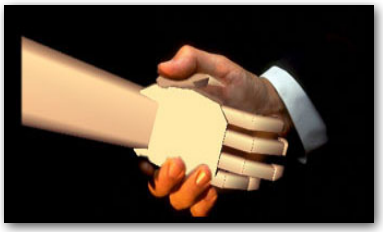
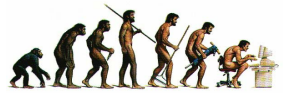
# Human-Computer Interaction

**Session 13**
Agent-based interaction





## Evolution of user interfaces



| Year | Paradigm | Implementation |
|---|---|---|
| 1950s | None | Switches, punched cards |
| 1970s | Typewriter | Command-line interface |
| 1980s | Desktop | Graphical UI (GUI), direct manipulation |
| 1980s+ | Spoken Natural Language | Speech recognition/synthesis, Natural language processing, dialogue systems |
| 1990s+ | Natural interaction | Perceptual, multimodal, interactive, **conversational**, tangible, adaptive |
| 2000s+ | Social interaction | **Agent-based**, anthropomorphic,social, emotional, affective, **collaborative** |



## Interaction paradigms

- tools ➜ operate
- smart tools ➜ instruct
- assistants ➜ converse
- companions ➜ collaborate



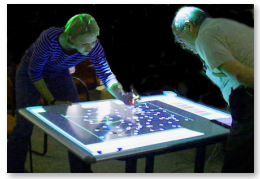
## More than „division of labor"

involves users actively in problem-solving

- leverage their skills
- steer solving process based on preferences or experiences
- increase user's trust, understanding, justifiability of solution

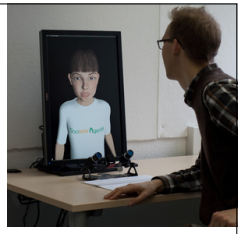
**Example**: Human-guided Search
(Klau et al. 2002)

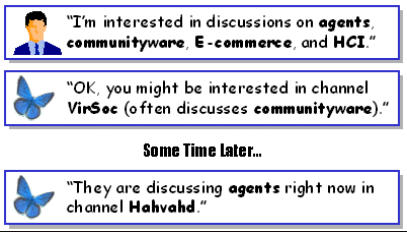
- user can monitor, modify, or track back solutions
- user can apply, halt, or modify algorithms
- user can constrain and focus search
- improved performance, up to the best heuristic algorithms around

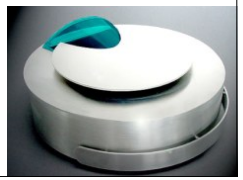


# Terminology

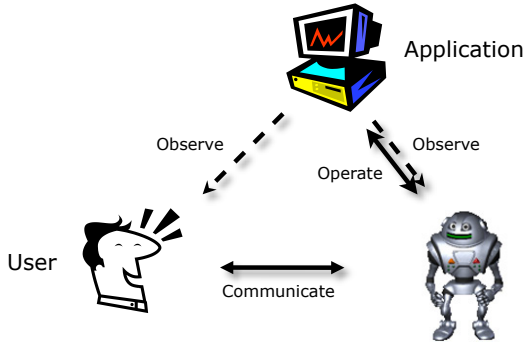
- Agent
  - a computer system that observes and initiates actions in its environment
  - able to communicate with other agents
  - has a specific expertise and carries out specific tasks
  - different degrees of autonomy





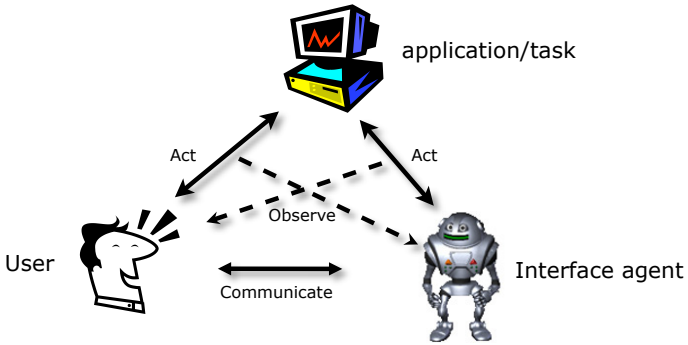
# Interface agents




- Agent mediates between user and application
  - accepts the operating of the system for the user
  - communicates with, supports the user



# Collaborative (interface) agents




- User and agent cooperate on a shared task
  - can both take actions
  - observe each other's actions
  - communicate abouth their task and the collaboration



# Pro & contra of agent-based interfaces?


(U. Maryland)

vs.


(MIT Media Lab)

Ben Shneiderman and Pattie Maes debated these issues and more on panels at the IUI 97 and CHI 97 conferences

BEN SHNEIDERMAN

*„Users should **comprehend** the display, feel in **control**, be able to **predict** the system, take **responsibility** for their actions"*

*„**Responsibility** will be the central issue in this debate."*

*„**Direct manipulation**: rapid, reversible, incremental, point & click, immediate feedback, reduces error, encourages exploration"*

*„Future is moving in the direction of information **visualization**"*

*„**Overview** is most important, giving users a sense of context."*

*„Anthropomorphic or social interface is **not** to be the future of computing."*



PATTIE MAES

*„Agents are **personalized**, **proactive**, **long-lived**, **adaptive** to user, acts on user's behalf based on knowledge of user preferences"*

*„Necessary because environment becomes complex, users become naive, number of tasks and issues increase"*

*„Agents are **no alternatives to direct manipulation**, nor are they necessarily personified or deal with NL interaction. You still need a well-designed interface when incorporating agents in an application. However, some task I may just not do myself."*

*„Using an agent **doesn't imply giving up all control**, just over the details and that saves me a lot of time."*

*„The true **challenge** lies in **designing the right user-agent interface.**"*



BEN SHNEIDERMAN

*„Speech is important for niches but will **not** be a generally usable tool, and it **degrades** your problem solving performance."*

*„Anthropomorphic representation **misleads** designer, **deceives** users, increases **anxiety** about computer usage, **interferes** with predictability, **reduces** user control, **undermines** users' responsibility."*

*„Users want to have the feeling that **they** did the job-not some magical agent."*

*„**human-to-human interaction is not a good model** for the design of user interfaces."*

*„Get past the argumentation about a system being more friendly or more natural or intuitive, focus on real user performance and real tasks. Do your **scientific evaluation**."*



PATTIE MAES

*„A good user-agent interface takes care of two issues: **understanding** (of the agent) and user's felt control over tasks but its **possible delegation** to the agent."*

*„Most successful interfaces are the ones where the agents are pretty much **invisible**."*

*„Ben focuses on professional users and well-structured task domains and well-organized information domains. We are dealing with **untrained** end users and **ill-structured** and **dynamic** information domain."*

*„Users **do not** always want to have **all of control**."*

# Agent-based interfaces -- reality & future

# How can robots become collaborative partners?

(Breazeal et al. 2004)

**Problem**: today's robots don't interact with people as people

- not aware of other's goals and intentions
- don't adjust their behavior to help us
- no joint attention, no spatial or mental perspective-taking
- don't know what's hard to access or important for the human
- don't communicate to establish shared beliefs, coordinate, and demonstrate commitment
- don't live up to the social models that humans use to understand and predict their behavior



# Prerequisite: Collaboration


*„Must design collaboration into systems from the start."*

Features of a multi-agent collaboration

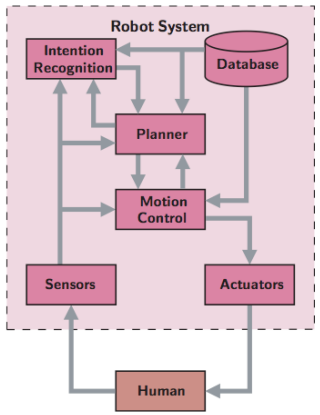
- No master-slave relationship, but equality of partnership
- Agents have different beliefs, knowledge, and capabilities and are aware of this
- Agents share a goal and are committed to this goal
- Collaborate during both planning and executing action
- Comunicate with each to coordinate their collaboration

*Coordinating actions means coordinating minds*

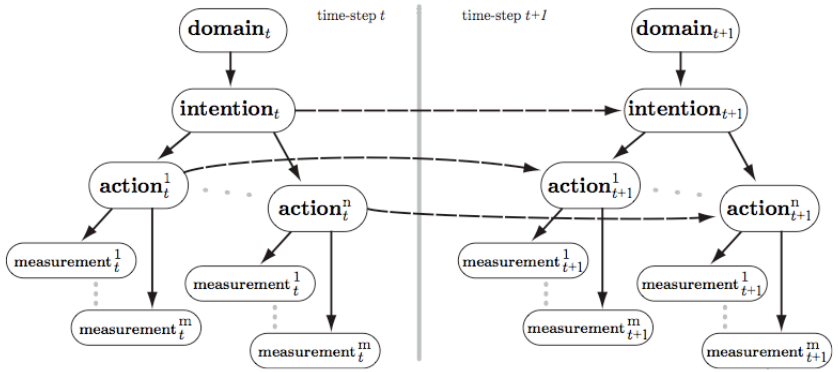

# Usually tackled inferentially

- Intention recognition
  - read (non-)verbal cues
  - probabilistic forward model
- Proactive planning & execution
  - actions that support the infered intentions
  - actions that urge the user to unravel her intentions, i.e. decrease robot's uncertainty
- Database
  - model of the environment & actions
  - FSMs for certain forms of interaction

*„Proactive cooperation"*




(Schrempf et al. 2005, Univ. Karlsruhe)




(Schrempf et al. 2005, Univ. Karlsruhe)



# SharedPlans formalism

(Grosz & Sidner 1990; Grosz & Kraus 1996, 1999)

- Formalizes how agents move from individual goals and intentions into collaborative, coordinated activity based on representations of the minds of the other agents:
  - what is mutually believed and intended?
  - what commitments have been taken by whom?
- Predominant model in multi-agent collaboration in A.I. and collaborative interfaces in HCI



# Collaborative discourse theory

(Grosz, Sidner, Kraus, Lochbaum 1974-1998)

replace pump and belt:

**E:** Replace the pump and belt.

replace belt:

**A:** Ok, I found a belt in the back.

**A:** Is that where it should be?

**A:** [removes belt]

**A:** It's done.

**E:** Now remove the pump.

...

replace pump:

**E:** First the flywheel.

...

**E:** Now take the pump off the plate.

**A:** Already did.



# Collaborative discourse theory

(Grosz, Sidner, Kraus, Lochbaum 1974-1998)

## intentional structure

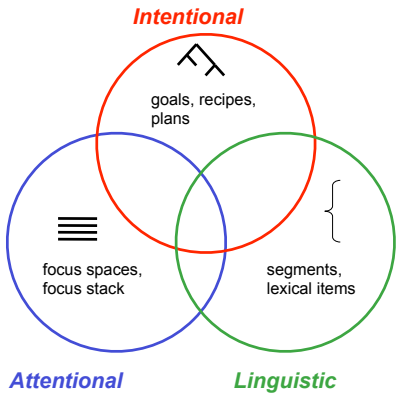
- hierarchy of individual or shared goals and sub-goals (partial SharedPlan)

## linguistic structure

- hierarchy of segments, each serving a purpose in the intentional structure

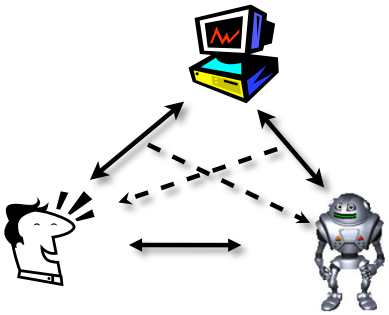
## attentional structure

- context represented as focus stack of discourse segments



# Example: COLLAGEN

Charles Rich
Candace Sidner
Neal Lesh

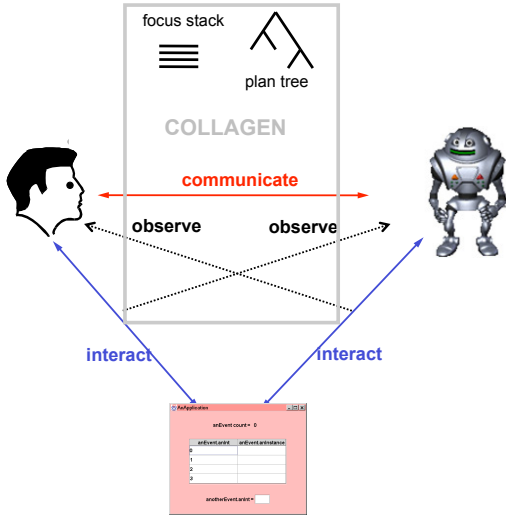


Mixed-initiative problem solving assistant

- employ SharedPlan formalism to manage what's called collaborative discourse
- task-oriented spoken language dialogue



# Collagen






# Embodied conversational agents

- have human-like body and employ it for action and communication purposes
- recognize and interpret verbal and nonverbal input behavior
- generate expressive output behavior
- process the multiple functions of conversational behavior
- can take active role in dialogue

*„Computer interfaces that hold up their end of conversational, have bodies and know how to use it for conversational behaviors as a function of the demands of dialogue and of emotion, personality, and social convention"*

(Justine Cassell 2000)

# ECAs - motives

Interaction should be intuitive and foster cooperation

- familiar communication and interaction strategies

Tasks appear less complex when in a team

- expertise and proactivity of the agent supports the user (e.g., expert critics, subtask completion, coordination)

Metaphor of a mediator becomes tangible

- „somebody" is there, with me, and helps me out (a persona)

Motivational and social factors

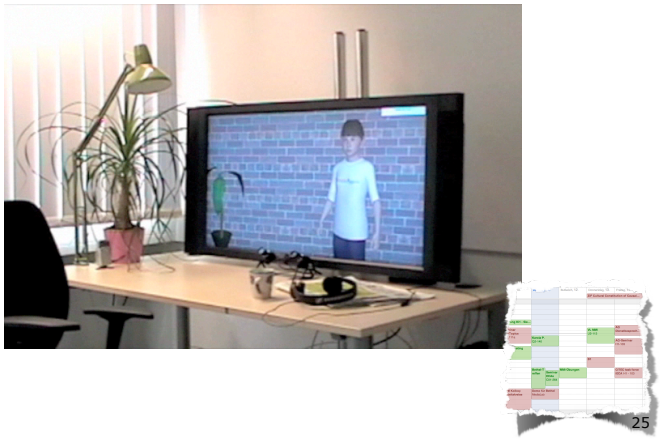
- interacting with „somebody" is more entertaining and motivating, entails socio-affective effects

Basic research perspective

- a tool for investigating human conversation and social cognition, both still being not fully understood

# Example

BILLIE (Uni Bielefeld)





# ECAs - problems & challenges

Theory
- No adequate model of cf and cb's and their contextual factors, many small fragments for isolated aspects

Complexity
- Handling content and interaction regulation at the same time requires rich, dynamic knowledge about the user and discourse

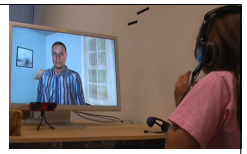
Concurreny & timing
- Input understanding, response/dialogue planning, and output generation must run fast, parallel

Interactivity
- Interlocutors interact and coordinate on different time scales in parallel, no message „ping-pong"

Input & output limitations
- Shortcomings of sensor & recognition technology and behavior generation methods



# Effects



Interaction tends to be more entertaining (Takeuchi & Naito, 1995; Koda & Maes, 1996; van Mulken et al., 1998, Krämer et al., 2002)

Acceptance is higher (Hubona & Blanton, 1996; Ahern, 1993)

Increased intelligence, trustworthiness, believability (Sproull et al. 1996; Walker, Sproull & Subramani, 1994; Rickenberg & Reeves, 2000)

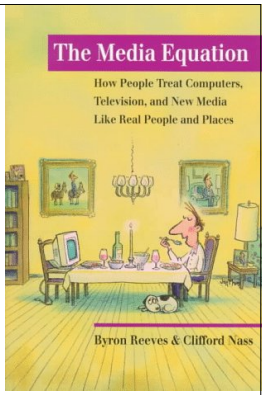
User are more inclined to delegate tasks to the system (Milewski & Lewis, 1997)

Natural language interaction is fostered, reciprocal communication strategies evoked (Krämer, 2005)



# Social effects

Some(!) researchers believe that computers are liked better when they
- praise the user or other computers
- match the user's personality
- become like the user over time
- they are „teamed" with the user
- use humor
- conduct reciprocal self-disclosure




*(Reves & Nass 1996, Moon 1998, Morkes et al. 1998)*

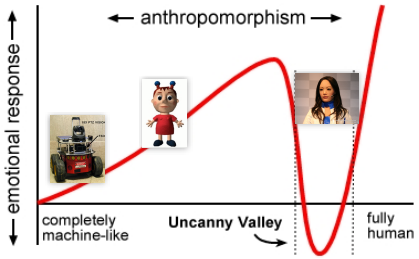
**Anthropomorphization**:
Humans tend to treat machines as social beings, appraise their behavior as if human

Increased with embodied agents (robots, virtual characters)!

# Effects

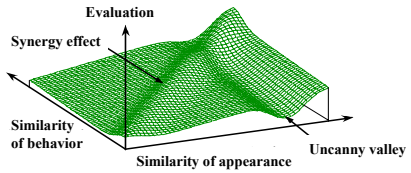
Human-like appearance

- impact on social evaluation
- similarity with self
- realism raises high expectations about behavior




Speculative!

Hypothetical „uncanny valley" (Mori 1970; Ishiguro (2005)






# Embodied agents are social actors

Draw attention to face, where most socio-communicative cues are delivered *(Dehn & van Mulken, 2000)*

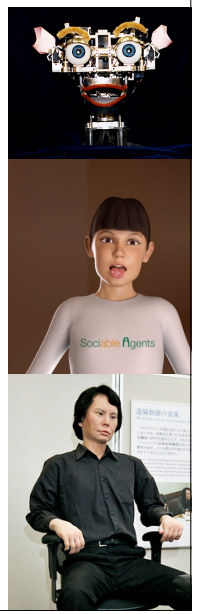
Interactions tend to be more entertaining *(Koda & Maes, 1996; van Mulken et al., 1998, Krämer et al., 2002)*

Social dialogue *(Bickmore 2003; Kopp et al., 2005)*

Impression management and social facilitation/inhibition *(Sproul et al. 1996; Rickenberg & Reeves 2000)*

Facial mimicry *(Bailenson & Yee 2005; Sommer, Krämer & Kopp, 2008, Krämer et al. in prep.)*

Motor resonances *(Chaminade et al.)*



# Social machines?

(C. Breazeal, MIT)

Interactive Toys

**"Social as entertainment"**

*„Future applications require robots to address*

Professional Service Robots

**"Social as interface"**

*the socio-emotive and psychological aspects of people, in long-term relations"*

**"Social as relationship"**

BANDAI "elder toys"

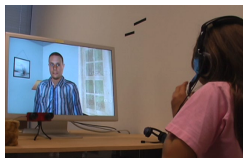
NEC "babysitters"

OMRON "pets"

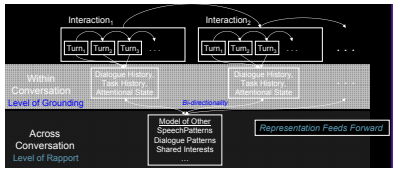
# Social machines?

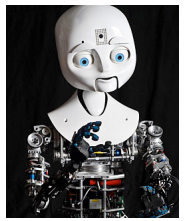
- **Socially evocative** - capitalize on feelings evoked when humans nurture, care, or are involved with their "creation"
- **Socially situated** - perceive and react to a social environment, distinguish between other social agents and objects
- **Social interface** - employ human-like social cues and modalities.
- **Socially receptive** - passive but benefit from social interaction, e.g. through learning by imitation
- **Socially embedded** - socially interact with other agents and humans; aware of human interactional structures
- **Socially intelligent/sociable** - aspects of human style social intelligence, pro-actively engage with humans in order to satisfy internal aims based on deep models of human social competence

# An emerging trend



- Relational Agents *(Bickmore 2003)*
  - increase trust by building solidarity, familiarity, affect through small talk
- Virtual rapport with silent listener *(Gratch et al. 2006, 2007)*
- Long-term rapport *(Cassell & Tepper 2007)*
- Social robots *(Dautenhahn 1995, 2000; Breazeal 2002, 2003)*
- Social resonance & alignment *(Kopp 2010)*



# Relational agents

## Cooperation and **relationship**

- Cooperative, goal-directed activity is supported by positive relationships among the cooperation partners, e.g., fosters trust (Deutsch, 1973; Marsh, 1994)
- Creating and maintaining a relationship requires successful collaborations

## Relational agents (Bickmore 2003)

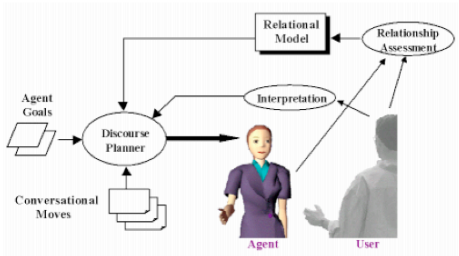
- Computational artifacts designed to build and maintain long-term, social-emotional relationships with their users

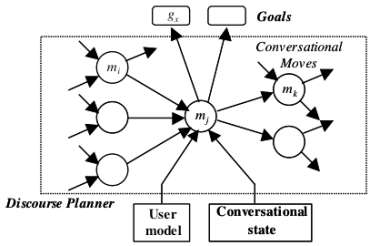
Timothy Bickmore
Northeastern Univ.



# The first relational agent

Embodied conversational agent augmented with a discourse planner that dynamically interleaves task moves and relational moves to satisfy task goals given a set of relational constraints.



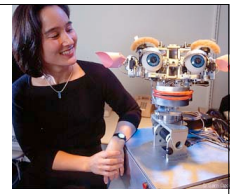




Bickmore & Cassell (CHI 2001)



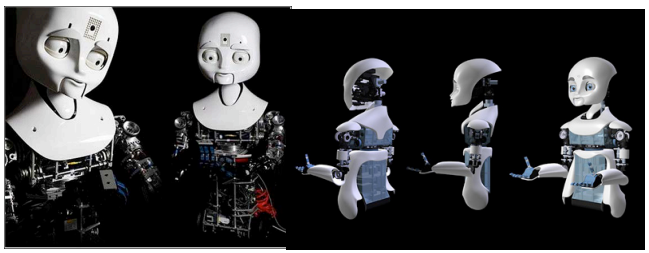
# Social robots

*Leonardo*



Cynthia Breazeal
Robotic Life Group
MIT Media Lab

*Nexi / DMS*



# Example: Leonardo

Goal: a robot that can act as a cooperative partner

- maintaining mutual understanding of other's internal states
- performing learned tasks collaboratively with a human partner
- social learning of new tasks
- utilizing social cues to demonstrate commitment, manage collaboration, support learning and teaching




# Recap

- Models of cooperation
  - shared beliefs, intentions, attention
  - commitment, coordination
  - mutual support & responsiveness
- Models of communication **in** cooperation
  - collaborative discourse theory, SharedPlans formalism
  - communication tied to intentional structure of collab.
- Models of communication **as** cooperation
  - agent-based dialogue models
  - agents with beliefs, desires, intentions, obligations



# Problems & future challenges

Models of communication as cooperation are based on mentalistic notions, principles of rationality and explicit regulation

**Complexity & Tractability**

- Intentionality in communication (e.g. social, communicative, referential)
- From individual beliefs & intentions to common ground (collective beliefs & intentions) with recursion
- Understanding & generating behaviors, intention recognition, etc.

**Adequacy?**

- Assumes full mutual mental model of cooperative agents
- **Ψ**: Largely based on intuition and philosophical argumentation
- Addresses mental states, not the actual coordination that takes place



# Embodied cooperation

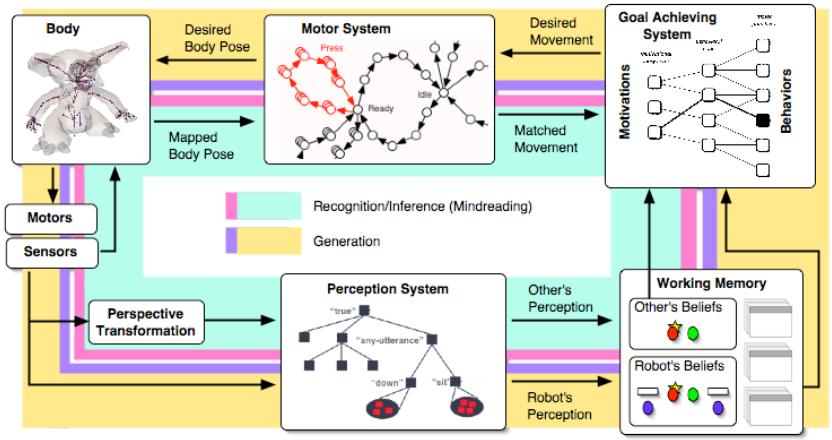
**Much coordination actually happens without explicit communication!**

**Embodied cognition** (Wilson 2002)

**Psychology of joint action**
(Knoblich & Sebanz 2003, Brass et al.)

- accounts for coordination, not only for decision making
- agents coordinate via co-representation, simulation, and anticipation
- observation not a pre-condition, knowing the other's task is sufficient

# Cognitive & embodied approaches




(Breazeal et al. 2007)



Universität Bielefeld

## Sociable Agents Group

CITEC

Sociable Agents

Center of Excellence Cognitive Interaction Technology – Bielefeld University – Faculty of Technology

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OVERVIEW

Adaptive Tutoring
Machine Learning
Companionship and Personalization
Expressive Social Robots
Coordinated Dialogue
Imitation, Motor Cognition
Speech-Gesture Alignment
Linguistic Alignment
Multimodal Virtual Agents

### Research in the Sociable Agents Group

Our research projects target systems and tools to make machines conversational, cooperative, convergent, and companionable, and to explore these abilities in novel human-machine interaction scenarios.

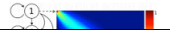
### Adaptive Embodied Communication

*with Matthias Weigelt (Univ. Saarbrücken), Bettina Bläsing (Sport Sciences)*

Instructions about sequences of actions are better memorized when offered with appropriate gestures. In this project, the virtual human Max accompanies instructions with self-generated gestures. The quality of the resulting memory representations in the human listener is then assessed by Max (Split-Method). This provides for a measure of listener's comprehension and can be used by Max for adapting its use of particular instructions and gestures in a closed-loop scenario.

### AMALIS – Adaptive Machine Learning of Interaction Sequences

*with Thomas Herrmann (Ambient Intelligence)*



Interaction scenarios are full of multivariate sequences of data, e.g., speech, nonverbal behavior

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## Possible theses topics

CITEC

**http://www.techfak.uni-bielefeld.de/ags/soa/theses/open-topics.html**

Sociable Agents

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Offene Themen für Abschlussarbeiten

ACTIVITIES

Int. Conference on Intelligent Virtual Agents (IVA 2011)
GESPIN 2011 -- Gesture+Speech in Interaction
Special Issue of Cognitive Processing on Cognitive Robotics
Doctoral Symposium at KogWis2010
Workshop MOG2010

### Welcome to the Sociable Agents Group

We develop intelligent systems for intuitive, natural human-machine interaction. Using virtual humans, 3D avatars and humanoid robots, we investigate how models of human communication and cognition can be transferred to machines in order to make them conversational, cooperative, adaptive and companionable. Our research encompasses empirical study of human behavior, computational modeling of the cognitive and sensorimotor processes that underlie reciprocal communication, and the development and evaluation of technology that brings those capabilities to bear in actual human-machine interaction scenarios.

Current research projects focus on embodied approaches to learning, recognition and production of conversational behavior (language, gesture, nonverbal behavior), engagement and coordination in dialogue (communicative feedback), and inter-personal adaptation (dynamic alignment, long-term familiarity).

NEWS [ARCHIVE]

- Invited presentations at the Workshop on Evaluation of Interactive Cognitve Systems, keynotes to the Gesture Workshop 2011 (Athens) and GESPIN 2011
- The website of IVA'2011 is online, the CfP is about to be sent out
- Stefan delivered a keynote to the HART - Human-Agent-Robot-Teamwork workshop at the Lorentz Center in Leiden.
- Amir's video "Embodying Social Signal Processing" won the Audience Award *and* the Jury Award at IVA 2010 GALA! Watch an extended version on YouTube.



# Summary of this lecture

- HCI is classically concerned with usable tools, starting to look into interactive and collaborative systems
- Formal models and systems for framing collaboration as a joint activity are around
- Social and relational behavior can be exploited carefully to foster collaboration
- Embodied companions offer opportunities for increasing engagement, coordination, and interaction, and for studying how basic abilities of cooperation can be acquired via social learning

# Overall summary

## Human-Computer Interaction

- Basic goals, views, history
- Human: perception, reasoning, action
- Interface: styles & technology
- Usability: guidelines, design, evaluation
- Speech: recognition, synthesis, processing
- Dialog: problems, methods, systems
- Multimodality: fusion, fission
- Agents: conversational, collaborative
- Companions: effects, social & relational agents, embodied cooperation

**tools**
**➜ operate**

**smart tools**
**➜ instruct**

**assistants ➜ converse**

**companions**
**➜ collaborate**



Universität Bielefeld

## Courses to complete this module in the next semester

CITEC

- Seminar „Kognitive Modellierung" (Kopp, Bienek), Do 14-16
- Seminar „Dialogsysteme: Praxis" (Schlangen), Mi 14-16
- Projekt „Virtuelle Realität" (Pfeiffer), n.V.