Affect in agent architectures

Professor Ruth Aylett
Vision Interactive Systems & Graphical Environments
MACS, Heriot-Watt University
www.macs.hw.ac.uk/~ruth

Overview

- Affective computing
- 'Doing the right thing'
- Low-level: Panicking sheep
- High-level: Empathic characters

Affective computing

- A growing field currently
  - Affective interfaces
  - Affective systems in agent architectures
- Reaction against Descartian dualism
  - Influence of Damasio
  - Evolutionary argument
- Humaine NoE

Why is it important?

- Socially-located computing
  - A consequence of pervasive computing
  - Computers, robots, intelligent systems in the human social context
- Emotions essential in human decision making, perception, learning
  - 'Emotional intelligence'
  - Computers must recognise, understand, even 'have' and express emotions

Synthetic characters

- Graphically-embodied agents
  - A method of humanising the interface
  - Virtual actors, inhabitants of virtual worlds
    - Which may be immersive
  - Education, training, therapy
    - The concept of 'social presence'
- Embodiment makes a difference
- Strong autonomy
  - Each has own sense-reflect-act cycle
  - Unlike computer games characters

Agents and action selection

- Competent agents must 'do the right thing'
  - The action-selection problem
- Top-down reflection
  - Planning action sequences
  - Guarantees task achievement - but slow, brittle, unresponsive; human focussed
- Bottom-up reaction
  - Stimulus-response architectures
  - Guarantees relevance, but prone to global minima; animal focussed

Two affective approaches

- In reflective architectures (symbolic)
  - Cortex: cognitive integration
  - Appraisal rules linked to reasoning
  - Coping behaviour
  - Ortony, Clore and Collins; Frijda; Lazarus; Sherer
- In behavioural architectures (sub-symbolic)
  - Brain limbic system: (neuro-)physiological integration
  - Homeostasis
    - Conflict resolution and avoidance of dithering
  - Linked to drives

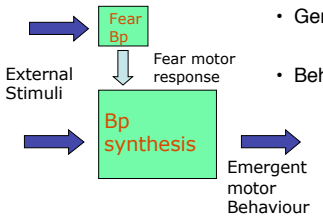
Low-level emotion

- Six primitive emotions
  - 'universal' - facial expressions recognised across cultures (Ekman)
  - Fear, anger, joy, surprise, disgust, misery
- In humans and other animals too
  - strong biological inspiration

The role of basic emotions

- Modifying behaviour
- Modifying physiology
  - Adrenaline alters physical properties
- Initiating behaviour
- Maintaining behaviour
  - Like short-term memory
- Sharing behaviour
  - Form of communication

Fear as a behaviour pattern (Bp)

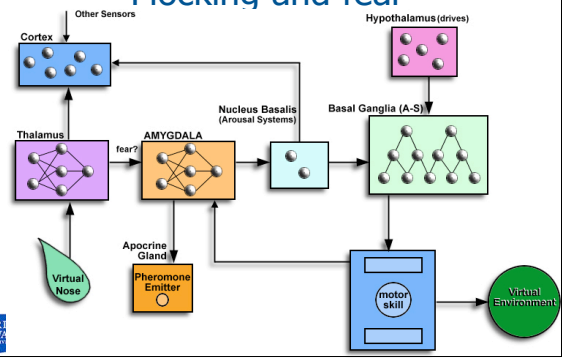


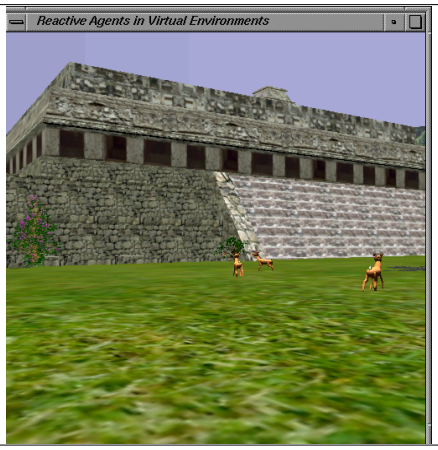
- Generates response entering into synthesis process
- Behaviour *modification*

Fear as sensory pre-condition

- Fear as *internal* sensory stimulus
  - Generated by external stimulus
  - Temporal profile
    - High attack, slow decay (adrenaline level)
- Sensory pre-condition for behaviour pattern switching
  - Activates flight behaviour
    - Until decay below threshold

Flocking and fear





Fear as communication

- Activates physiological processes
  - Produces pheromones
  - Transmitted to others
- Acts as substitute for original sensory stimulus
  - Important in herding and flocking animals

Implementing pheromones

- Artificial Aprocrine gland
- Pheromones modeled using free expansion gas.
- Boltzmann formula use to model pheromone density distribution.
  - Depends on Altitude, Temperature, Volume, Number of molecules (Emotion Intensity).

Virtual nose

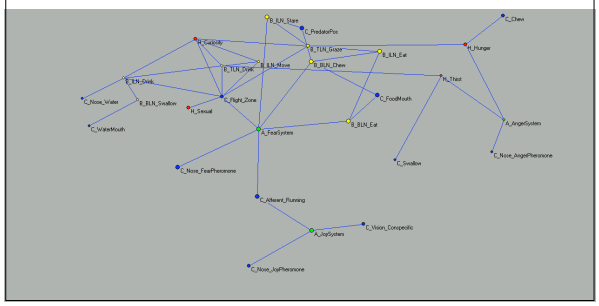
- Density detected by virtual nose
  - Abstract binary mask to model molecule type
  - Nose detects molecule type via receptors
- Fear propagates
  - Sensory input generates molecules from other flock members

Signalling in a VE

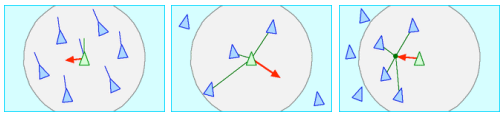
Amygdala

```
- <contents>
  - <node>
      <system name="A_FearSystem" />
      <input weight="0.2" from="C_Nose_FearPheromone" />
      <input weight="0.5" from="C_Flight_Zone" />
      <input weight="0.3" from="C_Afferent_Running" />
      <input weight="-0.5" from="C_Vision_Conspecific" />
      <function name="tansig" />
    </node>
  - <node>
      <system name="A_JoySystem" />
      <input weight="0.2" from="C_Nose_JoyPheromone" />
      <input weight="0.5" from="C_Vision_Conspecific" />
      <input weight="0.4" from="C_Afferent_Running" />
      <input weight="-0.4" from="H_Hunger" />
      <input weight="-0.4" from="H_Thirst" />
      <function name="sigmoid" />
    </node>
  - <node>
      <system name="A_AngerSystem" />
      <input weight="0.2" from="C_Nose_AngerPheromone" />
      <input weight="0.4" from="H_Hunger" />
      <input weight="0.4" from="H_Thirst" />
      <function name="sigmoid" />
    </node>
  </contents>
```

Virtual Brain (connections)

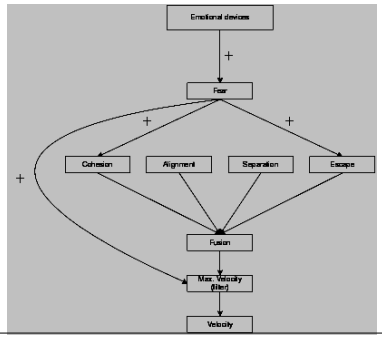


Reynolds' Flocking



Alignment Separation Cohesion

Emotional Flocking



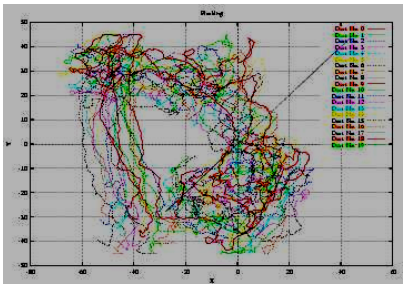
Characterising Behaviour

- Characterising emergent behaviour is hard.
- Need to measure overall complexity
- Using singular values and entropy to compute complexity.

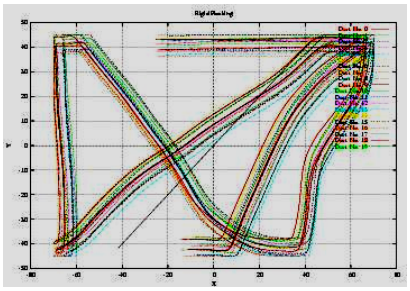
Computing complexity.

- 600 samples were obtained
  - For 5,10,15 and 20 animals.
  - A matrix was created with the animals position x,y and velocity vx,vy.
- Singular values for each matrix obtained
- Entropy obtained.
- Complexity computed

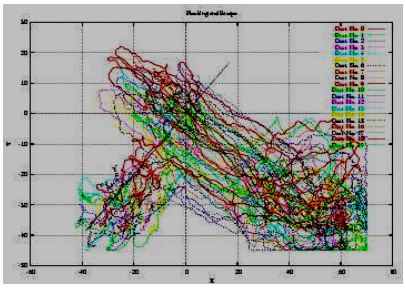
Plot (Flocking)



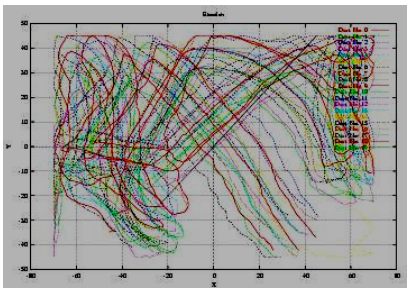
Plot (Flocking Rigid)



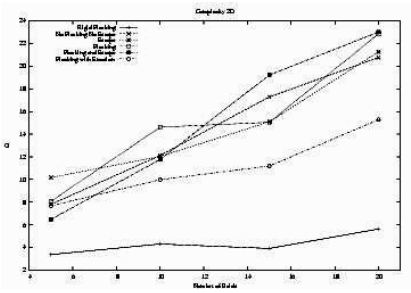
Plot (Flocking & Escape)



Plots (Emotion)



Complexity



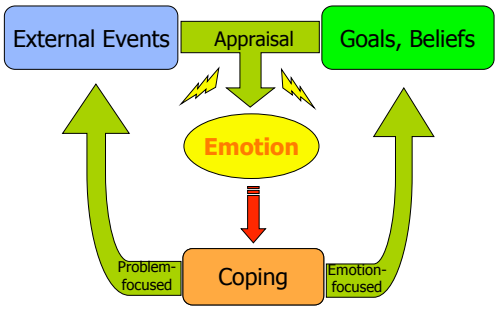
What emotion does

- In this case, mediates between individual and social behaviour
  - Individual should graze as widely as possible (klinokinesis)
  - But herd should stay together

High-level emotion

- Appraisals
  - Assessments of events, actions, objects wrt agent goals
- Valence
  - Whether emotion is positive or negative
- Arousal
  - Degree of physiological response
- Implementing appraisals
  - Domain-specific rules
  - Probability of impact on agent's goals
  - Produces coping behaviour

Cognitive Appraisal Theory



Smith and Lazarus' cognitive-motivational-emotive system

Modeling Appraisal and Coping

- Appraisal as plan-evaluation
  - Causal interpretation mediates agent-environment relationship
  - Define appraisal variables in terms of features of interpretation
  - Fast, reactive, parallel
- Coping as generalized plan critics

  Map to operators that change interpretation
  - Problem-focused → execute step, add plan step
  - Emotion-focused
    - Denial → Change belief
    - Find silver lining → Change utilities
    - Shift blame → Change causal attribution
      → Dialogue moves
    - Distancing → Drop goal / intention

Emotion theory
Ortony, Clore and Collins (OCC)

- Extremely widely used for agents
  - Ortony, A; Clore, G. & Collins, A. 1988 The cognitive structure of emotions. Cambridge University Press

Group	Types
Well-being	joy, distress
Fortunes-of-others	happy-for, gloating, resentment, sorry-for
Prospect-based	hope, satisfaction, relief, fear, fears-confirmed, disappointment
Attribution	pride, admiration, shame, reproach
Attraction	love, hate
Well-being | Attribution	admiration + joy ♦ gratitude
(compound emotions)	Reproach + distress ♦ anger Pride +joy ♦ gratification Shame +distress ♦ remorse

OCC Model - more detail

- Emotions defined in terms of situations, goals, and others

Group	Specification	Name & type
Well Being	Appraisal of situation as *event*	Joy - pleased about *event* Distress - displeased about *event*
Fortunes of Others	Appraisal of situation as *event* affecting another	Happy-for: pleased about an event desirable for another Resentment: displeased about an event desirable for another
Prospect-based	Appraisal of situation as a prospective event	Hope: pleased about a prospective desirable event Fear: displeased about a prospective undesirable event

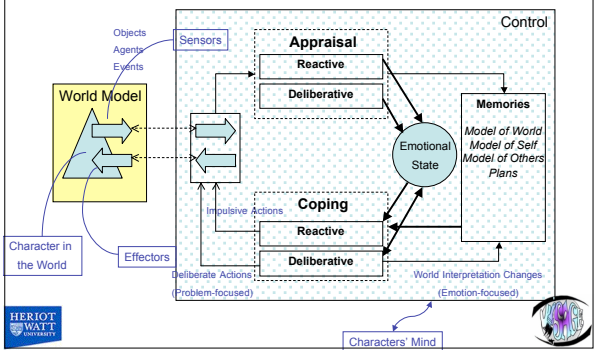
High-level emotion

- VICTEC and eCIRCUS - FP5 & FP6
  - Partners in UK, Germany, Portugal and Italy
  - Emergent narrative for Personal/Social Education
  - Anti-Bullying
  - Creation of empathy and social immersion for users

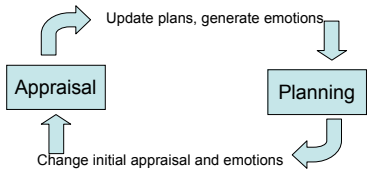
Creation of empathy

- The invisible friend
  - Emergent narrative
  - Advice between episodes
  - Influences behaviour

Empathic Character Architecture

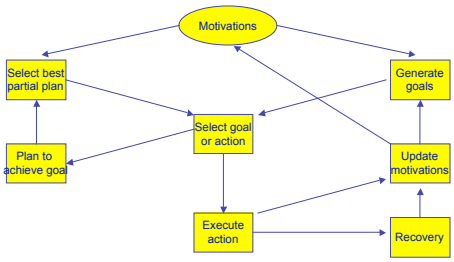


Appraisal and planning in FearNot!



- Use of OCC prospect-based emotions
  - Events congruent with goals: hope
  - Threatening goals: fear
- A standard partial-order continuous planner as starting point + belief values on effects
  - From Russell & Norvig

Continuous planner



Appraisal

- OCC-based
  - Reactive Level - Emotional Reaction Rules
    - Event
    - Appraisal Variables
  - Deliberative Level
    - Goal activation
    - Monitors actions and updates probability
  - Mood and arousal
- Emotions decay exponentially
  - Rate of decay and thresholds set by personality parameters

Update phase

- Look for activated goals
  - Create *intention* to achieve pre-conds
  - Initial hopes and fears
- Update existing plans wrt event
  - Modify effect beliefs
- Remove plan flaws - one per cycle
  - Unsupported links (eg. Book kicked away)
  - Link extensions (e.g Book thrown over)
  - Redundant actions now supplying no causal links
- If plan achieved, generate relief or satisfaction

Focus phase

- Choose goal and plan to work on
  - Intentions with highest hope/fear
  - Plan with fewest steps furthest from goal
    - Measured by no. open pre-conds

h(plan) = (1+ numSteps + numOpenPreconds +numInterThreats*2)/Bel(plan)

    - Inter-goal threats: actions violating protected condition on *interest goal* (e.g. not getting hurt)
  - Best plan brought into focus and generates emotions

Coping phase

- Internal emotion-based coping
  - Acceptance: low probability of success so accept failure of plan, and possibly goal
    - Used for inter-goal threats depending on emotional balance
  - Mental disengagement: lower goal importance
  - Denial: may ignore a threat if from low probability effect

Generating actions

- (1) Physical Acts
  - Map onto graphics
  - This can be non-trivial: positioning; outcomes
- (2) Speech Acts
  - Several speech acts require a response
    - Speech act appraised in the reactive layer
      - Answer generated according to valence
    - Answers (positive/negative) appraised in the deliberative layer
    - The strongest answer (emotions) is returned

Defining John's Personality

Defining John's Personality

```
<EmotionalThreshold emotion="Love" threshold="3"
    decay="5" />
<EmotionalThreshold emotion="Hate" threshold="3"
    decay="5" />
<EmotionalThreshold emotion="Hope" threshold="4"
    decay="8" />
<EmotionalThreshold emotion="Fear" threshold="1"
    decay="2" />
.
.
.
.
.
<EmotionalThreshold emotion="Reproach"
    threshold="2" decay="8" />
<EmotionalThreshold emotion="Gratitude"
    threshold="3" decay="5" />
<EmotionalThreshold emotion="Anger" threshold="3"
    decay="5" />
```

Defining John's Personality

```
<EmotionalReaction desirability="-5" praiseworthiness="-
    5">
  <Event action="SpeechAct"
    parameters="sabotageinvitation,[SELF]" />
</EmotionalReaction>
.
.
.
.
.
<EmotionalReaction desirability="-4" praiseworthiness="-
    3">
  <Event action="SpeechAct" target="[SELF]"
    parameters="insult" />
</EmotionalReaction>
```

Defining John's Personality

```
<ActionTendency action="SpeechAct([Subject],insult)">
    <Preconditions />
    <ElicitingEmotion type="Anger" minIntensity="5">
        <CauseEvent />
    </ElicitingEmotion>
</ActionTendency>
.
.
.
.
.
.
.
.
<ActionTendency action="cry">
    <Preconditions />
    <ElicitingEmotion type="Distress" minIntensity="6">
        <CauseEvent />
    </ElicitingEmotion>
</ActionTendency>
```

Defining John's Personality

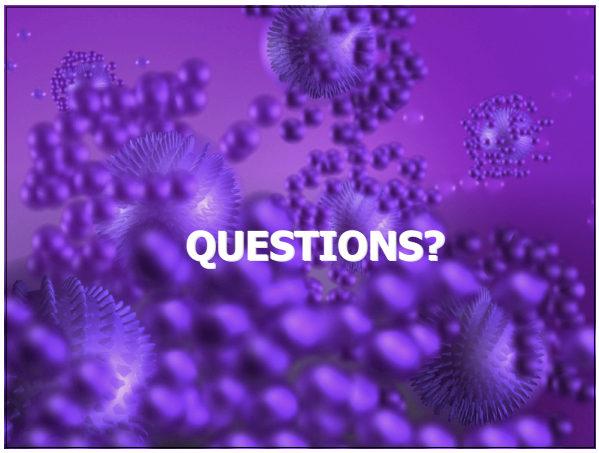
```
<ActivePursuitGoal name="AcceptInvitation([friend])">
 <PreConditions>
  <RecentEvent occurred="True" subject="[friend]"
   action="Question" target="[SELF]"
   parameters="invite" />
  <Property name="Like([SELF],[friend])"
   operator="GreaterThan"
   value="0" />
 </PreConditions>
 <SucessConditions>
   <Property name="InvitedToParty([friend],[SELF])"
   operator="="    value="True" />
 </SucessConditions>
 <FailureConditions>
   <Property name="InvitedToParty([friend],[SELF])"
   operator="="
   value="False" />
 </FailureConditions>
</ActivePursuitGoal>
```

Goals

Defining John's Personality

```
<Action name="Question([target],[question])">
 <PreConditions>
  <Property name="[target]" operator="!=" value="[AGENT]" />
 </PreConditions>
 <Effects>
  <Effect probability="1">
   <Property name="SpeechContext()" operator="="
   value="#EVENT([AGENT],Question,[target],[question])" />
  </Effect>
 </Effects>
</Action>
<Action name="InferenceOperator1([Inviter],[Invited])">
 <PreConditions>
  <RecentEvent occurred="True" subject="[Invited]" action="Reply"
   target="[Inviter]" parameters="invite,positiveanswer" />
 </PreConditions>
 <Effects>
  <Effect probability="1">
   <Property name="InvitedToParty([Inviter],[Invited])" operator="="
   value="True" />
  </Effect>
 </Effects>
</Action>
```

Actions

Conclusions

- Affect is an essential part of an agent architecture
  - Spock could never have evolved
- Mediates both behaviour and planning
  - Can produce some of the glue that makes them work together
- And so far more functional and useful embodied agents
  - Interacting more successfully in human social context