Emotions in Cognitive Agents within the Fluent Calculus

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Problem Description

General Goal

- Integrate simple models of emotions in formal theories of reasoning about action and change
- Extend autonomous agents, which use high-level cognitive capabilities of reasoning and planning, with mechanisms to quickly select goals and react to opportunities
- Resulting agent architecture is based on a formal theory which can be used to prove properties.
- Agents can perform ef£ciently in real-world applications.

Selection Problem

- How should an agent deal with con¤icting goals, which goal should it strive for, which goal should it evade ?
- Example: A robot in a coffee delivery scenario can ful£ll the next delivery request or go to a charging station to recharge its battery.
- Which of the current goals should an agent pursue ?

Selection Criteria

- Importance: Some goals, as, e.g., always maintaining a high energy level, are of great value for a robot.
- Prospect of success: The expected probability of a plan to reach the goal should be taken into account. An agent will then be able to seize opportunities and avoid dangerous situations.
- Urgency: An agent should consider the time frames, in which a goal can be reached, in order not to miss deadlines.
- Criteria are combined and the goal with the highest expected value is selected. This selection process is reexecuted every time the agent receives new information.

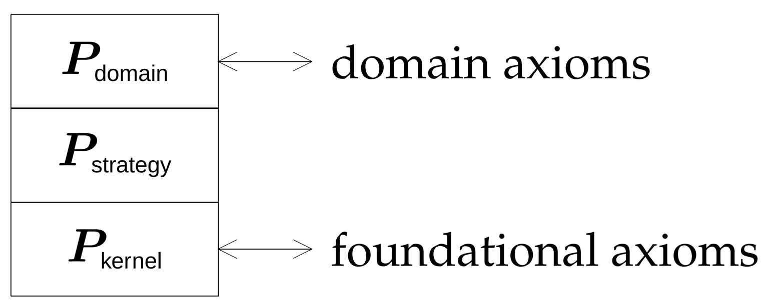
Modulations of the Goal Selection

- Outside in¤uences, like exogenous actions, can lead to sudden changes of a selection criteria for a goal, e.g., a sudden breakdown of a robot's battery.
- Modulations can be interpreted as simple models of emotions, e.g., being scared.
- If there is no time/information needed to think logically about the next step, then there is guidance by emotions. Quick reactions to feelings ensures adaptive behavior.
- Successful mechanism during human evolution

Previous and Related Work

Fluent Calculus and FLUX

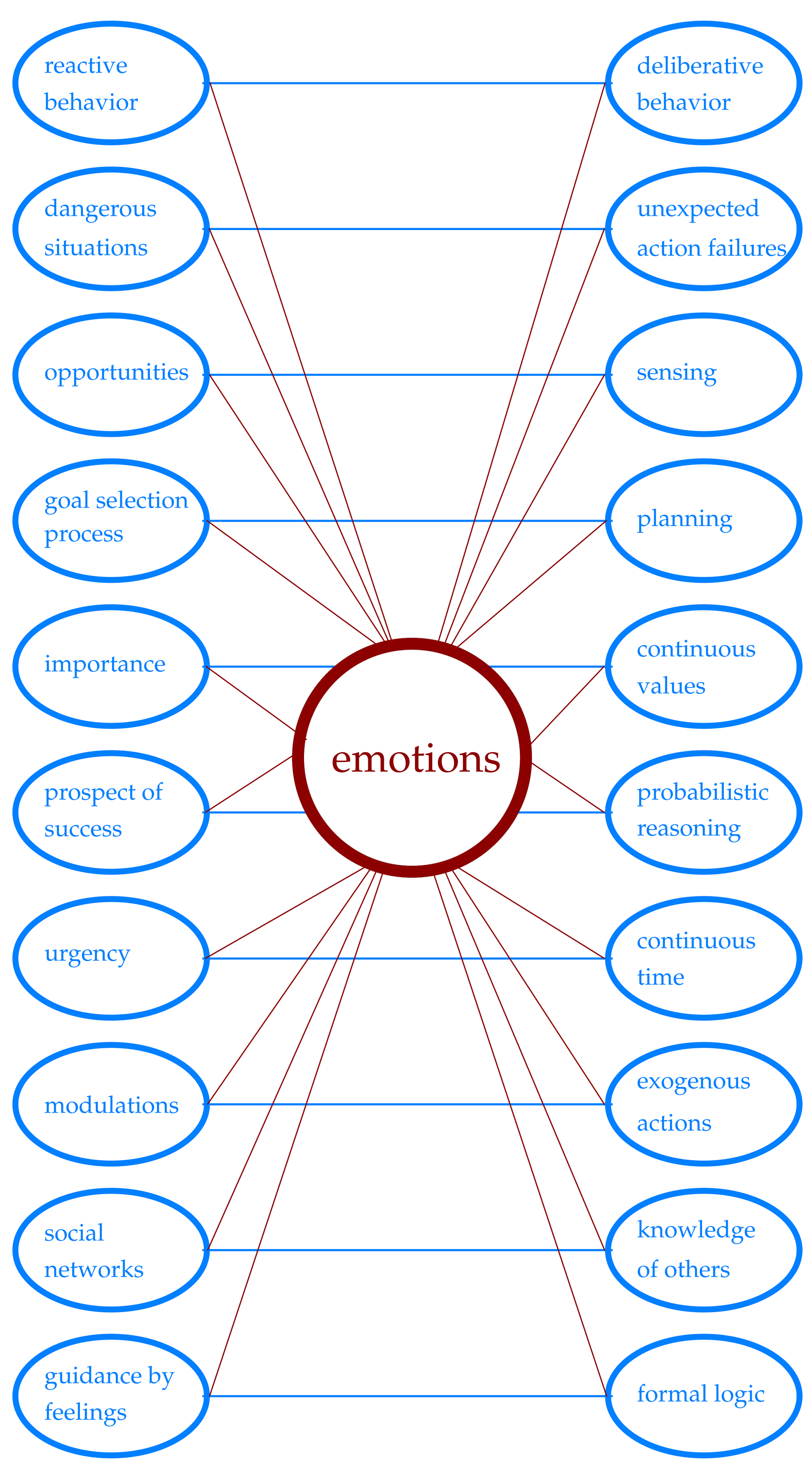
- Fluent calculus is an axiomatic theory for reasoning about actions [Thielscher, 1999].
- Fluent calculus extends the situation calculus [Reiter, 2001] by the notion of a state.
- Frame problem is solved by state update axioms.
- Within the ¤uent calculus, a variety of important aspects have been successfully addressed in the past:
  - the rami£cation problem
  - the quali£cation problem
  - nondeterministic actions, concurrent actions, continuous change
  - noisy sensors and effectors
  - communicative actions
  - knowledge, belief, and sensing
- FLUX is a high-level agent programming language based on the Fluent Calculus.



Components of FLUX programs

- Incomplete states are progressed using an ef£cient constraint solver [Thielscher, 2004].

General Architecture



Cognitive Architectures

- The construction plan for a soul [Dörner, 2001]. This architecture aims at rebuilding all mental processes on a machine. Neurons are used as basic entities.
- The cognition and affect architecture [Sloman, 2001]. Speci£cations of architectures for complete agents are used to £nd out what sorts of states and processes are supported by those architectures.
- A variable threshold interrupt £lter [Wright, 2000]. An ongoing execution of a plan use resources, both cognitive and physical, that are limited. Therefore, these activities will need protecting from interruption. The £lter mechanism represents a simple model of concentration.

Solution

Quali£cation Problem

- The executability of an action can never be predicted with absolute certainty; at any time, actions in the real-world may surprisingly fail.
- Agents need the ability to reason about unexpected failures of actions. The reasons for such failures have an in¤uence on the expected probability of success for a goal.
- The FLUX system has been extended such as to allow for planning under the default assumption that actions succeed as they normally do, and to reason about these assumptions in order to recover from unexpected action failures [KI, 2001, with Michael Thielscher].

Specifying Action Failures

- The use of sensing actions helps an agent to determine very precisely the reason for the unexpected failure of a plan to reach the chosen goal. Therefore, sensing actions provide useful informations on arising opportunities and dangers.
- I have combined an approach to unexpected action failures with an account of sensing actions in FLUX [KI, 2004, submitted].

Continuous Time and Concurrency

- The £rst selection criteria, importance of a goal, can be represented with continuous values. In order to take into account the third criteria, urgency, the agent has to reason about the available time frames. Therefore, it is necessary to represent continuous time in the architecture and to plan with both, deliberative and natural actions.
- The FLUX architecture has been extended to accommodate such processes [IJCAI, 2003].

Knowledge of other Agents

- In some scenarios, agents have to communicate and to solve tasks together with other agents. They will work in a network of agents where each single agent may take a different role.
- Knowledge of other agents will foster ef£cient communication. Simple models of social emotions can be represented using such knowledge.
- The integration of knowledge states with knowledge of other agents and communicative actions into Fluent Calculus and FLUX has been successful [KR, 2004, with Iman Narasamdya and Michael Thielscher].

Future Thesis Work

Probabilities

- The prospect of success is an important aspect to consider when choosing a goal. To represent such considerations in Fluent Calculus and FLUX, probabilistic reasoning has to be integrated into the formalism.
- A method to represent probabilistic state transitions and to reason about the probability for a goal to hold after the projected execution of a plan has to be de£ned for Fluent Calculus and FLUX.

Combination of all the Approaches

- All the above approaches have to be combined into one system. In such a system, it will also be possible to implement the goal selection process and a threshold interrupt £lter for stable behavior. Unexpected opportunities and dangers during the execution of a plan would then modulate this selection process and could be seen as the agent reacting adaptively to emotions.
- The approach should be applied to a simple delivery scenario. It should be shown that my system performs ef£ciently in the presence of con¤icting goals and constant change.