Conversational Agents as Facilitators for Group Interaction

Gaurav Singh Tomar

School of Computer Science
Language Technologies Institute
Agenda

- CSCL and Conversational Agents
- Dimensions of Support
- How Bazaar Works
- Tales of the Bazaar
- Deploying Conversational Agents
Conversational Agents

- State-based computer programs
- Interact with human beings through natural language
  - text
  - speech
  - images
  - video
Dialogue systems

Collaborative Conversational Tutors

- Conversational Agents as Facilitator for Group Interaction

Facilitator Tutors

- Programming tutor - dialogue system for computer programming instruction
Collaborative Conversational Tutors
Collaborative Conversational Tutors
CSCL with Conversational Agents

• Students working with a partner and dialogue agent for support learn 1.24 s.d. more than individuals without support (Kumar et al., 2007a)

• Personalized agents increase supportiveness and help exchange between students (Kumar et al., 2007b)

• Agents that employ social strategies are more effective than those that don’t (Kumar et al., 2010; Ai et al., 2010)

• Students are sensitive to agent rhetorical strategies such as displayed bias (Ai et al., 2010), openness to alternatives (Kumar et al., 2011), and targeted elicitation (Howley et al., 2012)

• Students show learning gains (Dyke et al., 2012) and interact more intensely (Adamson et al., 2013) when supported by a facilitating agent using Accountable Talk moves.
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### Multi-Dimensional Multi Party Dialog

<table>
<thead>
<tr>
<th>Time</th>
<th>Username</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:57:35</td>
<td>S02</td>
<td>noooo i think that the daddy is homozygous dominant and the mommy is heterozygous dominant. GG, Gg</td>
</tr>
<tr>
<td>12:58:22</td>
<td>S01</td>
<td>50% of the children are white so if one parent is gg and the other is Gg then this will create a 50% chance of having white.</td>
</tr>
<tr>
<td>12:58:27</td>
<td>Tutor</td>
<td>So S01, what I hear you saying is recessive traits can be hidden in parents, but still show up in some of the children.</td>
</tr>
<tr>
<td>12:58:35</td>
<td>S01</td>
<td>yeah</td>
</tr>
<tr>
<td>12:58:39</td>
<td>S02</td>
<td>nooooooooo</td>
</tr>
<tr>
<td>12:58:49</td>
<td>Tutor</td>
<td>I wonder what S03 has to say.</td>
</tr>
<tr>
<td>12:59:10</td>
<td>S02</td>
<td>nothing she dont care</td>
</tr>
<tr>
<td>12:59:33</td>
<td>S03</td>
<td>shut up S02!!! i dont understand whats going on</td>
</tr>
<tr>
<td>13:00:12</td>
<td>S02</td>
<td>S03, its okay. just re look at the problem mamacitaaaaa</td>
</tr>
<tr>
<td>13:00:22</td>
<td>Tutor</td>
<td>Let’s move on to the next problem...</td>
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</table>
Support for Collaborative Learning

• Support for collaborative learning can be described as *scripts* that scaffold and sequence the learners’ interactions.

• A collaborative activity can be composed of multiple complementary scripts.

(Dillenbourg and Tchounikine, 2007)
Dimensions of Support

- **Macro**
  sequence, timing, large structure of activity

- **Micro**
  hints, feedback, support for student actions
Dimensions of Support

- **Static**
  pre-defined sequences, sentence templates

- **Dynamic**
  responsive to student behavior, context
Dimensions of Support

- **Static**
  - Macro: Lesson Plan
  - Micro: Timed Templates

- **Dynamic**
  - Macro: Facilitation
  - Micro: Feedback
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Basilica

- Modular event-based agent architecture
- Multiple collaborative conversational contexts
- Pioneer platform for dynamic scripting support

Kumar et al, 2007, 2010
# Behavior Coordination

<table>
<thead>
<tr>
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<td>12:58:35</td>
<td>yeah</td>
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<tr>
<td>S02</td>
<td>12:58:39</td>
<td>noooooooooooooo</td>
</tr>
<tr>
<td>Tutor</td>
<td>12:58:49</td>
<td>I wonder what S03 has to say.</td>
</tr>
<tr>
<td>Tutor</td>
<td>12:59:00</td>
<td>Let’s move on to the next problem...</td>
</tr>
<tr>
<td>S03</td>
<td>12:59:04</td>
<td>...</td>
</tr>
</tbody>
</table>
Basilica Event Flow

most of the two-way links manage behavior coordination...

....
Bazaar

- Based on Basilica
- Simplified event flow
- Built-in coordination between behaviors
Basilica, but...

- Make implicit filter-actor pattern explicit
- Move inter-actor coordination out of each component, and into the framework
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<tr>
<td>13:00:22</td>
<td>Tutor</td>
<td>All right, we're wrapping up. Thanks, team!</td>
</tr>
</tbody>
</table>
Pre-process

React
Actions are proposed with a timeout (window of relevance) and a priority value.

Advisors (left by earlier accepted actions) influence the selection of incoming proposals to:

- reserve the floor for followups
- prefer proposals from certain sources
• Accepted proposals leave advisors that linger for a time after the proposal is enacted.

• When a proposal is accepted or rejected, it sends a callback to notify the originating component.
## Experimental Tradeoffs

<table>
<thead>
<tr>
<th>Constraints</th>
<th>+</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow</td>
<td>Repeatable, Predictable, Internal validity</td>
<td>Behavior juxtapositions, Missed opportunities</td>
</tr>
<tr>
<td>Flexible</td>
<td>Adaptable, Natural exchanges, External validity</td>
<td>Adds error variance, Less control of time</td>
</tr>
</tbody>
</table>

- Narrow Constraints:
  - Repeatable
  - Predictable
  - Internal validity

- Flexible Constraints:
  - Adaptable
  - Natural exchanges
  - External validity
Discussion

• Bazaar is a reusable, freely-available platform for CSCL research

• Softening timing leads to a tradeoff between internal and external validity

• Support along multiple dimensions can be coordinated gracefully
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- CSCL and Conversational Agents
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Tales of the Bazaar

Research Platforms for CSCL
Dimensions of Support

- Lesson Plan
- Cue Cards
- Facilitation
- Feedback
Revoicing and APT

- Can tutor-led Academically Productive Talk (APT) increase student learning?
- 9th grade Biology, groups of 3 students
- Tutor offers “Revoice” and “Say More” APT moves in response to student contributions:

**S01**
50% of the children are white so if one parent is gg and the other is Gg then this will create a 50% chance of having white babies

**Tutor**
So S01, what I hear you saying is recessive traits can be hidden in parents, but still show up in some of the children.
Revoicing and APT

- Static, macro-scripted (rigidly timed) problem sequence
- Static APT micro-reminders

![Revoicing example](image)

- Dynamic social prompts (Kumar et al, 2010)
- Dynamic revoicings (APT) of student explanations: Bazaar reserves floor-space for student responses, promotes tutor follow up moves
Targeting Student Self-Efficacy
Howley, Adamson, Dyke, Rosé, 2012

• How do targeted prompts affect the self-efficacy of student participants?

• Knowledge construction dialogues delivered by “professor” tutor

• Social moves from “clueless student” tutor, plus targeted questions to high/low efficacy students

• In a time-constrained setting, overly-soft timing can mean all of the dialogues don’t get started.
  - choice of priorities and timeouts is important!
Facilitating Debate

WhiteboardChat: Republicans (abc)

File

Whiteboard:

Chat: (331)

Democrats 1:32:15 AM PST: hi... i personally believe that women should have choice what to do with their bodies

Republicans 1:32:41 AM PST: but many times women are young and immature and take wrong decisions and regret later

Democrats 1:33:04 AM PST: abortion should ultimately be the choice of women

Republicans 1:33:38 AM PST: abortion leads to certain complications if not carried out properly.. abortion is equal to murder

Democrats 1:34:04 AM PST: i believe in pro choice..

Republicans 1:34:32 AM PST: fetus has a life and right to grow and live.. by abortion we are killing that right

Talker 1:34:42 AM PST: Say Something, Republicans

Talker 1:34:58 AM PST: (democrats) Science says a sperm cell does not constitute a human being. Science does say a zygote and beyond constitute a human being. Science should be the basis of law. So abortion is not equivalent to murder. Don't you agree to this?

Message:
Facilitating Debate

• Can a balanced debate engender multi-perspective knowledge?

• Discussant participation is dynamically encouraged

• Dynamically detect the current topic and the dominating “side” of the debate.

• Facilitator/Tutor dynamically directs the conversation by introducing facts and talking points for the weaker side
Distributed Learning Environments
Massive Open Online Courses (MOOCs)
Collaboration Opportunities in MOOC environment

Asynchronous
Lack of sense of immediacy

Synchronous
Feel more involved
Two Challenges

Getting people into groups

Making a group work once it is formed
Group Formation

- **Ad-hoc**
  - Pair matching
  - Rolling basis

- **Transactive jigsaw**
Ad-hoc Group Formation

### Bazaar Assignment: Reflection on the Visualization of the Networks (External Resource)

Click here to start this collaborative activity.

---

### The Lobby: Week 3

Log in with your edx username.

- Note that whenever you log in, you will be assigned to a new team.
- If the user you are matched with does not enter the room, come back to the lobby and you will be matched with someone else.

<table>
<thead>
<tr>
<th>Username</th>
<th>Student1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Enter the Lobby

---

<table>
<thead>
<tr>
<th>Time</th>
<th>User</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>20:09</td>
<td>Student1</td>
<td>joined</td>
</tr>
<tr>
<td>20:09</td>
<td>System</td>
<td>Hi, Student1.</td>
</tr>
<tr>
<td>20:09</td>
<td>System</td>
<td>Welcome to the matchmaker lobby. Hang on for a few minutes, we'll match you up with a team as soon as enough students join.</td>
</tr>
<tr>
<td>20:09</td>
<td>System</td>
<td>Student1, you're on Team 2.</td>
</tr>
<tr>
<td>20:09</td>
<td>System</td>
<td>Your team's discussion area is ready, Student1. Follow this link to join the discussion. After you join your team's discussion area, please follow VirtualDragan's instruction there.</td>
</tr>
</tbody>
</table>
Group Management and Coordination

Conversational Agent Based Support

- An architecture for collaborative conversational agents - **Bazaar**
- Extension for supporting synchronous group work in distributed learning environments
Iterative Design Based Research Process

Data Infrastructure
unifies social interaction
into uniform interface

Learning Analysis
analyzes learning paths
conditioned on social network

Intervention
links students
through discussions
Iterative Design Based Research Process

Data Infrastructure
unifies social interaction into uniform interface

Learning Analysis
analyzes learning paths conditioned on social network

Intervention
links students through discussions

- Dialog systems (agents)
- Recommender systems
- Discussion forums, videos, quizzes ...
Iterative Design Based Research Process

- MOOCDB
- DiscourseDB
- DataStage

Data Infrastructure
unifies social interaction into uniform interface

Learning Analysis
analyzes learning paths conditioned on social network

Intervention
links students through discussions
Iterative Design Based Research Process

Data Infrastructure
unifies social interaction into uniform interface

Learning Analysis
analyzes learning paths conditioned on social network

- Time series analysis
  - Survival models
  - Recurrent neural networks
  - Graphical models

Intervention
links students through discussions
Three Cycles

Data, Analytics, and Learning
UTArlingtonX - LINK5.10x
Ended - Dec 22, 2014

Big Data in Education
TeachersCollegeX - BDE1x
Ended - Aug 26, 2015

Medicinal Chemistry
DavidsonX - D001x
Ended - Dec 11, 2015

8-9 week long
Our goal is to do our best to guide you through this course to get the maximum benefit it has to offer. It would be helpful to us to hear specifically what your expectations are going forward so we can better offer guidance along the way. Any comments or feedback for us?

Hi Shenal

I'm joining the course from Switzerland

I'm joining the course from Colombia

Tanguy T has joined the discussion.

Welcome, Tanguy T
Please join our discussion to get acquainted and think about what we learned this week. We have discussed [what goals you might have for your participation in this course, how well the course content matches expectations] Currently we are discussing what expectations you have for the remainder of the course Please join in.

I like the course so far - based on the pre-test, I see that we are going to get deep into the Medicinal Chemistry. I liked that we started off with some non-scientific stuff
**Prompt 1:** Reflect on the structure of the dual-layer structure of the course. Describe your experience of coming to understand different course elements.

**Prompt 2:** For today’s exercise, please pick and tell a problem that prediction modeling or behavior detection could be used for. It could be something relevant to your work, or it could be something you just think is nifty. It could also be the same problem you picked last week, or a new problem. *shrugs* It’s all good. My example would be predicting if a student is gaming the system, in online math homework. Now your turn.

**Prompt 3:** The liver is a primary organ for drug metabolism. In cases of drug overdoses, the liver is often at risk to be damaged by drug metabolites. Discuss in general terms how the liver can be vulnerable to the metabolites that it makes.
Collaborative interaction supported by a virtual agent
Making the group work once it is formed

- Knowledge construction dialogues
- Academically Productive Talk moves
- Other facilitation moves like consolidation

Pilot studies in a fake meteorology course on edge edX for - An Exploratory Study: Assisting Synchronous Chat in a MOOC through Agent Facilitation Moves
WEATHER MOOC

- Watch a video on introductory concepts to meteorology
- Synchronous chat collaboration with a group of people and an agent
- Give a short quiz on the concepts
VirtualCarolyn 8:16:51 PM
I noticed that you are talking about low pressure wind direction. If you want to check your knowledge on low pressure wind direction with me say ‘LET’S DISCUSS ABOUT low pressure wind direction’ and I will ask some questions on it.

Oliver 8:17:11 PM
LET’S DISCUSS ABOUT low pressure wind direction

Germán 8:17:11 PM
let’s discuss about low pressure wind direction

VirtualCarolyn 8:17:11 PM
Will you like to answer some questions related to low pressure and wind direction?

Germán 8:17:15 PM
yes
Micro script

- Detecting topics being talked about
- Starting KCDs on request by participants
- Academically Productive talk moves
- Consolidation moves
New Facilitation Move - Summarization

● Why?
  ○ Provide frame of reference to new entrants in the chat discussion

● How?
  ○ By agent
    ■ mention list of topics covered
  ○ By other participants
    ■ agent requests other participants

● When?
  ○ At-least two new topics have been discussed
    ■ by other participants
  ○ Else
    ■ by agent
Consolidation move requested by agent

<table>
<thead>
<tr>
<th>User</th>
<th>Time</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arka</td>
<td>9:23:43 PM</td>
<td>has joined the discussion.</td>
</tr>
<tr>
<td>VirtualCarolyn</td>
<td>9:23:45 PM</td>
<td>Welcome, Arka. Can any one of you provide a summary of our discussion till now to Arka</td>
</tr>
<tr>
<td>Germán</td>
<td>9:24:16 PM</td>
<td>we were talking about the intersection of cold and warm fronts and the chance of precipitation at this intersection</td>
</tr>
<tr>
<td>Natty</td>
<td>9:24:20 PM</td>
<td>hinarka we have been talking about cold fronts and precipitation</td>
</tr>
<tr>
<td>VirtualCarolyn</td>
<td>9:24:20 PM</td>
<td>I noticed that you are talking about warm front precipitation. If you want to check your knowledge on warm front precipitation with me say 'LET'S DISCUSS ABOUT warm front precipitation' and I will ask some questions on it.</td>
</tr>
<tr>
<td>Tomit</td>
<td>9:24:37 PM</td>
<td>Lets not discuss about warm front precipitation</td>
</tr>
<tr>
<td>Arka</td>
<td>9:24:41 PM</td>
<td>thanks guys</td>
</tr>
<tr>
<td>Arka</td>
<td>9:24:58 PM</td>
<td>lets discuss warm front precipitation</td>
</tr>
</tbody>
</table>
Consolidation move made by agent

<table>
<thead>
<tr>
<th>User</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>diyiy</td>
<td>8:08:20 PM</td>
</tr>
<tr>
<td>VirtualCarolyn</td>
<td>8:08:21 PM</td>
</tr>
</tbody>
</table>

Welcome, diyiy
We have been discussing on topics like [low pressure temperature, cold front temperature, warm front temperature]
Please join in.
Welcome, Gaurav
Can any one of you provide a summary of our discussion till now to Gaurav

Yohan
10:03:28 PM ED
but i don't know it means F has high chance of rain

Guest 241750266
10:03:56 PM ED
well Yohan just explained that the chance of precipitation is lower behind a warm front because it leaves warm air and warm air expands rather than condenses

Guest 241750266
10:04:59 PM ED
I think that the low pressure might increase the chance of rain at F, but at C the air is warmed up

Yohan
10:05:07 PM ED
Guest 241750266 mentioned earlier that there is a high chance of rain at F.

VirtualCarolyn
9:46:49 PM EDT
Others, do you agree or disagree with Manmeet?

Guest 241750266
9:47:10 PM EDT
I agree with manmeet too, good input

Yohan
9:47:44 PM EDT
what's the numbers in the map by the way?

Gaurav
9:47:55 PM EDT
I think wind speed

VirtualCarolyn
9:32:10 PM EDT
We can talk about cold fronts and temperature in a little more detail.

VirtualCarolyn
9:32:10 PM EDT
Can you explain why the temperature is cooler behind a cold front? Feel free to refer to points on the map.

Cassie T
9:32:18 PM EDT
Because a cold front brings cold air with it
Empirically Grounded Design Principles

Group formation

✗ Ad Hoc pairwise matching

✓ Ad Hoc but a single continuous chat room welcoming students into the chat on a rolling basis

Empirically Grounded Design Principles

**Group management & coordination**

- Conversation summary by agent or participants
- Tracking students’ activity (presence and participation) and topics covered
- Detecting and handling goalless interactions

Empirically Grounded Design Principles

Group management & coordination

- Non-adaptive timing of activity prove fast for large groups and slow for small groups
- Adaptive timings and delays for the prompts based on the number of students in the chat room
- Students with no peers
- Knowledge construction dialogs by agent for students with no peers

Cycle I - DALMOOC
Cycle II - BDEMOOC
Cycle III - MCMOOC
Survival Modeling

- Proportional log odds model capturing probability at each time point that a student will drop out at the next time point.

- Hazard ratio indicates how much more or less likely a student is to drop out based on how many standard deviations higher or lower a factor’s value is than average.

Survival Model

- Regression model that captures the changes of probability of survival over time
  \[ S(t) = Pr(T > t) = 1 - F(t) = \int_{0}^{\infty} f(x)dx \]

- Hazard Ratio
  \[ \lambda(t) := \lim_{dt \to 0} \frac{Pr\{t < T \leq t + \Delta t | T > t\}}{\Delta t} \]

Graphically:
- Hazard Ratio < 1
- Hazard Ratio = 1
- Hazard Ratio > 1

Participation Week
Positive Impact of Chat Participation on Dropout

Survival analysis
• students who made at least one attempt to participate in a chat during the first 6 weeks
• unit of analysis: each 2 day period

Dependent variable:
• drop = 1 on the last 2 day time window when at least one click was recorded (0 otherwise)

Control variables
• clicks on videos
• clicks on discussion forums

Independent variables:
• Participation in

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Hazard Ratio</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video Clicks</td>
<td>2.38</td>
<td>P &lt; .0001</td>
</tr>
<tr>
<td>Forum Clicks</td>
<td>.51</td>
<td>P &lt; .0001</td>
</tr>
<tr>
<td>Match Attempts</td>
<td>2.33</td>
<td>P &lt; .0001</td>
</tr>
<tr>
<td>Match Success</td>
<td>.44</td>
<td>P &lt; .01</td>
</tr>
<tr>
<td>Interaction between Attempts and Match</td>
<td>.76</td>
<td>P &lt; .05</td>
</tr>
</tbody>
</table>

Language Technologies Institute
Carnegie Mellon University
Positive Impact of Collaborative Chat in MOOCs

- Assess impact of chat participation on dropout along the way using a survival analysis
  - **Unit of analysis:** each 2 day period
  - **Dependent variable:** Drop = 1 on the last active time period (0 otherwise)
  - **Control variables:** Number of clicks on videos and number of clicks on discussion forums
  - **Independent variable:** Participation in collaborative chat reflection activities

Reduction in attrition of between 40% and 70% across 3 studies
Facilitator Tutor

Multi-Stream
Mixed Initiative Planning
Dialogue System for
Computer Programming Instruction

Best Presentation Award at CMU Student Research Symposium, 2015
Novel Aspects

- **Mixed Initiative Planning**
  - *User initiative*
  - *System initiative*

- **Multi Stream**
  - *natural language dialog between student and system*
  - *continuous stream of code written by the student*
Multi-Stream Understanding

Interactive Dialog

Virtual Agent

Task-Based Actions
nthCircularPrime:

Discussion
What else?
root 4:13:47 PM
I am writing the code to test primality

VirtualCarolyn 4:14:06 PM
Let's finish going through the plan together first, and then we'll get to writing code.

root 4:15:18 PM
It was easy to write this method

root 4:15:24 PM
I have done that before

VirtualCarolyn 4:15:48 PM
Great! You've written a method to check prime numbers. Let's move on to the next section.

From the problem definition I can see that I need to check

public class nthCircularPrime {
    public static int isPrimeInteger(int n){
        int j = 2;
        while (j <= n / 2)
            if (n % j == 0)
                return 0;
            j++;
    return 1;
}

    public static void main(String[] args) {
    }
}
Programming Buffer

Assignment Instructions

Test Cases
Dialogue Management Model

- Decides on type and timing of system’s dialog moves using both dialog and code streams

- Novelty is in using knowledge of student’s code to inform tutoring
Agent Component Network
Agent Component Network
Agent Component Network
Questions?

gtomar@cs.cmu.edu

cs.cmu.edu/~dadamson/bazaar
edX platform lacks support for pervasive chat interactions.  
Building this support in our ongoing collaboration with edX.

Opportunities for embedding Bazaar interactions

- Instantaneous reflection/discussion chat
- Breakout Groups from Discussion Forums - Unhangouts + Bazaar
- Video/Activity centric discussions

Scripted Support: From Synchronous to Ubiquitous