Can we use new ways of modeling complex systems to optimize student learning

Professor Robin Braun

School of Electrical and Data Engineering
University of Technology Sydney

International Association of University Presidents, Triennial, 5th-8th July 2017, Hofburg, Vienna, Austria

Outline

Policy making

- The best that we can do in making policy is to use evidence to shape our decisions
- This applies to policy at all levels
  - The Vice Chancellor deciding to put resources in A, B or C, or
  - The subject coordinator deciding to spend more to doing this or that
- The evidence is clear.
  - Fail to plan and you plan to fail
  - Fail to use evidence and your plans have a goods chance of failing

Policy making

- The best that we can do in making policy is to use evidence to shape our decisions
- This applies to policy at all levels
  - The Vice Chancellor deciding to put resources in A, B or C, or
  - The subject coordinator deciding to spend more to doing this or that
- The evidence is clear.
  - Fail to plan and you plan to fail
  - Fail to use evidence and your plans have a goods chance of failing

Policy making

- The best that we can do in making policy is to use evidence to shape our decisions
- This applies to policy at all levels
  - The Vice Chancellor deciding to put resources in A, B or C, or
  - The subject coordinator deciding to spend more to doing this or that
- The evidence is clear.
  - Fail to plan and you plan to fail
  - Fail to use evidence and your plans have a goods chance of failing

Policy making

- The best that we can do in making policy is to use evidence to shape our decisions
- This applies to policy at all levels
  - The Vice Chancellor deciding to put resources in A, B or C, or
  - The subject coordinator deciding to spend more to doing this or that
- The evidence is clear.
  - Fail to plan and you plan to fail
  - Fail to use evidence and your plans have a goods chance of failing

Policy making

- The best that we can do in making policy is to use evidence to shape our decisions
- This applies to policy at all levels
  - The Vice Chancellor deciding to put resources in A, B or C, or
  - The subject coordinator deciding to spend more to doing this or that
- The evidence is clear.
  - Fail to plan and you plan to fail
  - Fail to use evidence and your plans have a goods chance of failing

Policy making

- The best that we can do in making policy is to use evidence to shape our decisions
- This applies to policy at all levels
  - The Vice Chancellor deciding to put resources in A, B or C, or
  - The subject coordinator deciding to spend more to doing this or that
- The evidence is clear.
  - Fail to plan and you plan to fail
  - Fail to use evidence and your plans have a goods chance of failing

Policy making

- The best that we can do in making policy is to use evidence to shape our decisions
- This applies to policy at all levels
  - The Vice Chancellor deciding to put resources in A, B or C, or
  - The subject coordinator deciding to spend more to doing this or that
- The evidence is clear.
  - Fail to plan and you plan to fail
  - Fail to use evidence and your plans have a goods chance of failing

How to get the evidence

- Its expensive
  - It relies on having tried something before, and having collected the evidence about that trial
  - It relies on being able to interpret that evidence, and
- Often it does not exist at all
  - Policy makers often have to "invent" it
  - Many times it is for something that has never been done before

How to get the evidence

- Its expensive
  - It relies on having tried something before, and having collected the evidence about that trial
  - It relies on being able to interpret that evidence, and
- Often it does not exist at all
  - Policy makers often have to "invent" it
  - Many times it is for something that has never been done before

How to get the evidence

- Its expensive
  - It relies on having tried something before, and having collected the evidence about that trial
  - It relies on being able to interpret that evidence, and
- Often it does not exist at all
  - Policy makers often have to "invent" it
  - Many times it is for something that has never been done before

How to get the evidence

- Its expensive
  - It relies on having tried something before, and having collected the evidence about that trial
  - It relies on being able to interpret that evidence, and
- Often it does not exist at all
  - Policy makers often have to "invent" it
  - Many times it is for something that has never been done before

How to get the evidence

- Its expensive
  - It relies on having tried something before, and having collected the evidence about that trial
  - It relies on being able to interpret that evidence, and
- Often it does not exist at all
  - Policy makers often have to "invent" it
  - Many times it is for something that has never been done before

How to get the evidence

- Its expensive
  - It relies on having tried something before, and having collected the evidence about that trial
  - It relies on being able to interpret that evidence, and
- Often it does not exist at all
  - Policy makers often have to "invent" it
  - Many times it is for something that has never been done before

So how do we make decisions if we don't have the evidence?

We Model it

- Can we use Equation Based Modeling?
  - Probably not
  - Few have the expertise
  - Gives us answers in the aggregate which generally translates to likelihoods, not absolutes
- Can we try to use EBM
  - Perhaps yes, and we should if we can

So how do we make decisions if we don't have the evidence?

We Model it

- Can we use Equation Based Modeling?
  - Probably not
  - Few have the expertise
  - Gives us answers in the aggregate which generally translates to likelihoods, not absolutes
- Can we try to use EBM
  - Perhaps yes, and we should if we can

So how do we make decisions if we don't have the evidence?

We Model it

- Can we use Equation Based Modeling?
  - Probably not
  - Few have the expertise
  - Gives us answers in the aggregate which generally translates to likelihoods, not absolutes
- Can we try to use EBM
  - Perhaps yes, and we should if we can

So how do we make decisions if we don't have the evidence?

We Model it

- Can we use Equation Based Modeling?
  - Probably not
  - Few have the expertise
  - Gives us answers in the aggregate which generally translates to likelihoods, not absolutes
- Can we try to use EBM
  - Perhaps yes, and we should if we can

So how do we make decisions if we don't have the evidence?

We Model it

- Can we use Equation Based Modeling?
  - Probably not
  - Few have the expertise
  - Gives us answers in the aggregate which generally translates to likelihoods, not absolutes
- Can we try to use EBM
  - Perhaps yes, and we should if we can

So how do we make decisions if we don't have the evidence?

We Model it

- Can we use Equation Based Modeling?
  - Probably not
  - Few have the expertise
  - Gives us answers in the aggregate which generally translates to likelihoods, not absolutes
- Can we try to use EBM
  - Perhaps yes, and we should if we can

So how do we make decisions if we don't have the evidence?

We Model it

- Can we use Equation Based Modeling?
  - Probably not
  - Few have the expertise
  - Gives us answers in the aggregate which generally translates to likelihoods, not absolutes
- Can we try to use EBM
  - Perhaps yes, and we should if we can

So what is the alternative?

Complexity Theory

- The modern field of Complexity has thrown up alternatives
- They fall into the area of Computational Modeling, and
- In particular, Agent Based Modeling
  - See list of resources at the end of this presentation

So what is the alternative?

Complexity Theory

- The modern field of Complexity has thrown up alternatives
- They fall into the area of Computational Modeling, and
- In particular, Agent Based Modeling
  - See list of resources at the end of this presentation

So what is the alternative?

Complexity Theory

- The modern field of Complexity has thrown up alternatives
- They fall into the area of Computational Modeling, and
- In particular, Agent Based Modeling
  - See list of resources at the end of this presentation

So what is the alternative?

Complexity Theory

- The modern field of Complexity has thrown up alternatives
- They fall into the area of Computational Modeling, and
- In particular, Agent Based Modeling
  - See list of resources at the end of this presentation

So what is the alternative?

Complexity Theory

- The modern field of Complexity has thrown up alternatives
- They fall into the area of Computational Modeling, and
- In particular, Agent Based Modeling
  - See list of resources at the end of this presentation

Let's clarify Simulation, Emulation, Modeling and Programming

Simulation This is where you create something that behaves like the real thing, but you know is is not actually the real thing

- Medical simulation
- Flight simulation
- Computer Network simulation

Emulation This is where you create something that behaves like the real thing. But it is used to better understand the real thing

- Build a small version of a bridge to make sure it still stands in the wind
- Use a wind tunnel to understand the behavior of an aircraft wing

Let's clarify Simulation, Emulation, Modeling and Programming

Simulation This is where you create something that behaves like the real thing, but you know is is not actually the real thing

- Medical simulation
- Flight simulation
- Computer Network simulation

Emulation This is where you create something that behaves like the real thing. But it is used to better understand the real thing

- Build a small version of a bridge to make sure it still stands in the wind
- Use a wind tunnel to understand the behavior of an aircraft wing

Let's clarify Simulation, Emulation, Modeling and Programming

Simulation This is where you create something that behaves like the real thing, but you know is is not actually the real thing

- Medical simulation
- Flight simulation
- Computer Network simulation

Emulation This is where you create something that behaves like the real thing. But it is used to better understand the real thing

- Build a small version of a bridge to make sure it still stands in the wind
- Use a wind tunnel to understand the behavior of an aircraft wing

Let's clarify Simulation, Emulation, Modeling and Programming

Simulation This is where you create something that behaves like the real thing, but you know is is not actually the real thing

- Medical simulation
- Flight simulation
- Computer Network simulation

Emulation This is where you create something that behaves like the real thing. But it is used to better understand the real thing

- Build a small version of a bridge to make sure it still stands in the wind
- Use a wind tunnel to understand the behavior of an aircraft wing

Let's clarify Simulation, Emulation, Modeling and Programming

Simulation This is where you create something that behaves like the real thing, but you know is is not actually the real thing

- Medical simulation
- Flight simulation
- Computer Network simulation

Emulation This is where you create something that behaves like the real thing. But it is used to better understand the real thing

- Build a small version of a bridge to make sure it still stands in the wind
- Use a wind tunnel to understand the behavior of an aircraft wing

Let's clarify Simulation, Emulation, Modeling and Programming

Simulation This is where you create something that behaves like the real thing, but you know is is not actually the real thing

- Medical simulation
- Flight simulation
- Computer Network simulation

Emulation This is where you create something that behaves like the real thing. But it is used to better understand the real thing

- Build a small version of a bridge to make sure it still stands in the wind
- Use a wind tunnel to understand the behavior of an aircraft wing

Let's clarify Simulation, Emulation, Modeling and Programming

Simulation This is where you create something that behaves like the real thing, but you know is is not actually the real thing

- Medical simulation
- Flight simulation
- Computer Network simulation

Emulation This is where you create something that behaves like the real thing. But it is used to better understand the real thing

- Build a small version of a bridge to make sure it still stands in the wind
- Use a wind tunnel to understand the behavior of an aircraft wing

Let's clarify Simulation, Emulation, Modeling and Programming

Modeling Create some abstract system that can be used to better understand the real thing

- Equation Based Modeling
- Agent Based Modeling

Programming This where modeling becomes embedded in and part of the real thing. It is the real world.

Let's clarify Simulation, Emulation, Modeling and Programming

Modeling Create some abstract system that can be used to better understand the real thing

- Equation Based Modeling
- Agent Based Modeling

Programming This where modeling becomes embedded in and part of the real thing. It is the real world.

Let's clarify Simulation, Emulation, Modeling and Programming

Modeling Create some abstract system that can be used to better understand the real thing

- Equation Based Modeling
- Agent Based Modeling

Programming This where modeling becomes embedded in and part of the real thing. It is the real world.

Let's clarify Simulation, Emulation, Modeling and Programming

Modeling Create some abstract system that can be used to better understand the real thing

- Equation Based Modeling
- Agent Based Modeling

Programming This where modeling becomes embedded in and part of the real thing. It is the real world.

Computational Modeling. What is it?

- Essentially Computational Modeling is interacting with a means of computing (a computer) using a "language" understood by both you and the computer.
- Everyday examples are Spreadsheets and Matlab, or programs written in computer languages
- Things like Matlab are mostly computational versions of Equation Based Modeling
- Things like NetLogo are computational versions of Agent Based Modeling

Computational Modeling. What is it?

- Essentially Computational Modeling is interacting with a means of computing (a computer) using a "language" understood by both you and the computer.
- Everyday examples are Spreadsheets and Matlab, or programs written in computer languages
- Things like Matlab are mostly computational versions of Equation Based Modeling
- Things like NetLogo are computational versions of Agent Based Modeling

Computational Modeling. What is it?

- Essentially Computational Modeling is interacting with a means of computing (a computer) using a "language" understood by both you and the computer.
- Everyday examples are Spreadsheets and Matlab, or programs written in computer languages
- Things like Matlab are mostly computational versions of Equation Based Modeling
- Things like NetLogo are computational versions of Agent Based Modeling

Computational Modeling. What is it?

- Essentially Computational Modeling is interacting with a means of computing (a computer) using a "language" understood by both you and the computer.
- Everyday examples are Spreadsheets and Matlab, or programs written in computer languages
- Things like Matlab are mostly computational versions of Equation Based Modeling
- Things like NetLogo are computational versions of Agent Based Modeling

Given that, what is the difference with Programming?

- Programming uses much of the same technology,
  - language and computation
  - but produces applications that make the computer perform a task
- Its primary purpose is not modeling, but may produce models in order for its applications to work.

Given that, what is the difference with Programming?

- Programming uses much of the same technology,
  - language and computation
  - but produces applications that make the computer perform a task
- Its primary purpose is not modeling, but may produce models in order for its applications to work.

Given that, what is the difference with Programming?

- Programming uses much of the same technology,
  - language and computation
  - but produces applications that make the computer perform a task
- Its primary purpose is not modeling, but may produce models in order for its applications to work.

Given that, what is the difference with Programming?

- Programming uses much of the same technology,
  - language and computation
  - but produces applications that make the computer perform a task
- Its primary purpose is not modeling, but may produce models in order for its applications to work.

Where does Actuation fit in?

- Actuation really is the difference between Modeling and Programming
- If you were to take a model and feed its outputs into an actuation,
  - ie. It does something instead of just providing information,
  - We would have a "program"

Where does Actuation fit in?

- Actuation really is the difference between Modeling and Programming
- If you were to take a model and feed its outputs into an actuation,
  - ie. It does something instead of just providing information,
  - We would have a "program"

Where does Actuation fit in?

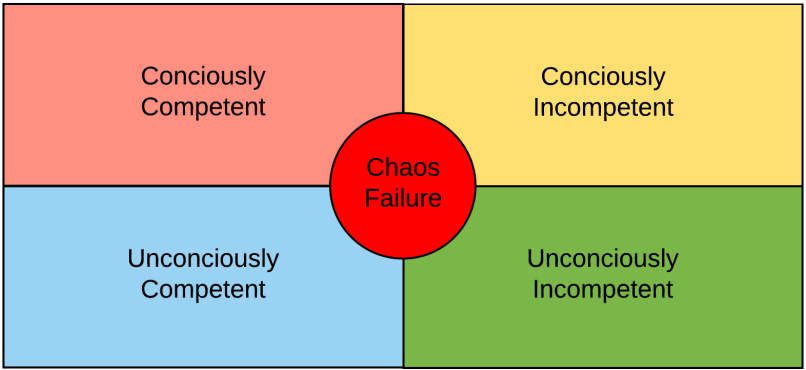
- Actuation really is the difference between Modeling and Programming
- If you were to take a model and feed its outputs into an actuation,
  - ie. It does something instead of just providing information,
  - We would have a "program"

Where does Actuation fit in?

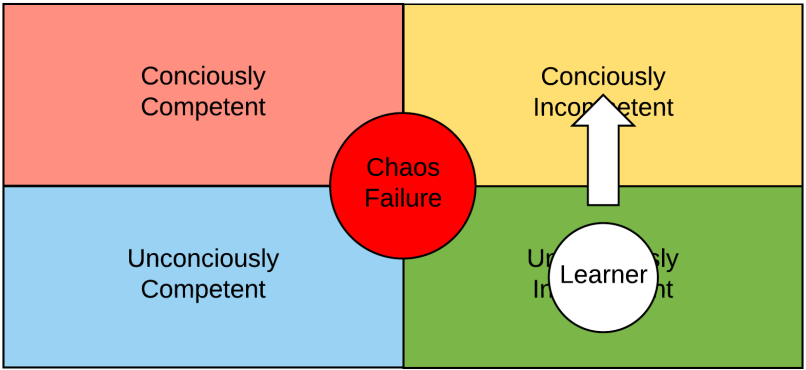
- Actuation really is the difference between Modeling and Programming
- If you were to take a model and feed its outputs into an actuation,
  - ie. It does something instead of just providing information,
  - We would have a "program"

Outline

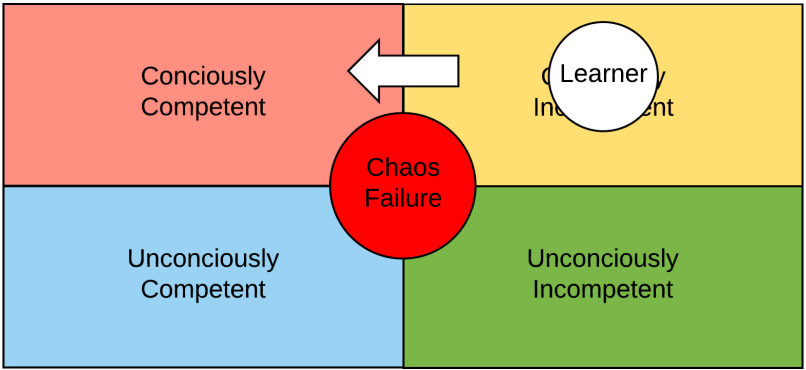
The Learning/Order/Chaos diagram



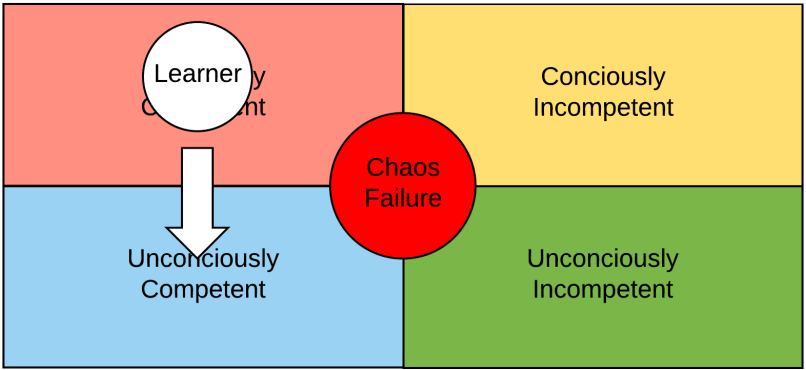
What happens when we teach?



What happens when students learn?



What happens when students get wise?



Outline

What then is Flipping in the context of modern engineering education?

- From a historical point of view, Engineering Education was characterized by the content that was required in each subject
- This lent itself to the model where the learners "received knowledge" from the lecturers.
- Then it was hoped that they would internalize it and eventually become consciously competent in tutorials and labs

What then is Flipping in the context of modern engineering education?

- From a historical point of view, Engineering Education was characterized by the content that was required in each subject
- This lent itself to the model where the learners "received knowledge" from the lecturers.
- Then it was hoped that they would internalize it and eventually become consciously competent in tutorials and labs

What then is Flipping in the context of modern engineering education?

- From a historical point of view, Engineering Education was characterized by the content that was required in each subject
- This lent itself to the model where the learners "received knowledge" from the lecturers.
- Then it was hoped that they would internalize it and eventually become consciously competent in tutorials and labs

What then is Flipping in the context of modern engineering education?

What this really means

- Flipping the classroom means completely removing responsibility for the knowledge (content) from the lecturer.
- This then frees up the lecturer to concentrate in moving the learner from "incompetent" to "competent". That is from the RHS to the LHS of the 4 quadrant diagram.
  - And, being sure to prevent dipping into chaos.
  - As apposed to just moving the learner up the RHS

What then is Flipping in the context of modern engineering education?

What this really means

- Flipping the classroom means completely removing responsibility for the knowledge (content) from the lecturer.
- This then frees up the lecturer to concentrate in moving the learner from "incompetent" to "competent". That is from the RHS to the LHS of the 4 quadrant diagram.
  - And, being sure to prevent dipping into chaos.
  - As apposed to just moving the learner up the RHS

What then is Flipping in the context of modern engineering education?

What this really means

- Flipping the classroom means completely removing responsibility for the knowledge (content) from the lecturer.
- This then frees up the lecturer to concentrate in moving the learner from "incompetent" to "competent". That is from the RHS to the LHS of the 4 quadrant diagram.
  - And, being sure to prevent dipping into chaos.
  - As apposed to just moving the learner up the RHS

What then is Flipping in the context of modern engineering education?

What this really means

- Flipping the classroom means completely removing responsibility for the knowledge (content) from the lecturer.
- This then frees up the lecturer to concentrate in moving the learner from "incompetent" to "competent". That is from the RHS to the LHS of the 4 quadrant diagram.
  - And, being sure to prevent dipping into chaos.
  - As apposed to just moving the learner up the RHS

What then is Flipping in the context of modern engineering education?

What this really means

- Flipping the classroom means completely removing responsibility for the knowledge (content) from the lecturer.
- This then frees up the lecturer to concentrate in moving the learner from "incompetent" to "competent". That is from the RHS to the LHS of the 4 quadrant diagram.
  - And, being sure to prevent dipping into chaos.
  - As apposed to just moving the learner up the RHS

Get students to think that the knowledge they acquire is a resource

- More and more we are thinking of knowledge as just another resource available to the practitioner.
- In earlier times, we would have thought of knowledge as being the end in itself
- Once we accept this basis, we free up the student to consider the full range of resources available to their practice
  - These may include language, mathematics, knowledge, experience, etc.

Get students to think that the knowledge they acquire is a resource

- More and more we are thinking of knowledge as just another resource available to the practitioner.
- In earlier times, we would have thought of knowledge as being the end in itself
- Once we accept this basis, we free up the student to consider the full range of resources available to their practice
  - These may include language, mathematics, knowledge, experience, etc.

Get students to think that the knowledge they acquire is a resource

- More and more we are thinking of knowledge as just another resource available to the practitioner.
- In earlier times, we would have thought of knowledge as being the end in itself
- Once we accept this basis, we free up the student to consider the full range of resources available to their practice
  - These may include language, mathematics, knowledge, experience, etc.

Get students to think that the knowledge they acquire is a resource

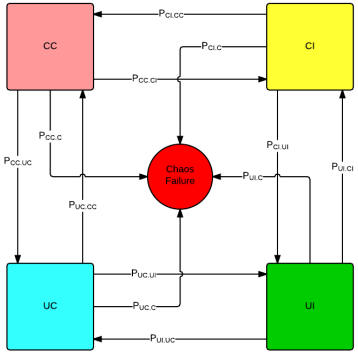
- More and more we are thinking of knowledge as just another resource available to the practitioner.
- In earlier times, we would have thought of knowledge as being the end in itself
- Once we accept this basis, we free up the student to consider the full range of resources available to their practice
  - These may include language, mathematics, knowledge, experience, etc.

Can we model this process

- We can try classic Markov state modeling
- Probability of movement out of the various states

$$
\begin{aligned}
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} + P_{UI.UC} - P_{UC.UI} \\
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} \\
P_{CI.E} &= P_{CI.CC} - P_{CC.CI} + P_{CI.C} + P_{CI.UI} - P_{UI.CI} \\
P_{CC.E} &= P_{CC.UC} - P_{UC.CC} + P_{CC.C} + P_{CC.CI} - P_{CI.CC}
\end{aligned}
$$

- Max prob of moving through the learning process -> min $P_{CC.CI}$ and max $P_{CI.CC}$

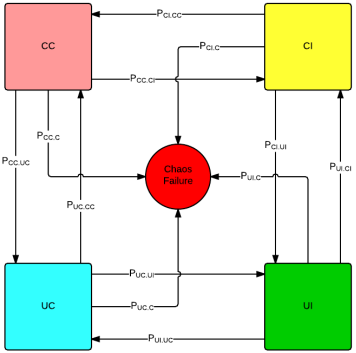


Can we model this process

- We can try classic Markov state modeling
- Probability of movement out of the various states

$$
\begin{aligned}
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} + P_{UI.UC} - P_{UC.UI} \\
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} \\
P_{CI.E} &= P_{CI.CC} - P_{CC.CI} + P_{CI.C} + P_{CI.UI} - P_{UI.CI} \\
P_{CC.E} &= P_{CC.UC} - P_{UC.CC} + P_{CC.C} + P_{CC.CI} - P_{CI.CC}
\end{aligned}
$$

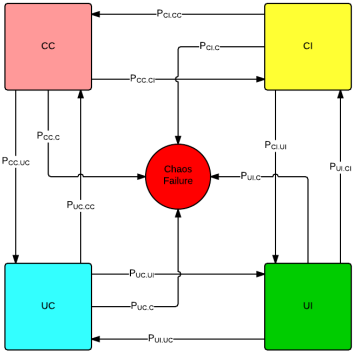
- Max prob of moving through the learning process -> min $P_{CC.CI}$ and max $P_{CI.CC}$



Can we model this process

- We can try classic Markov state modeling
- Probability of movement out of the various states

$$
\begin{aligned}
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} + P_{UI.UC} - P_{UC.UI} \\
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} \\
P_{CI.E} &= P_{CI.CC} - P_{CC.CI} + P_{CI.C} + P_{CI.UI} - P_{UI.CI} \\
P_{CC.E} &= P_{CC.UC} - P_{UC.CC} + P_{CC.C} + P_{CC.CI} - P_{CI.CC}
\end{aligned}
$$

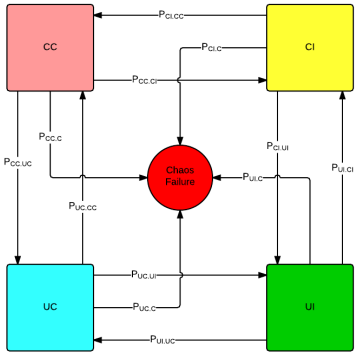


- Max prob of moving through the learning process -> min $P_{CC.CI}$ and max $P_{CI.CC}$

Can we model this process

- We can try classic Markov state modeling
- Probability of movement out of the various states

$$
\begin{aligned}
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} + P_{UI.UC} - P_{UC.UI} \\
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} \\
P_{CI.E} &= P_{CI.CC} - P_{CC.CI} + P_{CI.C} + P_{CI.UI} - P_{UI.CI} \\
P_{CC.E} &= P_{CC.UC} - P_{UC.CC} + P_{CC.C} + P_{CC.CI} - P_{CI.CC}
\end{aligned}
$$



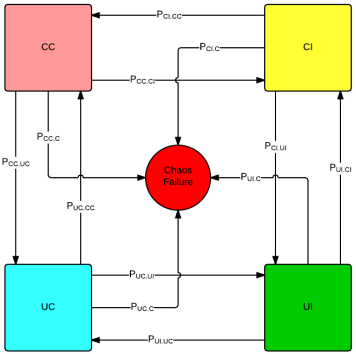
- Max prob of moving through the learning process -> min $P_{CC.CI}$ and max $P_{CI.CC}$

Can we model this process

- We can try classic Markov state modeling
- Probability of movement out of the various states

$$
\begin{aligned}
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} + P_{UI.UC} - P_{UC.UI} \\
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} \\
P_{CI.E} &= P_{CI.CC} - P_{CC.CI} + P_{CI.C} + P_{CI.UI} - P_{UI.CI} \\
P_{CC.E} &= P_{CC.UC} - P_{UC.CC} + P_{CC.C} + P_{CC.CI} - P_{CI.CC}
\end{aligned}
$$

- Max prob of moving through the learning process -> min $P_{CC.CI}$ and max $P_{CI.CC}$

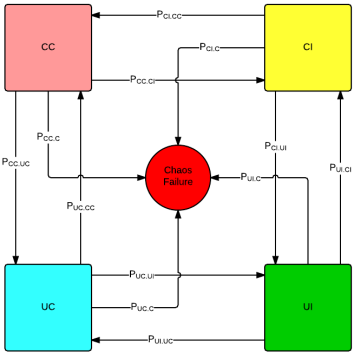


Can we model this process

- We can try classic Markov state modeling
- Probability of movement out of the various states

$$
\begin{aligned}
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} + P_{UI.UC} - P_{UC.UI} \\
P_{UI.E} &= P_{UI.CI} - P_{CI.UI} + P_{UI.C} \\
P_{CI.E} &= P_{CI.CC} - P_{CC.CI} + P_{CI.C} + P_{CI.UI} - P_{UI.CI} \\
P_{CC.E} &= P_{CC.UC} - P_{UC.CC} + P_{CC.C} + P_{CC.CI} - P_{CI.CC}
\end{aligned}
$$

- Max prob of moving through the learning process -> min $P_{CC.CI}$ and max $P_{CI.CC}$



So what is Agent Based Modeling

- Agent based modeling (ABM) considers the actors in a system to be agents that behave according to rules independently
- Nearly all systems can be represented by ABMs
- For example, let's consider why passengers waiting for a train accumulate around a platform in interesting patterns
  - It would be difficult imagining how to model this using EBM.
    - Differential equations, boundary conditions, etc. ick.
  - The actors (agents) would be such items as people, trains, platform edges, stairs, balustrades, etc.
- On the other had, in an ABM, the Agents behave according to rules in the model, producing outcomes quite easily.
- One could imagine these techniques being applied to the learning process

So what is Agent Based Modeling

- Agent based modeling (ABM) considers the actors in a system to be agents that behave according to rules independently
- Nearly all systems can be represented by ABMs
- For example, let's consider why passengers waiting for a train accumulate around a platform in interesting patterns
  - It would be difficult imagining how to model this using EBM.
    - Differential equations, boundary conditions, etc. Ick.
  - The actors (agents) would be such items as people, trains, platform edges, stairs, balustrades, etc.
- On the other had, in an ABM, the Agents behave according to rules in the model, producing outcomes quite easily.
- One could imagine these techniques being applied to the learning process

So what is Agent Based Modeling

- Agent based modeling (ABM) considers the actors in a system to be agents that behave according to rules independently
- Nearly all systems can be represented by ABMs
- For example, let's consider why passengers waiting for a train accumulate around a platform in interesting patterns
  - It would be difficult imagining how to model this using EBM.
    - Differential equations, boundary conditions, etc. etc.
  - The actors (agents) would be such items as people, trains, platform edges, stairs, balustrades, etc.
- On the other had, in an ABM, the Agents behave according to rules in the model, producing outcomes quite easily.
- One could imagine these techniques being applied to the learning process

So what is Agent Based Modeling

- Agent based modeling (ABM) considers the actors in a system to be agents that behave according to rules independently
- Nearly all systems can be represented by ABMs
- For example, let's consider why passengers waiting for a train accumulate around a platform in interesting patterns
  - It would be difficult imagining how to model this using EBM.
    - Differential equations, boundary conditions, etc. etc.
  - The actors (agents) would be such items as people, trains, platform edges, stairs, balustrades, etc.
- On the other had, in an ABM, the Agents behave according to rules in the model, producing outcomes quite easily.
- One could imagine these techniques being applied to the learning process

So what is Agent Based Modeling

- Agent based modeling (ABM) considers the actors in a system to be agents that behave according to rules independently
- Nearly all systems can be represented by ABMs
- For example, let's consider why passengers waiting for a train accumulate around a platform in interesting patterns
  - It would be difficult imagining how to model this using EBM.
    - Differential equations, boundary conditions, etc. etc.
  - The actors (agents) would be such items as people, trains, platform edges, stairs, balustrades, etc.
- On the other had, in an ABM, the Agents behave according to rules in the model, producing outcomes quite easily.
- One could imagine these techniques being applied to the learning process

So what is Agent Based Modeling

- Agent based modeling (ABM) considers the actors in a system to be agents that behave according to rules independently
- Nearly all systems can be represented by ABMs
- For example, let's consider why passengers waiting for a train accumulate around a platform in interesting patterns
  - It would be difficult imagining how to model this using EBM.
    - Differential equations, boundary conditions, etc. etc.
  - The actors (agents) would be such items as people, trains, platform edges, stairs, balustrades, etc.
- On the other had, in an ABM, the Agents behave according to rules in the model, producing outcomes quite easily.
- One could imagine these techniques being applied to the learning process

So what is Agent Based Modeling

- Agent based modeling (ABM) considers the actors in a system to be agents that behave according to rules independently
- Nearly all systems can be represented by ABMs
- For example, let's consider why passengers waiting for a train accumulate around a platform in interesting patterns
  - It would be difficult imagining how to model this using EBM.
    - Differential equations, boundary conditions, etc. etc.
  - The actors (agents) would be such items as people, trains, platform edges, stairs, balustrades, etc.
- On the other had, in an ABM, the Agents behave according to rules in the model, producing outcomes quite easily.
- One could imagine these techniques being applied to the learning process

So what is Agent Based Modeling

- Agent based modeling (ABM) considers the actors in a system to be agents that behave according to rules independently
- Nearly all systems can be represented by ABMs
- For example, let's consider why passengers waiting for a train accumulate around a platform in interesting patterns
  - It would be difficult imagining how to model this using EBM.
    - Differential equations, boundary conditions, etc. etc.
  - The actors (agents) would be such items as people, trains, platform edges, stairs, balustrades, etc.
- On the other had, in an ABM, the Agents behave according to rules in the model, producing outcomes quite easily.
- One could imagine these techniques being applied to the learning process

Another example of Agent Based Modeling

- The well known Complex case of the Predator, Prey and Energy (wolf, sheep, grass).
- If we wanted to solve it using EBM we would have to understand Lotka-Volterra differential equations.
- And in particular the following pair

$$\frac{dPred}{dt} = K_1 Pred^2 - M\,Pred$$

and

$$\frac{dPrey}{dt} = B\,Prey - K_2 Pred\,Prey$$

Another example of Agent Based Modeling

- The well known Complex case of the Predator, Prey and Energy (wolf, sheep, grass).
- If we wanted to solve it using EBM we would have to understand Lotka-Volterra differential equations.
- And in particular the following pair

$$\frac{dPred}{dt} = K_1 Pred^2 - M\,Pred$$

and

$$\frac{dPrey}{dt} = B\,Prey - K_2 Pred\,Prey$$

Another example of Agent Based Modeling

- The well known Complex case of the Predator, Prey and Energy (wolf, sheep, grass).
- If we wanted to solve it using EBM we would have to understand Lotka-Volterra differential equations.
- And in particular the following pair

$$\frac{dPred}{dt} = K_1 Pred^2 - M\,Pred$$

and

$$\frac{dPrey}{dt} = B\,Prey - K_2 Pred\,Prey$$

So what is Agent Based Modeling

- The first equation says that the number of predators increases as predators interact with prey (by fixed constant K1) and decreases by a constant mortality rate (M).
- The second equation says that the number of prey increase by a constant birthrate (B) and decreases in interaction with predators (by a fixed constant K2).
- The solution to these ends up being cyclic like sinusoids
  - They only represent what happens in the aggregate, and would lead us to believe that the populations are deterministic.
  - That is that we can predict what they will be at any time

So what is Agent Based Modeling

- The first equation says that the number of predators increases as predators interact with prey (by fixed constant K1) and decreases by a constant mortality rate (M).
- The second equation says that the number of prey increase by a constant birthrate (B) and decreases in interaction with predators (by a fixed constant K2).
- The solution to these ends up being cyclic like sinusoids
  - They only represent what happens in the aggregate, and would lead us to believe that the populations are deterministic.
  - That is that we can predict what they will be at any time

So what is Agent Based Modeling

- The first equation says that the number of predators increases as predators interact with prey (by fixed constant K1) and decreases by a constant mortality rate (M).
- The second equation says that the number of prey increase by a constant birthrate (B) and decreases in interaction with predators (by a fixed constant K2).
- The solution to these ends up being cyclic like sinusoids
  - They only represent what happens in the aggregate, and would lead us to believe that the populations are deterministic.
  - That is that we can predict what they will be at any time

So what is Agent Based Modeling

- The first equation says that the number of predators increases as predators interact with prey (by fixed constant K1) and decreases by a constant mortality rate (M).
- The second equation says that the number of prey increase by a constant birthrate (B) and decreases in interaction with predators (by a fixed constant K2).
- The solution to these ends up being cyclic like sinusoids
  - They only represent what happens in the aggregate, and would lead us to believe that the populations are deterministic.
  - That is that we can predict what they will be at any time

So what is Agent Based Modeling

- The first equation says that the number of predators increases as predators interact with prey (by fixed constant K1) and decreases by a constant mortality rate (M).
- The second equation says that the number of prey increase by a constant birthrate (B) and decreases in interaction with predators (by a fixed constant K2).
- The solution to these ends up being cyclic like sinusoids
  - They only represent what happens in the aggregate, and would lead us to believe that the populations are deterministic.
  - That is that we can predict what they will be at any time

So why Agent Based Models

- Of course we know that the Predator, Prey, Energy system is NOT sinusoidal, and certainly not deterministic
- We notice amazing emergent properties.
  - eg. The populations adapt to different circumstances.
- There is a large degree of randomness in the actual interactions between the actors in the model
- ABMs have distinct advantages for modeling complex systems like this
  - You don't have to know calculus.
    - (Only a very small percentage of the population does)
  - The agents behave according to simple rules written in simple language
  - The interaction of these simple agents produces the complex behavior we want to demonstrate

So why Agent Based Models

- Of course we know that the Predator, Prey, Energy system is NOT sinusoidal, and certainly not deterministic
- We notice amazing emergent properties.
  - eg. The populations adapt to different circumstances.
- There is a large degree of randomness in the actual interactions between the actors in the model
- ABMs have distinct advantages for modeling complex systems like this
  - You don't have to know calculus.
  - Only a very small percentage of the population (prey)
  - The agents behave according to simple rules written in simple language
  - The interaction of these simple agents produces the complex behavior we want to demonstrate

So why Agent Based Models

- Of course we know that the Predator, Prey, Energy system is NOT sinusoidal, and certainly not deterministic
- We notice amazing emergent properties.
  - eg. The populations adapt to different circumstances.
- There is a large degree of randomness in the actual interactions between the actors in the model
- ABMs have distinct advantages for modeling complex systems like this
  - You don't have to know calculus.
  - Only a very small percentage of the population (prey)
  - The agents behave according to simple rules written in simple language
  - The interaction of these simple agents produces the complex behavior we want to demonstrate

So why Agent Based Models

- Of course we know that the Predator, Prey, Energy system is NOT sinusoidal, and certainly not deterministic
- We notice amazing emergent properties.
  - eg. The populations adapt to different circumstances.
- There is a large degree of randomness in the actual interactions between the actors in the model
- ABMs have distinct advantages for modeling complex systems like this
  - You don't have to know calculus.
  - Only a very small percentage of the population (prey)
  - The agents behave according to simple rules written in simple language
  - The interaction of these simple agents produces the complex behavior we want to demonstrate

So why Agent Based Models

- Of course we know that the Predator, Prey, Energy system is NOT sinusoidal, and certainly not deterministic
- We notice amazing emergent properties.
  - eg. The populations adapt to different circumstances.
- There is a large degree of randomness in the actual interactions between the actors in the model
- ABMs have distinct advantages for modeling complex systems like this
  - You don't have to know calculus.
    - (Only a very small percentage of the population does)
  - The agents behave according to simple rules written in simple language
  - The interaction of these simple agents produces the complex behavior we want to demonstrate

So why Agent Based Models

- Of course we know that the Predator, Prey, Energy system is NOT sinusoidal, and certainly not deterministic
- We notice amazing emergent properties.
  - eg. The populations adapt to different circumstances.
- There is a large degree of randomness in the actual interactions between the actors in the model
- ABMs have distinct advantages for modeling complex systems like this
  - You don't have to know calculus.
    - (Only a very small percentage of the population does)
  - The agents behave according to simple rules written in simple language
  - The interaction of these simple agents produces the complex behavior we want to demonstrate

So why Agent Based Models

- Of course we know that the Predator, Prey, Energy system is NOT sinusoidal, and certainly not deterministic
- We notice amazing emergent properties.
  - eg. The populations adapt to different circumstances.
- There is a large degree of randomness in the actual interactions between the actors in the model
- ABMs have distinct advantages for modeling complex systems like this
  - You don't have to know calculus.
    - (Only a very small percentage of the population does)
  - The agents behave according to simple rules written in simple language
  - The interaction of these simple agents produces the complex behavior we want to demonstrate

So why Agent Based Models

- Of course we know that the Predator, Prey, Energy system is NOT sinusoidal, and certainly not deterministic
- We notice amazing emergent properties.
  - eg. The populations adapt to different circumstances.
- There is a large degree of randomness in the actual interactions between the actors in the model
- ABMs have distinct advantages for modeling complex systems like this
  - You don't have to know calculus.
    - (Only a very small percentage of the population does)
  - The agents behave according to simple rules written in simple language
  - The interaction of these simple agents produces the complex behavior we want to demonstrate

So why Agent Based Models

- Of course we know that the Predator, Prey, Energy system is NOT sinusoidal, and certainly not deterministic
- We notice amazing emergent properties.
  - eg. The populations adapt to different circumstances.
- There is a large degree of randomness in the actual interactions between the actors in the model
- ABMs have distinct advantages for modeling complex systems like this
  - You don't have to know calculus.
    - (Only a very small percentage of the population does)
  - The agents behave according to simple rules written in simple language
  - The interaction of these simple agents produces the complex behavior we want to demonstrate

Outline

NetLogo

- For those interested to explore Agent Based Modeling, you can download NetLogo for free.
  - https://ccl.northwestern.edu/netlogo/
- Also, see the excellent book by Wilensky and Rand

NetLogo

- For those interested to explore Agent Based Modeling, you can download NetLogo for free.
  - https://ccl.northwestern.edu/netlogo/
- Also, see the excellent book by Wilensky and Rand

NetLogo

- For those interested to explore Agent Based Modeling, you can download NetLogo for free.
  - https://ccl.northwestern.edu/netlogo/
- Also, see the excellent book by Wilensky and Rand

Complexity Resources

- Complexity Explorer from the Sante Fe Institute
  - https://www.complexityexplorer.org/
- Complexity Academy (Ireland)
  - http://complexitylabs.io/

Complexity Resources

- Complexity Explorer from the Sante Fe Institute
  - https://www.complexityexplorer.org/
- Complexity Academy (Ireland)
  - http://complexitylabs.io/

Complexity Resources

- Complexity Explorer from the Sante Fe Institute
  - https://www.complexityexplorer.org/
- Complexity Academy (Ireland)
  - http://complexitylabs.io/

Complexity Resources

- Complexity Explorer from the Sante Fe Institute
  - https://www.complexityexplorer.org/
- Complexity Academy (Ireland)
  - http://complexitylabs.io/

Outline

What we are doing

- One doctoral candidate working using ABM to better understand safety systems on a railway in Sydney
- We have started a SIG to see if we can get a better understanding of the UTS Learning.Futures project
- I have another doctoral candidate using ABM to better understand Software Defined Networks applied to Layer 1 communications

What we are doing

- One doctoral candidate working using ABM to better understand safety systems on a railway in Sydney
- We have started a SIG to see if we can get a better understanding of the UTS Learning.Futures project
- I have another doctoral candidate using ABM to better understand Software Defined Networks applied to Layer 1 communications

What we are doing

- One doctoral candidate working using ABM to better understand safety systems on a railway in Sydney
- We have started a SIG to see if we can get a better understanding of the UTS Learning.Futures project
- I have another doctoral candidate using ABM to better understand Software Defined Networks applied to Layer 1 communications

References

See pages 51 and 57 of the reference below.

Quoting: "Agent-based computational modelling cannot help solve these estimation and identification problems on empirical grounds. At the theoretical level, however, they offer a unique opportunity for rigorous study of formal models containing neighbourhood- and/or network-based interdependences among individual behaviours. First of all, there is no unobserved Educational Choices and Social Interactions 51 (C) Emerald Group Publishing Limited heterogeneity within an agent-based model."

References

Educational Choices And Social Interactions: A Formal Model And A Computational Test, Gianluca Manzo, Class and Stratification Analysis Comparative Social Research, Volume 30, 47–100, 2013 by Emerald Group Publishing Limited

Complex Adaptive Systems: An Introduction to Computational Models of Social Life, John H. Miller & Scott E. Page, Princeton University Press

An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo, Uri Wilensky and William Rand, MIT Press, April 3, 2015

References


Educational Choices And Social Interactions: A Formal Model And A Computational Test, Gianluca Manzo, Class and Stratification Analysis Comparative Social Research, Volume 30, 47–100, 2013 by Emerald Group Publishing Limited


Complex Adaptive Systems: An Introduction to Computational Models of Social Life, John H. Miller & Scott E. Page, Princeton University Press


An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo, Uri Wilensky and William Rand, MIT Press, April 3, 2015

References


Educational Choices And Social Interactions: A Formal Model And A Computational Test, Gianluca Manzo, Class and Stratification Analysis Comparative Social Research, Volume 30, 47–100, 2013 by Emerald Group Publishing Limited


Complex Adaptive Systems: An Introduction to Computational Models of Social Life, John H. Miller & Scott E. Page, Princeton University Press


An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo, Uri Wilensky and William Rand, MIT Press, April 3, 2015