Language Technology II: Language-Based Interaction

Language Processing and Conversation Modeling in Educational Technologies

Ivana Kruijff-Korbayová
korbay@coli.uni-sb.de
www.coli.uni-saarland.de/courses/late2/

Outline

- Educational technology
- Intelligent tutoring systems
  - ActiveMath and DIALOG projects
  - AutoTutor
  - Mission rehearsal exercise
- Computer assisted language learning
  - From drill to skill
- Learning literacy with story telling systems

Educational technology

= technology used in learning/teaching:

- Computer-assisted learning (CAL), Computer-based training/learning (CBT/CBL) and computer aided instruction (CAI): interactive computer-based instruction (usually in specific subject area)
- E-learning: the use of Internet technologies to foster, deliver and to enable learning processes (IBL, WBL)
  - **Digital learning resources**
  - **Computer-mediated human-human interaction:** using various technologies for asynchronous or synchronous communication (email, mailing lists, discussion groups, blogs, wikis, conferencing, etc.)
  - **Human-machine interaction**, i.e., internet extension to CAL
- Computer assisted assessment (CAA): a way for students to assess their own progress and understanding (self-diagnosis / formative assessment), e.g.,
  - Quizes, possibly with feedback
  - **Essay-scoring** (cf. http://www.ets.org/research/erater.html)
- Intelligent tutoring systems: systems using the techniques of artificial intelligence to model an individual student's knowledge and to adapt the teaching process to the needs of that student; some degree of reasoning about the domain and the learner is performed

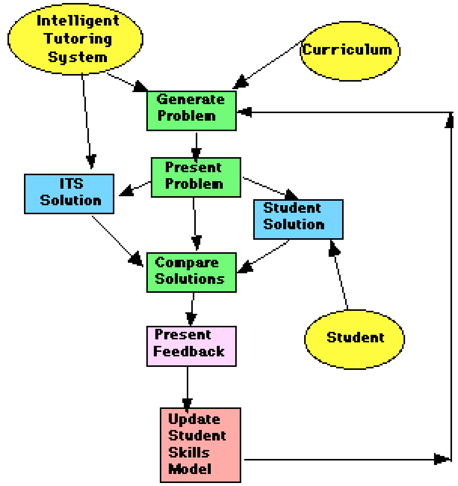
Uses of Computers in ET

- Passive medium, to provide a communication channel between learner and human tutor
- Medium for storing study material and providing it to learners for self-study
  - → CL techniques can be used for preprocessing and retrieval
- Medium supporting a human tutor
  - → CL techniques can be used for partial automation
- Automatic assessment
  - → CL techniques for student input processing and evaluation
- Intelligent tutorial systems
  - → CL techniques for student input and system output processing
    - Natural language interpretation and generation
    - Dialogue modeling

Intelligent Tutoring Systems

- Intelligent machines for teaching purposes:
  - 1926: Sidney L. Pressey built a machine with multiple choice questions and answers. This machine delivered questions and provided immediate feedback to the user.
  - Broadly defined, an intelligent tutoring system is educational software containing an artificial intelligence component. The software tracks students' work, tailoring feedback and hints along the way. By collecting information on a particular student's performance, the software can make inferences about strengths and weaknesses, and can suggest additional work. (cf. http://www.aaai.org/AITopics/html/tutor.html)
- Necessary components:
  - knowledge of the domain (topic or curriculum being taught)
  - knowledge of the learner
  - knowledge of teacher strategies

General ITS Architecture



Source: http://coe.sdsu.edu/eet/

ITS

Active learning through solving problems in a specific domain

- Domain Modeling
  - static vs. dynamic generation of solutions
- User Input
  - menu-based vs. unrestricted user input
  - meaning-insensitive vs. meaning-conscious analysis
  - combine shallow and deep processing
- System Output
  - canned text, templates or full-fledged generation
- Enhance Tutorial Strategies with Dialog Management

Active Learning

- How to best help students acquire knowledge, develop critical thinking skills, solve problems in a variety of situations and to think independently?
- Active learning techniques:
  - 490 BC, Socrates used problems and questions to guide students to analyze and think about their environments
  - **Socratic** vs. didactic teaching strategy
    - Self-analysis, self-explanation
    - Hints, "knowledge scaffolding"
    - Dialectic arguments
  - **Constructivism**: students learn by fitting new information together with what they already know ("mental construction")

⇒ the importance of flexible interaction for learning
  - the most flexible interaction is in natural language
  - the necessity of natural language dialog capabilities for the success of tutorial sessions empirically proven [Moore: cogsci 00/01?]

ITS Examples

- Ms. Lindquist (algebra)
- CATO (law case argument)
- Steve, PACO (procedural tasks in simulated environments)
- BEETLE (basic electric circuitry)
- CIRCSIM Tutor (blood pressure control)
- AutoTutor (computer literacy, physics)
- PACT geometry tutor
- Atlas-Andes, Why-Atlas, ITSPOKE (physics)
- DIALOG, LeActiveMath (mathematical proofs)
- Mission rehearsal Exercise

Mission Rehearsal Exercise

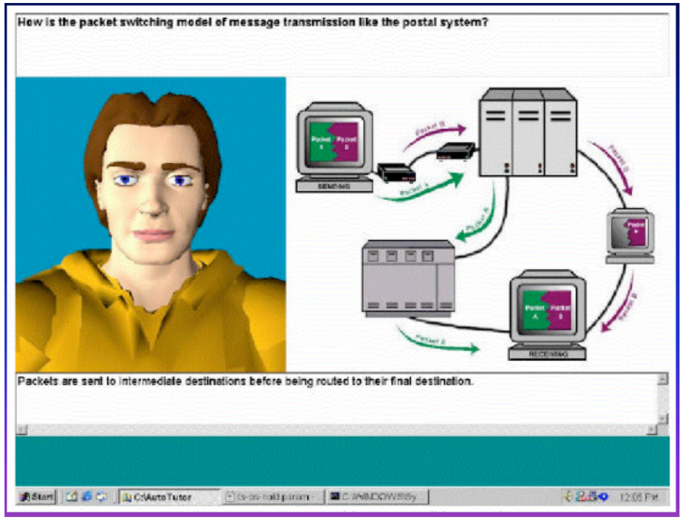
- Virtual reality training environment that brings together research in intelligent tutoring, natural language recognition and generation, interactive narrative, emotional modeling, and immersive graphics and audio.
- Focus on creating highly realistic and compelling face-to-face social interactions with virtual characters.
- The technology has been applied to a prototype training environment, focusing on the domain of decision-making training for military peacekeeping operations.
- http://www.ict.usc.edu/disp.php?bd=proj_mre

AutoTutor ITS

AutoTutor

- Web-based intelligent tutoring system developed by an interdisciplinary research team at the University of Memphis
- Based on extensive analyses of human-to-human tutoring, pedagogical strategies, and conversational discourse
- Simulates unskilled human tutors (peers)
- Aims to help the students learn by engaging them in a natural language conversation about a particular subject matter
  - basic computer literacy topics covered in an introductory course (e.g., hardware, operating systems, and the Internet)
  - Newtonian physics
- http://www.autotutor.org/

AutoTutor



AutoTutor: Example

AutoTutor:	When you turn on the computer, how is the operating system first activated and loaded into RAM?
Student:	When the computer is turned on a file is automatically booted up.
AutoTutor:	Anything else?
Student:	This file contains the operating system.
AutoTutor:	What else?
Student:	The operating system is then read into RAM and activated.
AutoTutor:	Right. The CPU exectues instructions in ROM, which helps the operating system to start.
Student:	After being read from ROM the OS is activated.
AutoTutor:	Right. Let's review what we've just gone over. The operating system [...]

AutoTutor: 5-Step Dialogue Frame

5 Step Dialog Frame

Step 1: Tutor asks question (or presents problem)
Step 2: Learner answers question
Step 3: Tutor gives short immediate feedback
Step 4: Tutor and Learner collaboratively improve the answer
Step 5: Tutor assesses learner's understanding

Learning Effect

AutoTutor: Curriculum Scripts

Loosely structured lesson plans (organise topics & content)

3 Macrotopics
- hardware
- operating systems
- internet

12 Topics each

Topic:
- basic concepts
- focal question
- ideal answers, answer aspects
- hints, prompts
- anticipated bad answers
- corrections for bad answers
- a summary

AutoTutor: Curriculum Script

- Answer aspects:

Tutor: Why do computers need operating systems?

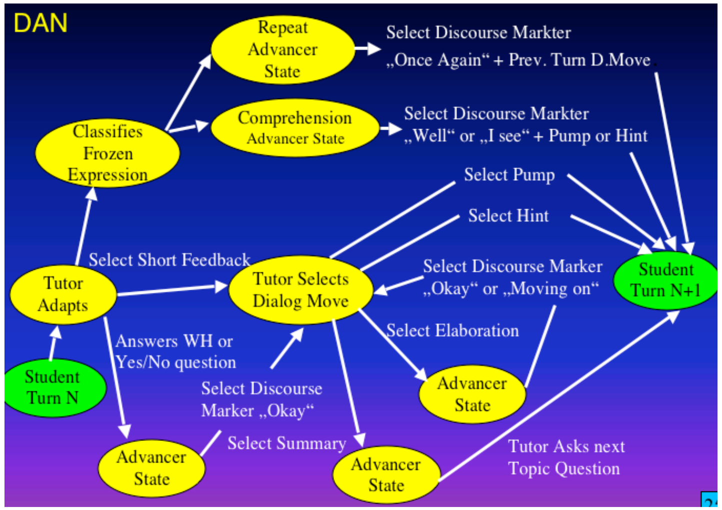
Good-Answer-1: The operating system helps load application programs.
Good-Answer-2: The operating system coordinates communications between the software and the peripherals.
Good-Answer-3: The operating system allows communication between the user and the hardware.
Good-Answer-4: The operating system helps the computer hardware run efficiently.

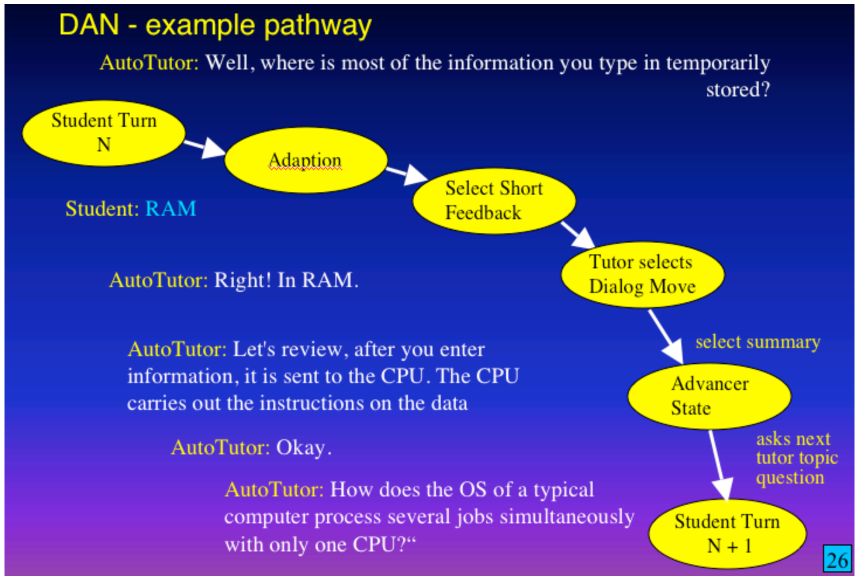
AutoTutor: Dialogue Move Categories

- Sensitive to quality and quantity of the student's contribution

1. Positive Immediate Feedback - „That's right" „Yeah"
2. Neutral Immediate Feedback - „Okay" „Uh-huh"
3. Negative Immediate Feedback - „Not quite" „No"
4. Prompting for more information - „Uh-huh" „What else"
5. Prompting (for specific information) - „If you add RAM, the CPU can store more data and larger ______?"
6. Hinting - „What about the size of programs you need to run?"
7. Elaboration - „With additional RAM, you can handle larger programs"
8. Splicing in/correcting content after a student error - „Storing the program on a floppy disk will not help you to run the program."
9. Summarizing - „So to recap,..."

AutoTutor: Dialogue Model





Dialog Move Selection

via 15 Production Rules

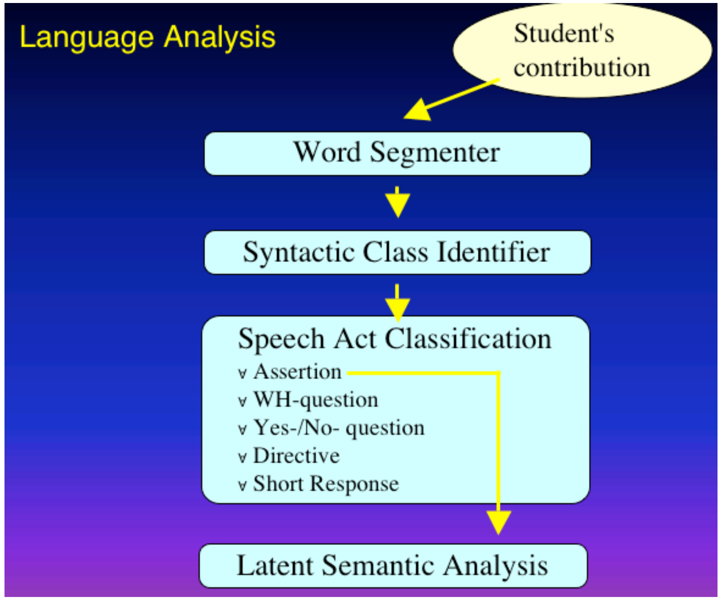
sensitive to

- assertion quality of preceding turn
- dialog history (global variables: ability, verbosity, initiative of learner)
- extent of coverage of GAA's

Examples:

IF [student Assertion match with GAA = HIGH or VERY HIGH]
THEN [select POSITIVE FEEDBACK]

IF[student ability = MEDIUM or HIGH
& Assertion match with good answer aspect = LOW
THEN [select HINT]



AutoTutor: Latent Semantic Analysis

- Computes relatedness score between two bags of words
  - Assertions and content of curriculum script
- LSA space: 30 articles about hardware, operating systems and Internet and curriculum script
- 2.3 MB corpus, 200 dimensions
- Statistical, no deep understanding
- Evaluation of students' answer assessment: reasonable correlation between system and human:
  - LSA/experts: .49
  - LSA/intermediate: .51
  - LSA/accomplished: .78

Problems: multiple answering

Tutor: How does CPU speed affect program speed?
Student: a program's commands are executed faster
Tutor: That is right!
Tutor: See if you know the answer to this.
Tutor: A fast CPU will make your programs run?
Student: faster!
Tutor: OK
Tutor: run faster.
Tutor: Let's see...
Tutor: How can a faster CPU help you in the future?
Student: the programs run faster
Tutor: Perfect answer!

Problems: confusion with "how"

Tutor: When users buy a computer, they definitely will consider how fast
Student: how fast it is
Tutor: Wait a minute, answer my question and then we'll do yours.
Tutor: Let me repeat.
Tutor: When users buy a computer, they definitely will consider how fast
Student: they will consider how fast the cpu ist
Tutor: Wait a minute, answer my question and then we'll do yours.
Tutor: Let me repeat.
...
Tutor: Okay,
Tutor: When users buy a computer, they definitely will consider how fast
Student: the cpu is
Tutor: Alright
Tutor: how fast the CPU is.

Problems: use of "not"

Tutor: How can you transfer regular photos onto a computer disk?
Student: it is not possible to transfer regular photos onto a computer disk with a scanner
Tutor: Um, yes, that is right!
...
Tutor: You need a modem to connect to the Internet if you have a dial up connection.
Tutor: How is the Internet accessed when users do not have a direct connection?
Student: it is not accessed by a modem
Tutor: Yeah, that's right!

Evaluation with Virtual Students

- Creation of virtual students
- Tutoring sessions with virtual students
- Evaluation by experts in language and pedagogy
  (ratings between 1 [very poor] and 6 [very good])
- Revision and adjustment of AutoTutor

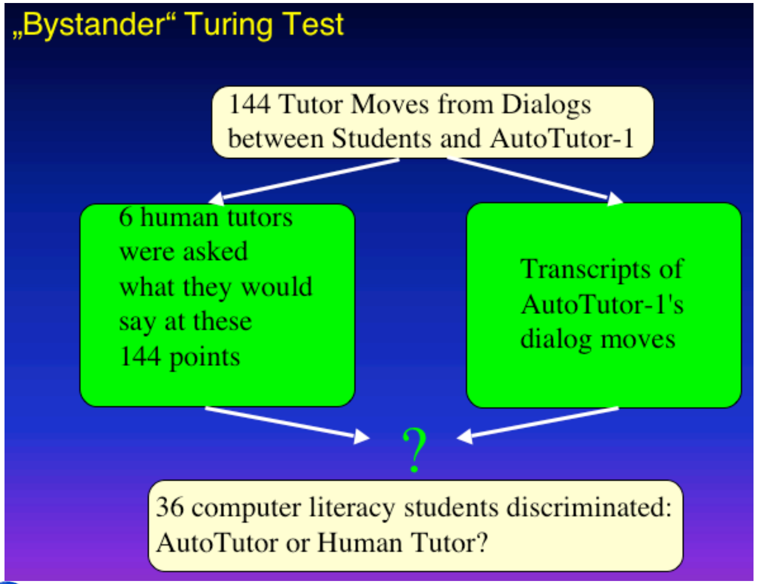
Evaluation criteria:
- discrimination of learner ability
- choice of appropriate dialog moves

2 judges → **Pedagogical effectiveness**
- pedagogical aspects
- dialog reasonable for normal human tutor?

2 judges → **Conversational appropriateness**
- politeness norms
- quality, quantity, relevance, manner (Gricean maxims)

Effect of AutoTutor on Learning Gains

- Assessment of learning gains - 3 conditions
  - AutoTutor
  - Reread
  - Control
- Significant differences in the students' scores among the 3 conditions, with means
  - AutoTutor 0.43
  - Reread 0.38
  - Control 0.36
- Gains in learning and memory
  - size increment of .5 to .6 SD units over control condition.



AutoTutor: Conclusions

- Strength:
  - Not purely domain specific
  - Easy creation of curriculum script (no programming skills needed)
  - Robust behavior
  - Sufficiently engaging for humans to complete sessions
  - Learning effects comparable to human peer-tutors
- Weaknesses:
  - Only shallow interpretation
  - Performance largely dependent on curriculum script
  - Emotional aspects:
    - Trouble understanding synthesized speech
    - Inappropriate speech acts sometimes irritate students

Input Understanding in DIALOG

DIALOG Project

- At UdS: Coli and Informatics
- Tutorial dialogue with a mathematical assistant system
- Dialogue data collected in WOZ experiments
- Domain modeling: naïve set theory, relations
- Backend theorem proving: Omega
- Dynamic proof management (no static solutions)
- Automatic construction of hints
- Deep natural analysis of user input

DIALOG Example

Tutor: Bitte zeigen Sie: Wenn $A \subseteq K(B)$, dann $B \subseteq K(A)$!
[Please show the following: If $A \subseteq K(B)$, then $B \subseteq K(A)$!]

Student: $A \subseteq B$ — *wrong*

Tutor: Das ist nicht richtig! Sie müssen als erstes die wenn-dann-Beziehung betrachten.
[That is not correct! First you have to consider the if-then-relation.] — *give-away-relevant-concept*

Student: $A \subseteq K(K(A))$ — *wrong*

Tutor: Das ist zwar richtig, aber im Augenblick uninteressant. Wissen Sie, wie sie die wenn-dann-Beziehung behandeln müssen?
[That may be correct, but at the moment not interesting. Do you know how to deal with the if-then-relation?] — *elaborate-domain-object*

DIALOG: Input Interpretation Tasks

- formula parsing and type checking
  - $A \cap B \in P(A \cap B) \in P(A \cap B) \cup P(C)$
- parsing and interpreting interleaved NL and ML
  - *A muss in B sein*
  - *B enthaelt kein x $\in A$*
- recognizing patterns expressing proof steps
  - *[wenn $A \subseteq K(B)$,] [dann $A \neq B$,] [weil $B \neq K(B)$]*
  - *[falls $A \subseteq B$ und $A \subseteq C$] [dann gilt $A \subseteq B \cap C$]*

DIALOG: Input Interpretation Tasks

- reference resolution
  - co-reference
    Da, wenn $A \subseteq K(B)$ sein soll, A Element von $K(B)$ sein muss. Und wenn $B \subseteq K(A)$ sein soll, muss es auch Element von $K(A)$ sein.
  - discourse deixis:
    den oberen Ausdruck,
    aus der regel in der zweiten zeile
  - metonymy: *Dies fuer die innere Klammer.*

DIALOG: Input Interpretation Tasks

- resolving imprecise or informal naming of domain concepts and relations:
  A enthaelt B,
  . . . dann sind A und B (vollkommen) verschieden, haben keine gemeinsamen Elemente
- interpreting informal descriptions of proof-step actions
  aufloesen, herausbekommen, ausrechnen, zerlegen, umstellen
- interpreting ill-formed input

DIALOG: Input Interpretation

- Preprocessing
- Math-expression identification and parsing
- Parsing using a NL grammar --> semantic representation
- Domain-specific interpretation in several steps
  - FrameNet concepts
  - Math ontology concepts
- Discourse interpretation, e.g., anaphora resolution
- Conversion into input for a domain reasoner (Omega)

Computer Assisted Language Learning

Computer Assisted Language Learning

- 40 years of development
  - Behavioristic CALL (50's-70's): repetitive language drills ("drill and practice"); computer mediates exposure to material
  - Communicative CALL (70's-80's): skill instead of drill (use of forms rather than forms themselves)
    - Computer as tutor (knows right answer)
    - Computer as stimulus (stimulate discussion, writing, critical thinking)
    - Computer as tool (word processing, spell- and grammar checking, etc.)
  - Integrative CALL using multimedia and internet
  - Intelligent CALL
    - Spoken input understanding and evaluation
    - Student's problem diagnosis and decision among a range of options

  (cf. http://www.gse.uci.edu/markw/call.html --1996)

  (cf. http://www.nestafuturelab.org/viewpoint/learn23.htm --2003)

- Typically, CALL refers to foreign language learning, however, some techniques also suitable for improving own language skills

(Potential of) NLP Techniques in CALL

- Speech recognition for pronunciation training
  - Comparison to model pronunciation & correction
  - Problem: high WER due to non-native and incorrect pronunciation
- Speech synthesis for example production
  - Unit-selection based: high quality, but high development cost
  - Fully synthetic speech: flexible, but low(er) quality
- Spelling checking
  - Non-word recognition using lexica and morphological analyzers
  - Wrong word recognition using heuristics or n-grams

  (a recent study has shown that error correction is more difficult in learner texts, possibly due to error accumulation)
- Grammar checking
  - Constraint relaxation and error anticipation: identify error source
- Text coherence assessment
- Dialogue: explanatory and/or learning through interaction

NLP Techniques in CALL: Examples

- Commercial systems for language learning
  - Signal processing and ASR for pronunciation training is common
  - Otherwise, multiple choice and gap-filling exercises with no NLP
  - Prerecorded spoken output
- Automated essay assessment: E-rater and Criterion (ETS)
  - Argumentative text structure analysis (intro, thesis, ideas, concl…)
  - Rhetorical structure analysis (e.g., justify, elaborate, exemplify…)
  - Centering-based analysis of reference-coherence
- Some research systems
  - Foreign language skills:
    - German Tutor and Geroline (Heift and Schulze 2003)
    - ALLES: learner input analysis at several levels (spelling, grammar, semantics)
    - DiBEx: grammar phenomena exercises with explanatory dialogue
  - LISTEN: reading tutor that listens and helps to improve reading skills (Jack Mostow etal. www.cs.cmu.edu/~listen)
  - Story listening systems (Justine Cassell et al. www.articulab.northwestern.edu)
  - Mission-Oriented Communicative Skills (ISI)

Mission-Oriented Communicative Skills

- Tools to support individualized language learning, and apply them to the acquisition of tactical languages
- Subsets of linguistic, gestural, and cultural knowledge and skills necessary to accomplish specific missions.
- To maximize learner motivation and give learners effective practice opportunities, learners practice on vocabulary items and learn gestures, and then apply them in simulated missions.
- In the simulation, learners interact with avatars and virtual characters.
- The training system enables learners to communicate directly with on-screen characters using a speech recognition interface.
- Objective is to make the toolset easily applicable to new tactical languages, missions, and training contexts.
- http://www.isi.edu/isd/carte/proj_tactlang/index.html

Learning Literacy

Story Listening Systems

- Help children to develop literacy
  - Oral and written language development are interleaved
  - Certain aspects of literacy learning take place first in informal settings
- Literacy learning with peers
  - Fantasy play with peers demonstrates more decontextualized language than with adults
  - Peers push each other to clarify
  - Peers provide eye contact, facial expression and other feedback
  - Peers model, invite, assist, direct, tutor, negotiate, affirm and contradict each other
- http://litd.psch.uic.edu/research/projects/sls/Questions_about_Sam.asp (cf. Justine Cassell and colleagues)

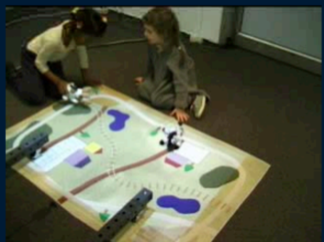
Story Listening Systems

Model of *Story Listening Systems*

1. Depend on children's oral narrative skills to bootstrap literacy
2. Introduce peers as playmates **in** the technology or with the technology
3. Encourage children to construct their own personally meaningful stories.
4. Invite the kind of embodied play away from the desktop that is most comfortable for young children
5. Use embodiment to evoke social resonance – a bond of familiarity and solidarity that supports learning.

Justine Cassell ArticuLab

StoryMat



- Under-determined
- Reflective
- Listening

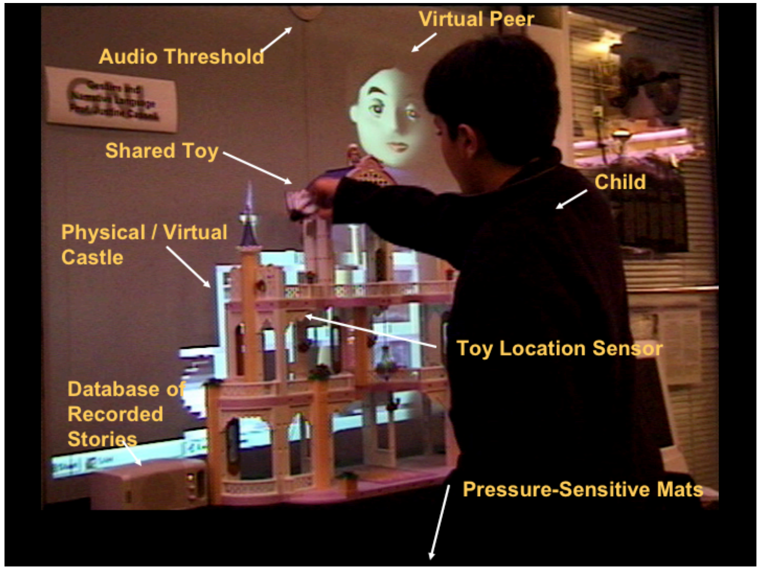
Cassell, J. and K. Ryokai (2001). "Making Space for Voice: Technologies to Support Children's Fantasy and Storytelling." Personal Technologies **5**(3): 203-224.

Justine Cassell ArticuLab

Sam, the Virtual Peer

Cassell, J., Ananny, M., et al. (2000) "Shared Reality: Physical Collaboration with a Virtual Peer." *Proceedings of CHI '00.*

Justine Cassell ArticuLab



Turn-taking with Sam

- Step 1: Sam tells a story
  Child gazes at Sam for 1st few seconds of Sam telling story (p<.01)
- S Step 2: Sam gives her turn
  Child gazes at Sam while Sam gives up turn (p<.01)
- Step 3: Child's turn
  While storytelling, child gazes at her task (p<.01)
- Step 4: Child gives her turn to Sam
  The child gazes at Sam when offering the turn (p<.01)
- Step 5: Child gives her turn to the human partner
  No evidence for gaze at human partner (not significant)
- Step 6: Human partner accepts or declines the turn
  No evidence for gaze at human partner (not significant)

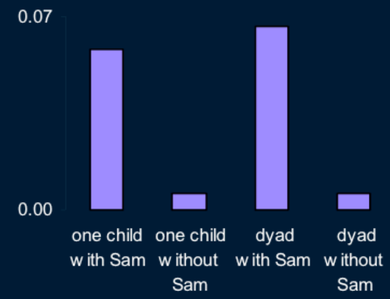
Two-Independent-Samples Test for each turn taking step to see where the children were looking

Justine Cassell ArticuLab

Justine Cassell ArticuLab

Results: Sam as a learning partner

- Increased use of *quoted speech*, and *temporal* and *spatial* information



$F(3, 24)=68.04$, $p<.01$

Justine Cassell ArticuLab

Conclusions

- Computer-assisted learning in various domains, including language, is wide-spread
- But, there is very little NLP in deployed systems
- Active learning requires natural language dialogue
- Research ITS:
  - using natural language processing and dialogue modeling
  - Various subject areas
  - But not much exists in CALL
- A lot can be achieved with simplified means, depending on domain
- Important:
  - Learner-oriented design
  - Realistic task design
  - Learning through interaction, active learning

References

- Hoffman, B. (ed.) (1994-2004) Encyclopedia of Educational Technology. San Diego State University. http://coe.sdsu.edu/eet/
- Nerbonne, J. (2003). Computer-Assisted Language Learning and Natural Language Processing. In R. Mitkov (Ed.), Handbook of Computational Linguistics (pp. 670-698): Oxford University Press.

References

- Graesser, A., Wiemer-Hastings, K., Wiemer-Hastings, P., Kreuz, R., &the Tutoring Research Group (1999). AutoTutor: A simulation of a human tutor. Journal of Cognitive Systems Research, 1,35-51. http://www.autotutor.org/publications/pubs.htm
- Wolska, M. and Kruijff-Korbayová, I. (2004) Analysis of mixed natural and symbolic language input in mathematical dialogs. In In Proceedings of the 42nd Meeting of the 42nd Annual Meeting of the Association for Computational Linguistics , Barcelona, Spain. http://www.ags.uni-sb.de/~chris/dialog/dialog-publications.html
- Gratch, J., Rickel, J., André, E., Badler, N., Cassell, J., Petajan, E. Creating Interactive Virtual Humans: Some Assembly Required. IEEE Intelligent Systems July/August 2002, 54-63. http://www.ict.usc.edu/disp.php?bd=proj_mre_pub
- Traum, D.R., Rickel, J. Embodied Agents for Multi-party Dialogue in Immersive Virtual World. International Joint Conference on Autonomous Agents and Multi-agent Systems (AAMAS 2002) (July 2002), 766-773.

References

- Schulze, M. and Heift, T. (2003) Student Modeling and ab initio Language Learning. In: System Volume 31, Issue 4, 2003, pp 433-588. http://germanicandslavic.uwaterloo.ca/~mschulze/publications.html
- Klenner, Manfred; Visser, Henriette: What exactly is wrong and why? Tutorial Dialogue for Intelligent CALL Systems. Linguistik Online 17, Mai 2003, http://www.linguistik-online.de/17_03/klennerVisser.html
- Schmidt, P.; Garnier, S.; Badia, T. et al: ALLES - Controlled language tools and information extraction tools for CALL applications. Proceedings of In-STIL/ICALL 2004, Juni 2005, http://sisley.cgm.unive.it/ICALL2004/papers/008Schmidt.pdf
- Burstein, J.; Chodorow, M.; Leacock, C.: Criterion - Online essay evaluation - An application for automated evaluation of student essays. Proceedings of the 15th Annual Conference on Innovative Applications of Artificial Intelligence, Acapulco, Mexico. August 2003, http://www.ets.org/Media/Research/pdf/erater_iaai03_burstein.pdf
- Ryokai, K., Vaucelle, C., Cassell, J. (2003) "Virtual Peers as Partners in Storytelling and Literacy Learning" Journal of Computer Assisted Learning 19(2): 195-208. http://www.soc.northwestern.edu/justine/jc_papers.htm