Construct

Kathleen Carley
Michael Kowalchuck
Construct

- Dynamic-Network Agent-Based simulation model for examining information diffusion and social change
- First multi-agent network model in socio-cultural area
- Features
  - Co-evolution of social structure and culture
  - Co-evolution of agents and their societies
  - Co-evolution of social and knowledge networks
  - Agents learn through interaction
  - Agents need not be “people”
  - Multi-fidelity input is possible
    - Exact knowledge network
    - Group level probabilities
Why Construct?

- Construct is a powerful tool for predicting how groups and networks evolve, and information, beliefs and activities diffuse.
- Construct allows you to construct and evaluate ‘what-if?’ scenarios
- Construct can be used in ORA!
How Has Construct Been Applied?

- Organizational theory
  - what organizations are efficient, and what ones are not?
  - how robust are certain organizations from threats and attacks?
- Key player forecasting
  - how will a network evolve over time, and what could it look like?
  - what agents are likely to be important due to network position?
- Intervention evaluation
  - how will specific interventions affect certain types of decisions?
  - what are the secondary effects of different interventions?
Construct is a sophisticated multi-agent simulation tool. The agents, social network, and knowledge base are dynamic. The effects studied are complex, varied, and highly non-linear.
Construct Evolves Meta-Networks

Meta-Network structure represented by multiple networks of people, knowledge & tasks

<table>
<thead>
<tr>
<th>People</th>
<th>Knowledge</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>People</td>
<td>Social Network</td>
<td>Knowledge Network</td>
</tr>
<tr>
<td></td>
<td>Who knows who</td>
<td>Who knows what</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Information Network</td>
<td>Needs Network</td>
</tr>
<tr>
<td></td>
<td>What types of knowledge are related</td>
<td>What knowledge is needed per task</td>
</tr>
</tbody>
</table>

(* adapted from Krackhardt & Carley, 1998)
Why Simulate?

- Counterfactual
  - can create hypothetical situations with more potency than existing ones
- Ethical
  - cannot test policies on real populations
- Preparatory
  - can examine a range of scenarios for systematic imaginative thinking
- Cost effective
  - creating technologies and procedures for data collection is expensive
- Faster
  - can mitigate the fact that evaluating existing systems is time consuming
- Flexible
  - can allow response to novel situations and unexamined alternatives
Simulation Procedure

- Control Case
- Intervention
- Intervention

- Initialize Actors
- Build Virtual City
- Run Construct
- Analyze Outputs

- Initialize Social Network

Defines Virtual Experiment

- Statistics, Analysis, Decisions
What Construct Can Tell Us

- Aggregate statistics on groups
  - what groups may do
  - overall trends among agents
- Probabilities for individuals
  - what they might do
  - what they are likely to know
- Confidence intervals
  - what the ranges might be
  - what outcomes are most likely
- Knowledge does not increase additively
Construct Internals

- Beliefs
- Interventions
- Outputs
- Social Network at Large
Agents Can Have Knowledge

- The “meaning” of the knowledge is user-defined
  - knowledge can be binary- or real-valued
  - knowledge can be learned as well as forgotten
  - individual agents have different learning, forgetting rates

FACT A

no knowledge at time $T - \varepsilon$

full knowledge at time $T$

full knowledge at time $T$

some knowledge at time $T + \varepsilon$
Agents Can Interact for Many Reasons

Homophily (Similarity)

Learning New Knowledge

Explicit Information Search
Agents Prefer Those with Similar Knowledge

• Agents prefer to interact via homophily
  • the more two agents share, the more likely the interaction
• Agents rely on transactive memory in their decisions
  • agents must know something about what the other agent knows
Agents May Also Value Expertise

- Expertise is a function of an agent’s knowledge
  - experts know facts in an area that another agent does not
- Expertise is relative
  - so in one interaction, an agent can be an “expert” while in another interaction the same agent is not an expert

- Preferred partner
  - 01101000
  - 10000110
  - 10101001
  - 10101001
Agents May Deliberately Seek Information

- Agents may search for specific knowledge facts
  - other agents may give references
- Agents may give references to a particular fact
  - agents may not know a fact, but may know others who know it

• Preferred partner
Detailed View of an Agent’s Behavior

1. Select an Initiating Agent
   - Represents an Agent’s Knowledge and Beliefs
   - 10101001

2. ...and a Fact to exchange...
   - ...Select an Agent to Interact with...
   - 00101011

3. ...Based on Relative Similarity or Relative Expertise, derive an Interaction Probability...
   - ...and Select an Agent to Interact with...
   - 10101011

4. ...Modulate the Interaction Probability by the Socio-Demographics, Proximity, media choice, etc.,
   - 10101011

...and Communicate.
Computing Interaction Probabilities

Probability of Interaction

Static Factors
- Physical Similarity
- Social Similarity

Knowledge Factors
- Knowledge Similarity
- Knowledge Expertise
- Knowledge & Transactive Memory

Red arrows are weights

Socio-Demographic similarity

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Static Factors

- Physical similarity
  - how close two agents are
  - can use a distance function
  - closer -> higher probability

- Socio-demographic similarity
  - computed from attributes
  - represent salient qualities
  - overlap -> higher probability

- Social similarity
  - catch-all for other features
  - can be ignored if not needed
  - more -> higher probability

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Knowledge Factors

- Knowledge similarity
  - how much info in common
  - more -> higher probability

- Knowledge expertise
  - how much other knows
  - more -> higher probability

- Knowledge weights
  - make some facts important
  - affect the calculation of similarity and expertise scores
Agents have pre-specified interaction spheres
- agents only interact with those in sphere, not with all others
- however, agents outside this sphere can affect it by passing knowledge through a series of intermediaries
Agents Interact Multiple Times

- Agents can initiate or receive communication (or both)
  - initiators actively seek out interaction partners
  - receivers passively wait for an initiator to contact them
  - Interactions result in an exchange of knowledge, beliefs, or TM
- Some agents initiate or receive multiple times
Select Initiation Order

- Initiation order is random in each time period
  - it will be different for each time period, and not tied to previous period
- Agents can initiate interaction more than once
  - but interactions occur at different times and do not occur all at once
- Initiation order has no bearing on facts transmitted or received
Diadic Interaction Mechanism

1. **Initiating Agent**
2. **Select Partner**
3. **Compute** with available recipients only
Construct Internals

- Beliefs
- Interventions
- Outputs
- Social Network at Large
- Interactions
Agents Can Have Beliefs

- Beliefs represent agreement with a principle
- Beliefs are a function of several factors
  - current knowledge
  - priors, including immediate past beliefs
  - composition of interaction sphere
  - influentialness of others and individual susceptibility to influence

![Knowledge and Beliefs Diagram]

- Prior
- Influentialness
- Knowledge
- No opinion
- Believe it
- Doubt it
Beliefs Can Change Over Time

- Beliefs change as a result of agent interactions
- Agents can have multiple beliefs
  - these beliefs can be conflicting
Some Agents Are More Influential

- Influential agents can sway beliefs
  - they have more effect on the beliefs of others
- Some agents are less prone to influence
  - some agents are more easily, less easily swayed than others
- Knowledge is independent of influentialness
  - Influential agents need not be knowledgeable
Agents Also Have Transactive Memory

- Knowledge
- Beliefs
- Who-Knows-What Transactive Memory
- Who-Believes-What Transactive Memory
Human Agents Are Boundedly Rational

- Agents in Construct are boundedly rational actors
  - their cognitive abilities are bounded, meaning that they cannot possess or process all information about others perfectly
  - their social abilities are also bounded, meaning that they may not possess or process all information about their social setting
Message Selection

- Communicated Message
  - Message Component
    - Belief
    - Knowledge
    - Transactive Memory
    - Transmission Weight
  - Sending Agent’s Internal Knowledge
Message Communication

Both Partners Participate

Creates

Communicated Message

Sends

Communicated Message

Sends

Creates
Agents Can Have Socio-Demographics

- Socio-demographics capture salient characteristics
  - information can be used to determine interaction probabilities
  - agents prefer to interact with those who are similar to them

- Gender
- Age
- Income
- Education
- Parent
- Race
Agents Can Have Proximity Measures

- Proximity helps bring agents together or pull them apart
- Construct has several proximity measures
  - physical proximity: a representation of physical distance
  - social proximity: a representation of social affinity
Agents Perform Tasks

- Agents compare their knowledge with pre-defined “truth”
  - if agents have relevant knowledge, they use it in the task
  - if agents lack a piece of knowledge, they guess
  - multiple agents can collaborate on a task
Agents Take Actions

- they perform tasks, evaluate a function, or act on a belief
- agents may perform intermediate tasks to help with final task
- Actions and tasks are usually dependent on knowledge
Interventions Can Manipulate Agents

- Interventions can change knowledge, beliefs, activities
  - experts know facts in an area that another agent does not
- Experimenter can specify type, duration of intervention
  - this can be used to compare different intervention types

- Knowledge Intervention
  - Agent exogenously learns knowledge

- Isolation Intervention
  - Agent can no longer interact with others

- Belief Intervention
  - Agent exogenously changes belief
Interventions Can Be New Agents

- These interventions can be contacted like other agents
  - they may have specific facts, knowledge, and beliefs
- Experimenter can specify type, duration of intervention
  - this can be used to compare different intervention types

- Printed Interventions
  - Available to agents who are literate

- Web Page Interventions
  - Available to those with internet access

- Mail Intervention
  - Available to those who check mail
Agents Themselves May Not Be Static

- Agents can be replaced via agent turnover mechanisms
  - agents come and go, as in human social networks
- New agents have different knowledge, interaction sphere
Behavioral Outcomes

- **Diffusion**
  - At time “x” how many people know fact 1
  - At time “x” how many people know 5 facts
  - At time “x” how many people know all the facts

- **Consensus**
  - At time “x” how many people have the same opinion about y

- **Performance Accuracy**
  - At time “x” what percentage of the tasks are analyzed correctly by the majority
  - Variation – simple, medium and complex task that vary in number of bits

*Stability Rates*
Accuracy

- Task is a binary classification task
  - String of 1’s and 0’s
- Goal is to determine if there are more 1’s or 0’s
- The task string = the number of facts
- Each person observes those task bits for which they have information
  - If individual knows Sik then individual can read Tjk
- If for the bits observed the person see’s more 1’s than 0’s then decide 1 else 0
- The group’s decision is the majority decision
- The true answer is calculated given the actual task bit strength
- Performance accuracy is percentage correct across 25 tasks each time period
Common Construct Output Measurements

- **Knowledge**
  - number who know a specific fact
  - number who know a range of facts

- **Beliefs**
  - number who hold a specific belief
  - number who act on a belief

- **Tasks**
  - number who should perform a task
  - number who perform a task
  - number who succeed at a task

• measurements must be aggregated!
Other Output Measurements

- Agent network
  - who talks to whom, and why
  - probability of specific interaction
  - likelihood of continued interaction

- Intervention communication
  - who communicates with it
  - does agent initiate or receive
  - do behavior patterns later change
  - how likely is repeat interaction

- measurements must be aggregated!
Where can I read more?

- **Original Description**

- **Illustrative Uses and Validation**