So, Julien Claire model will look very similar to Romeo and Juliet. Now, let us observe see the stock values and the flow equations does not change, initial love we can as we told we can set some values.

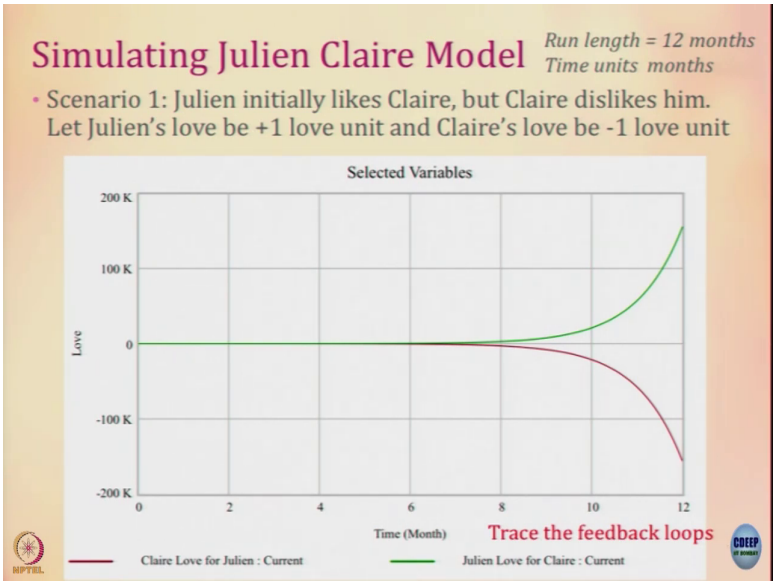
Let us try to capture the personalities by using the terms on Julien's reaction and Claire's reaction. In Julien's reaction is opposite of what Claire demonstrates, if Claire dislikes him he likes her, if Claire likes him he dislikes her, right; so, it is the opposite direction. So, let us put Julien's reaction is minus 1. Now, looking to Claire's reaction, if Julien likes her likes her,

then she is annoyed so, she dislikes him, if Julien ignores her then she likes him. So, it is also an opposite direction. So, let us put Claire's reaction as minus 1.

So, I just going to put Claire Julien's reaction a minus 1, Claire's reaction as minus 1 because both Julien's reaction to Claire's love and Claire's reaction to Julien's love are negative. And, every unit of love that Julien displays to Claire decreases Claire's love for Julien by one unit and vice versa, ok.

Now, let us go ahead and try to simulate this. Let us assume the initial love of Julien and initial love of Claire is 1 that is they both meet each other, but instantly they like each other. But, let us see what happens to their relationship based on their personalities right, is both love each other what do we expect, both will start to push each other away, right.

(Refer Slide Time: 04:19)

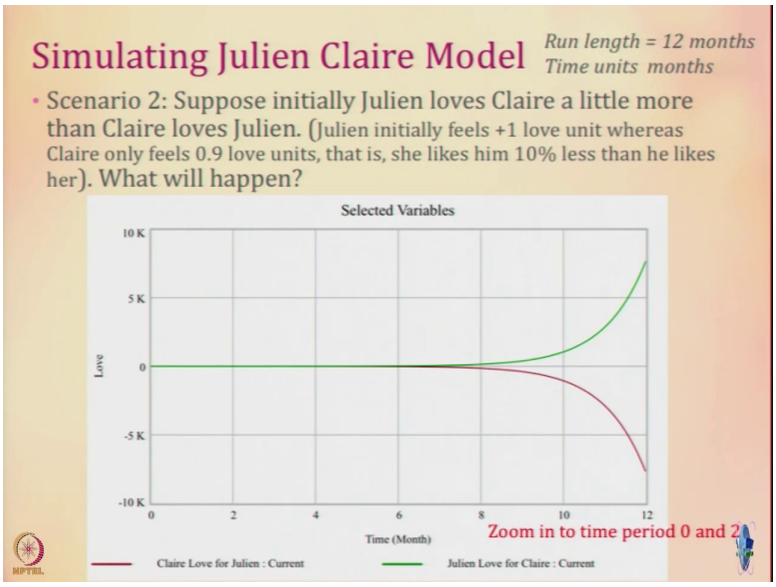


Julien she likes Claire, but Claire dislikes him; let Julien's love be plus 1 love unit and Claire's love be minus 1 love unit; he likes her, she does not like him, let us see where it goes, ok. We are also going to get a exponential behaviour; the green one is Julien's love for Claire and red one is Claire's love for Julien. As you can see more Claire dislikes Julien, Julien's love is going to keep increasing and as Julien's love keeps increasing, Claire's love Claire's love or whatever dislike for him increases and again we are getting exponential behaviour.

So, if we trace the loops; so, you will see that it is actually a positive feedback loop. So, say Claire's love increases for Claire; I mean, Julien's love for Claire increases suppose then Claire dislike starts to dislike him, the more Claire's dislikes the more Julien is going to love her. So, it becomes a positive feedback system because there are two negatives.

There are two negatives in the loop which resulted in a positive feedback system which is caused this behaviour indirect quite a few movie, movie plotlines based on this maybe I do not know if I am pronouncing in the correctly now, ranjana similar plotline right. He love her she does not like him she goes to kill him etcetera all the things happen because a dislike for him keeps growing.

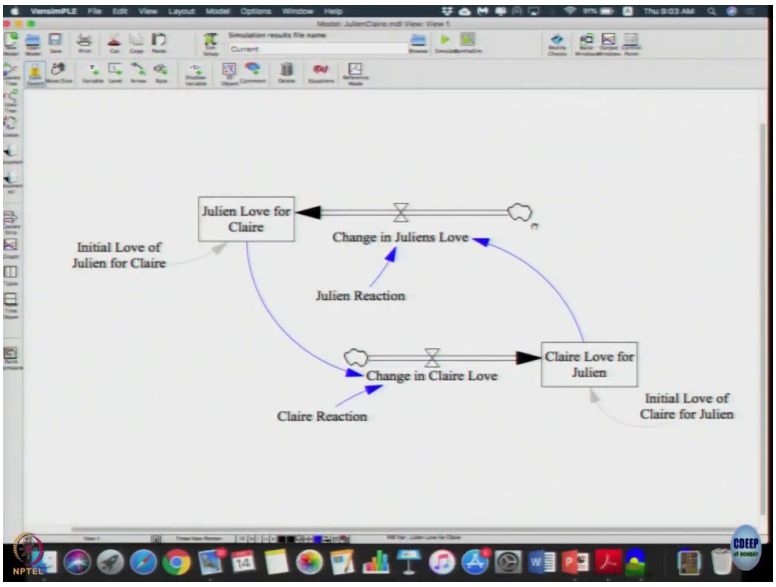
(Refer Slide Time: 05:58)



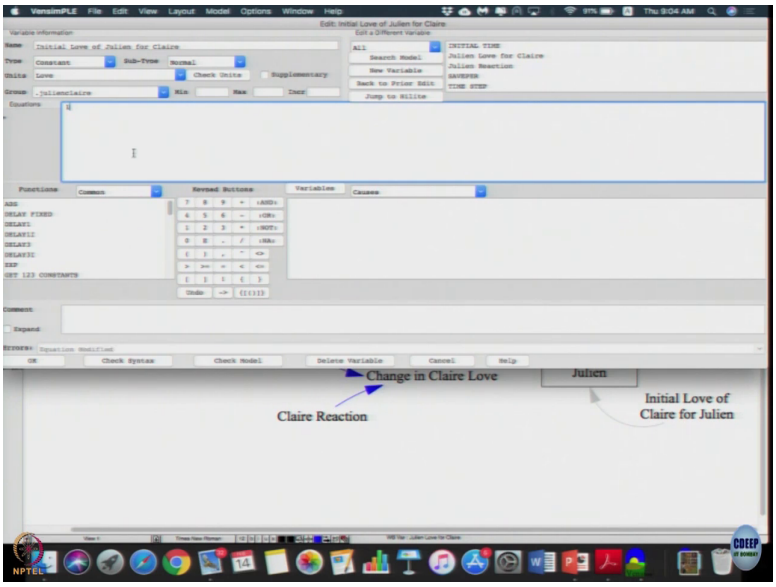
So, let us try out other such fun things. Suppose, initially Julien loves Claire little more than Claire loves Julien both love each other, but let us assume Julien initially feels plus 1 love unit where Claire only feels 0.9 love units, she likes him 10 percent less than he likes her, what do you expect will happen?

Let us see what happens, if you got a surprising the same behavior that is happening right, but it is not always so, we need to zoom into period 012. So, I cannot do it here let me just.

(Refer Slide Time: 06:37)

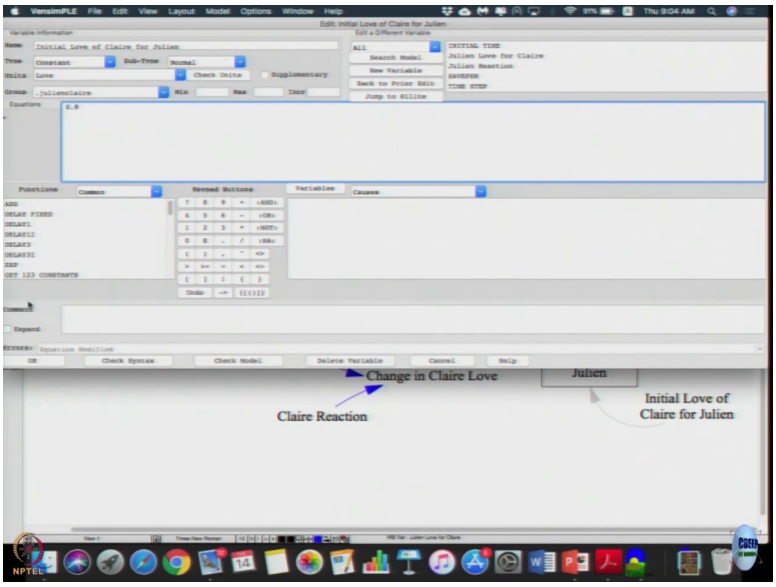


(Refer Slide Time: 06:41)



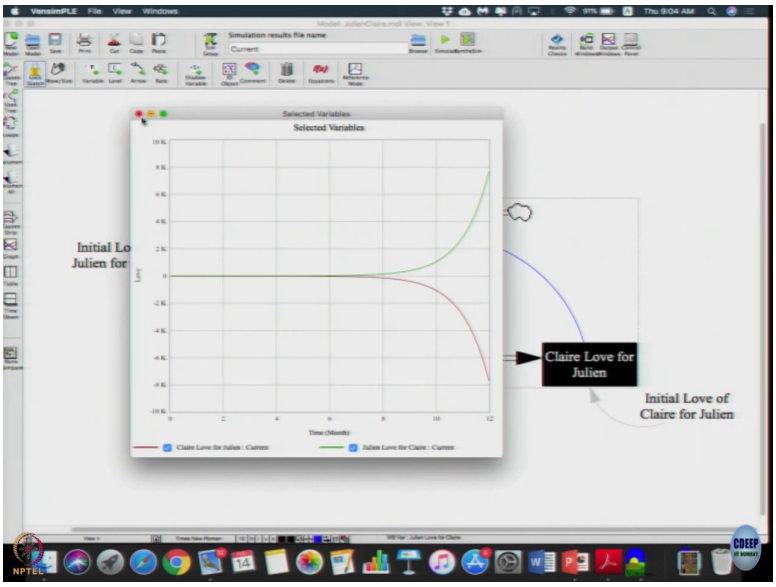
So, which will initial love for Julien for Claire is 1.

(Refer Slide Time: 06:45)



Initial love of Claire for Julien is 0.9, Julien's reaction Claire's reaction is minus 1, let us simulate it.

(Refer Slide Time: 06:57)



This graph here shows again exponential behavior which is fine.

(Refer Slide Time: 07:13)

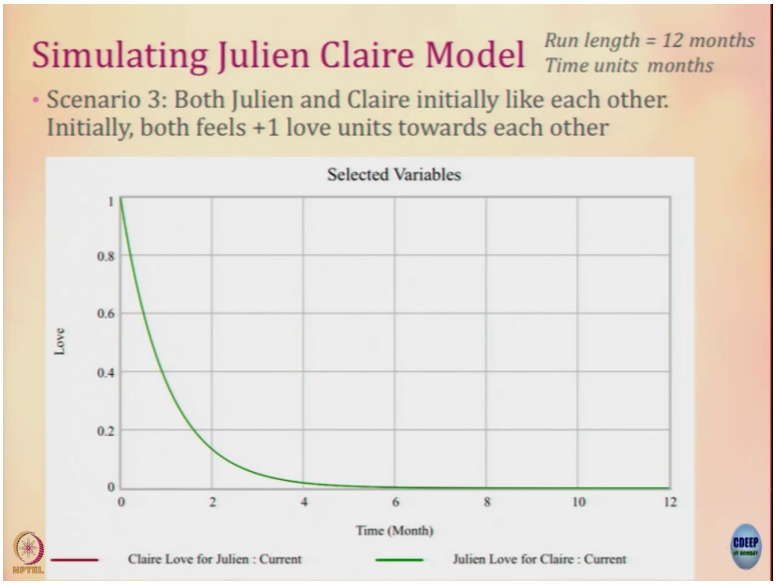
But, I told we need to zoom into period 0 and 2, already zoom graphs I have, at least if you zoom in you get some interesting crazy dynamics initial four periods. So, the red one is Claire's love for Julien and blue is Julien's love for Claire.

So, as Claire as Claire finds out that Julien loves him her love decreases and as her love decreases his love is also decreases slightly right, because when she loves him he starts to dislike her a bit. So, her love since it is positive she or he also likes her lesser, but at around period 1.4 around here her love actually becomes dislike from positive it goes to negative starts to dislike as soon as she starts disliking him his love starts to grow exponentially.

So, the change in loop dominance is what we just saw here, but it is at such a small time scale you may not have realized it. So, we just saw that it was interesting dynamics which

happened, but still positive negative feedback loops is what was kept dominating within the system.

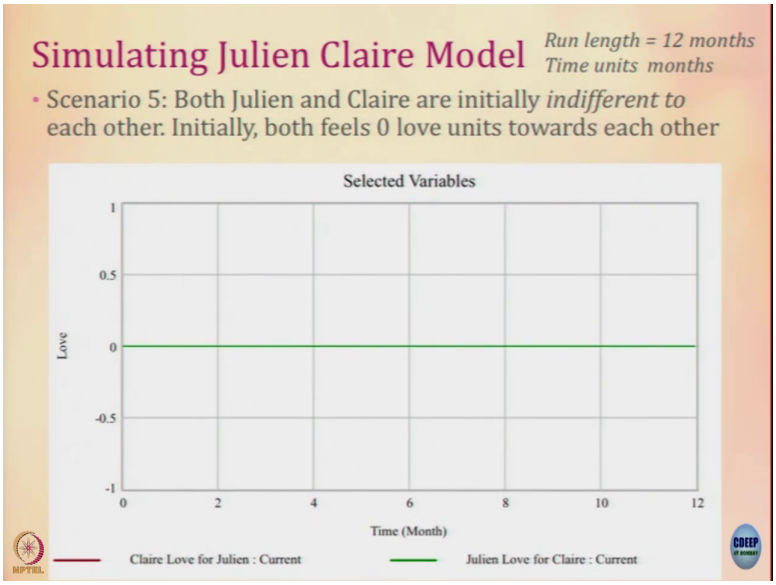
(Refer Slide Time: 08:27)



Now, suppose both Julien and care initially like each other both feel plus 1 love units towards each other then what will happen? Oscillations, no oscillations; she both like each other. So, then; so, since they both like each other they are going to like each other even less as time goes on and we are going to get a goal seeking behaviour to a point of kind of indifference within this model, where because each are going to like each other even lesser and lesser as time goes on and will have exponential. Since the first order system we are getting or rather it is a positive feedback system, but in this special case it is showing a asymptotic behaviour.

We can expect similar behavior when say both Claire and Julien dislike each other initially, when they dislike each other their dislike reduces with time and they results him again the point of indifference.

(Refer Slide Time: 09:35)

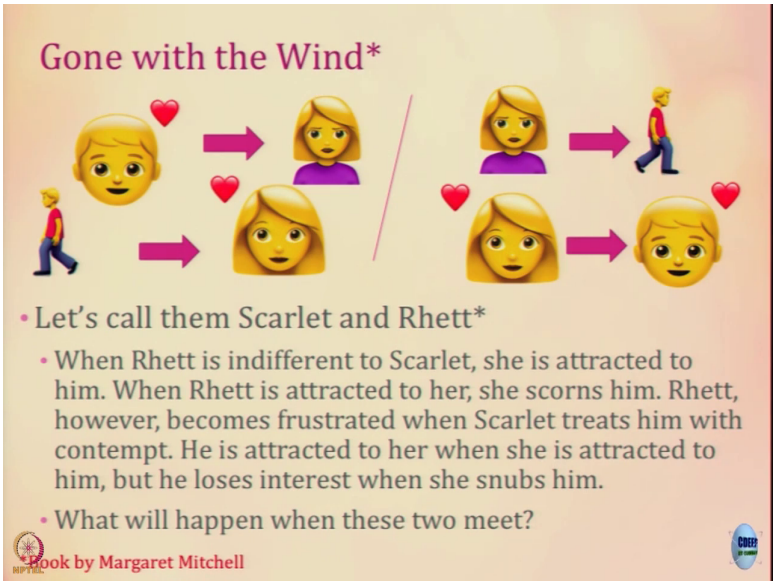


And eventually suppose Julien and Claire were initially indifferent to each other that both feels 0 love units that made a stock initially 0. So, there is no dynamics that can be observed within the system, right.

So, though the personalities are opposite when they like when one person when the partner likes when one person likes the partner does not like them and the partner likes the other person does not like them. Even then the system becomes a positive feedback system where

ones love is going to grow exponentially and other is dislike is going to grow exponentially as the dynamics that we just saw.

(Refer Slide Time: 10:18)



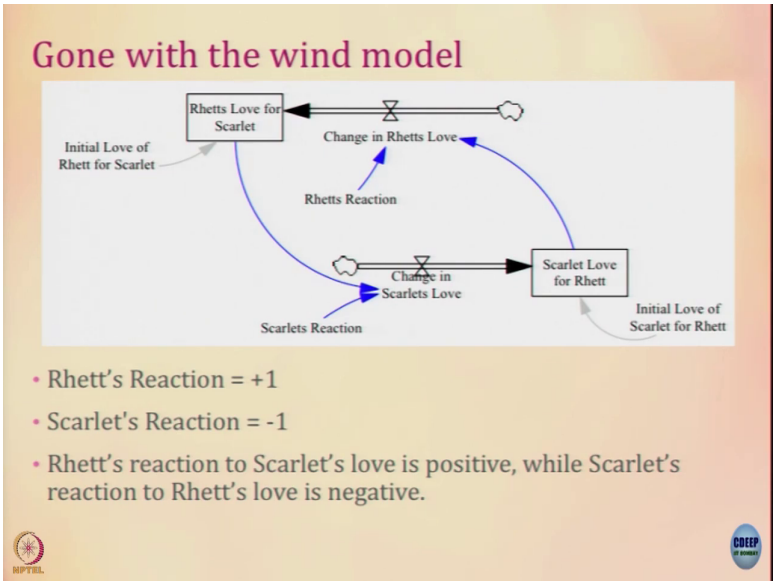
The personalities does not end there we have many other personalities also we will take up one more scenario based on gone with the wind. I do not know how many saw the movie or read the book or read some synopsis or some adaptation of it in some version somewhere. So, when he is initially not interested in her, she loves him and when she; when he reciprocates a love she starts to spurn him, but then when he; when she loves him is, when he loves her he likes to his love to be reciprocated and when she is she is spurns him then he also wants to walk away, he does not want to hang around, right.

So, let us call them Scarlett and Rhett, when Rhett is indifferent to Scarlett she is attracted to him when Rhett is attracted to her she is scorns him. Rhett however, becomes frustrated when

Scarlett treats him with contempt, he is attracted to her when she is attracted to him, but he loses interest when she snubs him. What will happen when these two meet?

Yeah; so, our model setting is going to be similar, we are going to have exact same model setting same stock of love. So, Rhett's love for Scarlett and Scarlett's love for Rhett and we are going to use the parameters. How can we set the parameters for say Rhett's reaction, how will Rhett's reaction be?

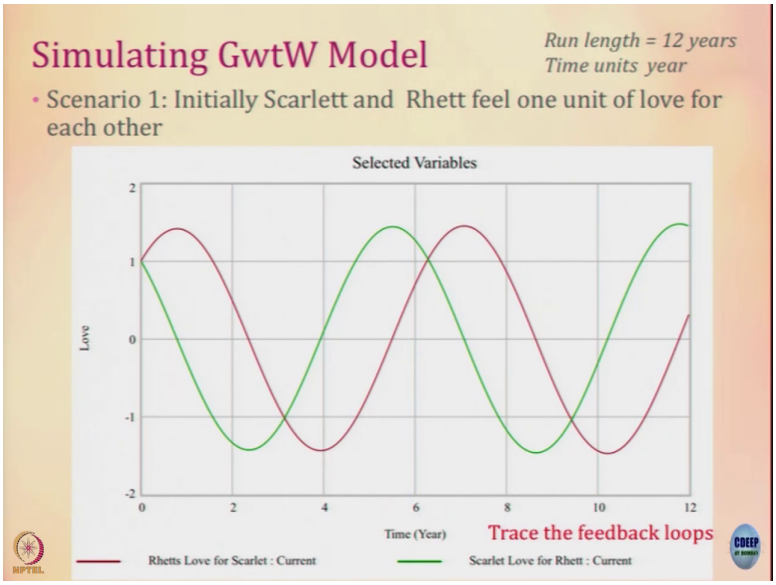
(Refer Slide Time: 11:52)



So, Scarlett loves him Rhett's is more attracted to her, right; so, it is in the same direction. So, Rhett's reaction is plus 1 positive, but when Rhett loves Scarlett then Scarlett's reaction is to scorn him, it is an opposite direction. So, it is in you can model it as minus 1 let us say, Scarlett's reaction is minus 1. So, Rhett's reaction is to Scarlett's love is positive, as Scarlett's reaction to Rhett's love is the negative opposite direction.

Now, let us suppose initially Scarlett and Rhett feel 1 unit of love for each other, there is their initial attracted to each other then what kind of dynamics can we expect. So, what feedback loop do we have, the previous two cases are positive feedback systems what feedback system is this. So, negative feedback system, right then what kind of dynamics can we expect.

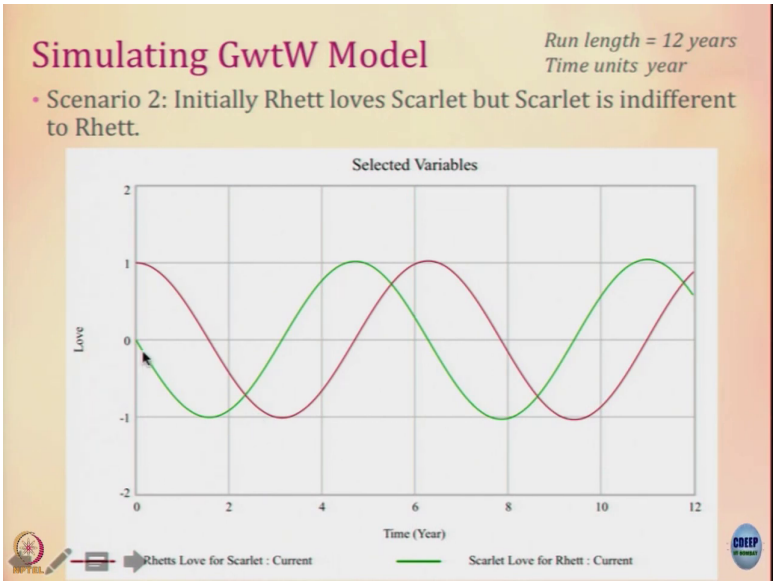
(Refer Slide Time: 12:50)



What you are going to get is system is going to oscillate if you have seen the movie there is a plotline. So, both love each other, but as Scarlett is going to dislike him as he loves her, but as long as love is somewhat positive his love increases, but then when she starts to actively scorn him and dislike him. His love falls continues to fall and then he starts to ignore her and when he starts ignoring her, her dislike reduces and then slowly again she is fall backs falls back in love with him. Once he starts loving him he also reciprocates her love and the game continues.

So, you get a nice oscillating systems of love for each other, Rhett's love for Scarlett and Scarlett's love for Rhett, the red and green lines. This is because we are having a negative feedback within the system. So, as Rhett's love increases and Scarlett dislikes him, Scarlett's dislikes him her his love reduces. So, the direction of change is negative; so, it is a negative feedback system is what we have just observed its causing oscillations, it is a first order negative feedback system.

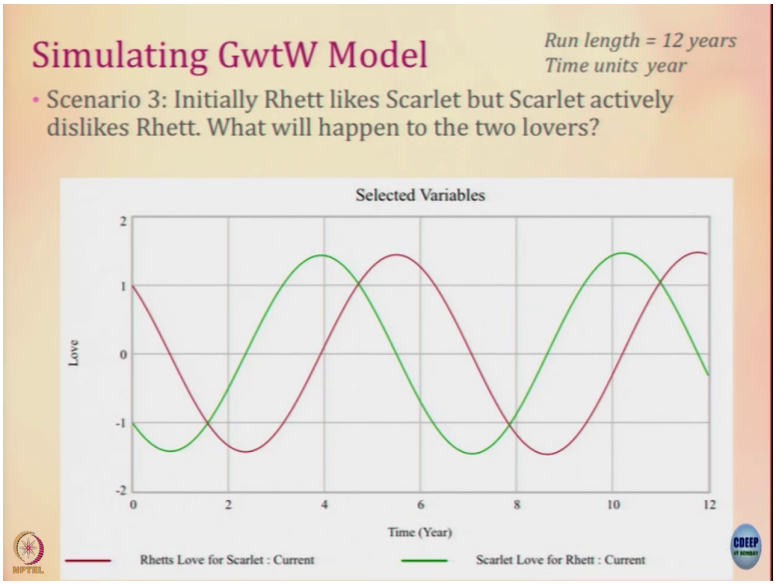
(Refer Slide Time: 14:21)



Again, we can have some interesting settings suppose initially Rhett's love for Scarlett, but Scarlett is indifferent to Rhett that is Scarlett initial value is 0 where Rhett's initial value is 1. So, she does not dislike him or like him; so, since he and then he loves her. So, immediately we can expect that Scarlett's will start to dislike him and as soon as she starts disliking Rhett's love is going to fall, but we can expect a similar oscillating systems. So, instead of

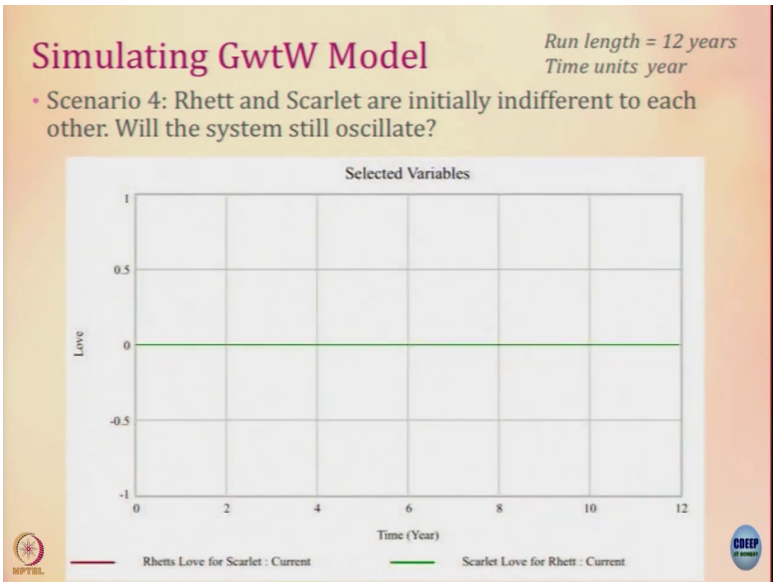
initial increase in love for Rhett, he will start to it will start to fall as Scarlett's dislike for him increases and system oscillates.

(Refer Slide Time: 15:09)



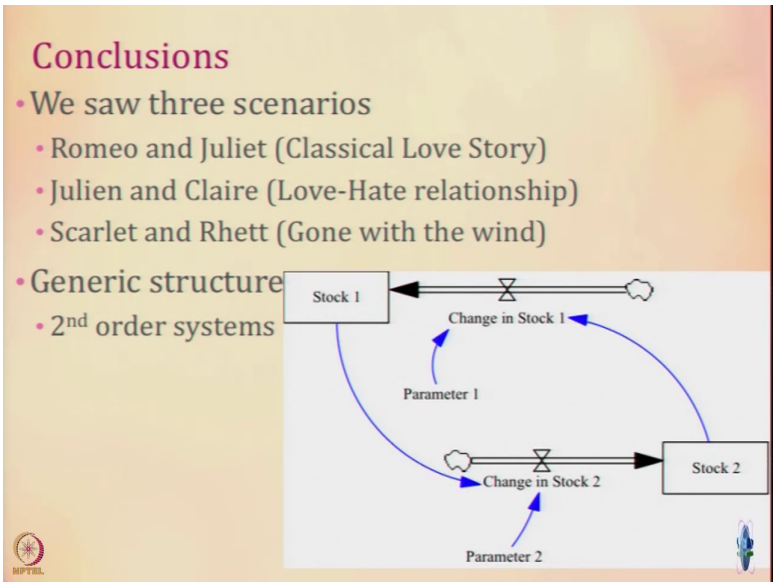
And initially Rhett like scarlet, but Scarlett actively dislikes Rhett there in the opposite sides, right; a Scarlett, a Scarlett actually dislikes Rhett, Rhett's love has to fall and as initially Rhett likes Scarlett, then she should actively dislike him more which is what happens. Initializations, he likes her she likes him even less again system will oscillate because of this second order negative feedback system that is present in our model.

(Refer Slide Time: 15:48)



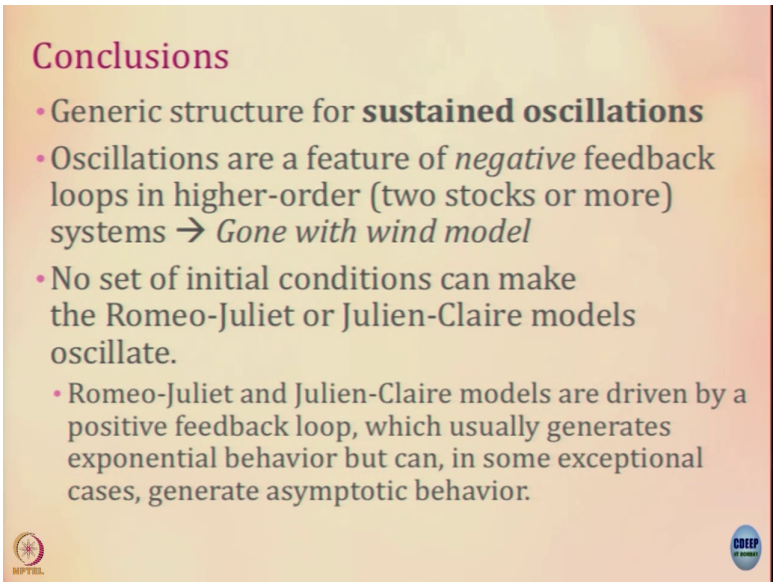
Suppose they are indifferent to each other what can we expect will system oscillate, no because stocks are 0 so, you do not expect it to oscillate. So, that is what you get, system does not oscillate.

(Refer Slide Time: 16:03)



I think I effectively ruined the books for you; so, that is the conclusion. These are three scenarios Romeo-Juliet, Julien-Claire and Scarlett-Rhett, but the interesting is all had the same generic structure and this is called a second order system that we have, where the stock, 2 stocks each independent changing, but the change in stock 2 this is affected by stock 1 and change in stock 1 is affected by stock 2, this the generic structure.

(Refer Slide Time: 16:41)

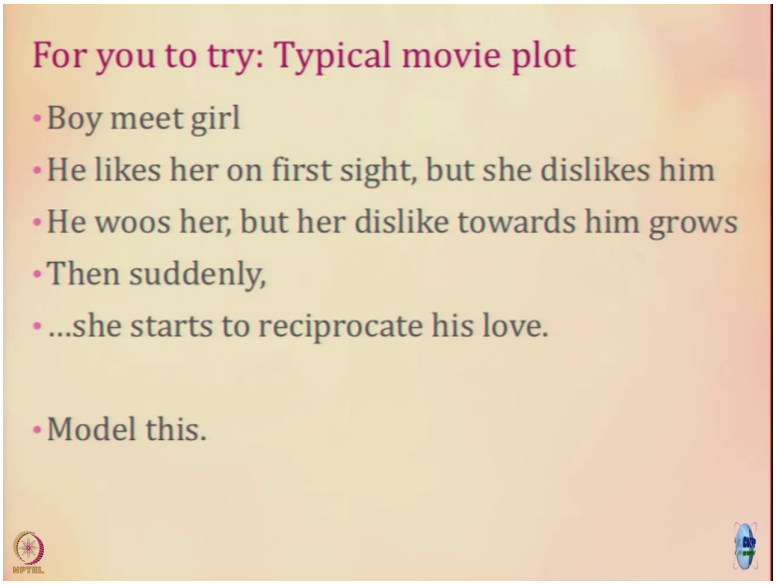


This is a generic structure for actually any system which is going to exhibit a sustained oscillation, this is a generic structure when you have this generic structure is going to cause sustained oscillation. But, what else is needed to ensure sustained oscillation we need negative feedbacks. So, second order system with negative feedbacks is only thing that is going to cause oscillations.

So, oscillations are feature for this, negative feedback loops in higher order two stocks or more systems similar to the gone with the wind model. So, you have multiple stocks with negative feedbacks that is when you are going to see oscillation within the system. Even if you have two stocks, but with the positive feedback system no set of initial conditions can make them oscillate.

So, Romeo and Juliet, and Claire and Julien-Claire model are driven by positive feedback loops. So, they are going to generate exponential behaviour, in some exceptional cases it does produce asymptotic behavior. So, for us to get sustained oscillations we need a second order negative feedback system is what is going to cause it. So, there is a learning in this class.

(Refer Slide Time: 17:51)



So, I will suggest you think of this typical movie plotline and see how we can model it boy meets girl, he likes her on first sight, but she dislikes him. He woos her, but her dislike towards him grows then suddenly, she starts to reciprocate his love.

As of now, I cannot we cannot change anything in a parameter setting to model this, there is a non-linear shift in feelings for each other. Their reactions try to model this how we are going

to do it, but kind of stocks is a reaction even governed by the others, the response or not and see how it works.

(Refer Slide Time: 18:30)

So, some more descriptions of that is also available online.

Thank you.