NTNU

Department of (department)

Examination paper for TDT4137 Cognitive Architectures

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skal ha flervalgskjema ☐

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Each of the 4 problems contribute 25% to the final result for this exam.
None of the questions require a long and wordy answer, try to be brief and to the point.

SUGGESTED SOLUTIONS
Please note: The suggested solutions are in most cases intended as **solution hints**, not necessarily complete solutions

Problem 1

a) Two key hypotheses associated with cognitive systems are "The Physical Symbol Systems Hypothesis " and "The Heuristic Search Hypothesis ». What do these hypotheses express?
Vernon, ch. 2:

1. The *Physical Symbol System Hypothesis:* A physical symbol system has the necessary and sufficient means for general intelligent action.
2. The *Heuristic Search Hypothesis:* The solutions to problems are represented as symbol structures. A physical-symbol system exercises its intelligence in problem-solving by search, that is, by generating and progressively modifying symbol structures until it produces a solution structure.

Some directions within cognitive systems are critical to these hypotheses. Why?
Intelligence is 'embodied', and not independent of an agent's physical body and functionality.

b) Briefly describe the different paradigms of cognition that are included in the curriculum, and what their differences are.
Vernon fig. 2.1 + text..

Give an example of an architecture from each of the paradigms, and justify why it belongs to that paradigm.
Cognitivist: Soar, Icarus, ACT-R; Emergent/Connectionist: Brooks, ANN-based.
Hybrid: Clarion, ACT-R.

c) In order to understand and model cognitive systems it is useful to analyse them on more abstraction levels. A famous model is David Marr's 3-level model. Describe the levels, how they are coupled and how the model is meant to be used.
Vernon ch. 1, fig. 1.6.

Which of the paradigms in b) does Marr's model belong to?
Cognitivist

d) What characterizes the knowledge level in an intelligent system?
*A separate level above the program level. It has **knowledge as medium** and **the principle of rationality as operational principle** : An agent with a goal and knowledge on how to achieve the goal, will always use its knowledge so the goal is achieved.*

What is the link between the knowledge level and a system's intelligence, according to Allen Newell?
A system is intelligent to the degree that it approximates the knowledge level.

Problem 2

a) What is a cognitive architecture, as the term is used in this subject?
An architecture is a fixed structure that defines what type of content that it may contain (for example a building architecture and its content which are its components and processes). A cognitive architecture is an architecture for cognitive components and processes.

Also provide a definition of cognition, either reproduced from the curriculum or your own.

Vernon:

Cognition is the process by which an autonomous system perceives its environment, learns from experience, anticipates the outcome of events, acts to pursue goals, and adapts to changing circumstances.[8]

b) Describe the essence of the architecture Soar, with emphasis on the

i) Overall architecture - preferably as a figure with comments
Fig. 6 + explaining text, procedural knowl. as production rules are central, semantic and eposiodc memories in addition. Decision cycle linked to WM.

ii) Knowledge types and associated memory structures
p. 13-16 – LTM: procedural, semantic, episodic; WM: percepts, actions, activated LTMs

iii) Problem-solving process - the main steps from input to output
p. 17-20 (decision cycle), fig. 4 (problem spaces)

iv) Learning process - what is learned and how
Ch. 8 – impasse -> chunking is main mechanism, + RL, episodes, sem.mem.structures

b) CLARION is another architecture. What are essential similarities to and differences from Soar ?
Similarities: Full cog. ark., action rules, aka chunking of (top-level) rules, goal-subgoal structure, rules, episodes og RL (but different roles)
Differences: Pure symbolic vs, hybrid, 4 modules, clear WM/LTM split (Soar) vs. temporal data storage and precepts as attr-value pairs in a less explicitly specified WM (Clarion), learning process, probl.solv. as decision procedure and MeandEnds-analysis vs. comb. av Q-values and tope-level rules.

Give a brief description of the architecture, with the list i)-iv) above as reference.

i) Overall architecture - preferably as a figure with comments
Fig. 1 + explaining text, the 4 modules with expl.+impl. knowl. are central

ii) Knowledge types and associated memory structures
p. 1-5 + Chong 114-116, symbolic upper layer, declarative rules; neural+RL bottom layer, procedural; NACS prim. declarative, GKS vs. AMN; ACS, prim. procedural, IDN decision network at bottom, with ARS action rules at top.

iii) Problem-solving process - the main steps from input to output
p. 8-9, Chong p. 116, rule-based+ similarity-based reasoning; +IDN; +MS for goal setting and MCS for overall control.

iv) Learning process - what is learned and how
Combines expl. rules at top from bottom proc., og impl. procedural skills at bottom by RL.

c) What is the "The Standard Model" for cognitive architectures, and what components does it contain?
The paper
Will CLARION fit into that model? If yes, in what way? If no, why not?
Depending on whether it is viewed as the current model as it is (No, Clarion is too complex), or as a flexible and extendible framework (Yes, with some modification of the SM).

Problem 3

a) What is a MOP, and what is its role in Schank's cognitive model? Sketch the structure of a "Dynamic Memory" where MOPs and cases (events) are linked. If you wish you may use the Casey system as an example.
Memory Organization Package. Kolodner book p. 108-112+124-126. A MOP organizes a set of similar situations (events) into generic units which descriptors are shared by less generic units and down to specific events. Organized in a 'discrimination tree'.

b) Describe the two steps in the MAC- FAC model and how they are used in analogy reasoning.
Forbus/Gentner paper 2nd page. «Many are called" searches by attributes and relations, while "Few are chosen" refine that set by using relations according to the structure mapping theory.

c) What is meant by "hedges" in connection with fuzzy sets?
Qualifiers for fuzzy set functions, e.g. very, less, very very, through assigning an exponential function.

d) A group of people was asked to enter the height of men and women, expressed in cm, using the categories:
Very very short (VVS), very short (VS), short (S),
Very very tall (VVT), Very tall (VT), Tall (T)

Here is the result for men's height:

	Short			Tall		
	V V S	V S	S	T	V T	V V T
Definitely not	148	157	172	167	176	182
Possibly	137	143	157	179	189	198
Definitely	126	129	142	191	202	214

And here for women's height:

	Short			Tall		
	V V S	V S	S	T	V T	V V T
Definitely not	153	155	161	160	170	174
Possibly	135	143	149	173	181	191
Definitely	117	131	137	186	192	208

i) Construct the membership function of the fuzzy variable Height for the values Short and Tall, for both women and men. The membership function can be shown graphically or as a function expression.
Straightforward drawing of membership function.

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ii) Based on this membership function, show the membership function for VVT and VT, for both men and women. The membership function can be shown graphically or as a function expression. For the exact impact of "Very very" and "Very "on the membership function, you may use the mechanism in the syllabus article or define your own.
Intended as an addition of hedges to the curves in i). But many did not read the question text properly and just drew membership functions based on the tables. The question could have been better written to avoid that mistake, so those who misinterpreted were given 70-80%, depending on how well it was answered given their interpretation.

Problem 4

Answer **True** or **False** to the following statements. A wrong answer gives a 0 score, but if you attach a brief explanation to your answer you may get it partially approved even if the answer is not correct.

1) The three layers of Kelso's abstraction model for cognitive systems are loosely connected to each other.
   ***F** – that is Marr's modell*
2) The principle of rationality (Newell) states that an agent who has knowledge will choose an appropriate goal for its knowledge.
   ***F** – opposite roles of goals and knowledge*
3) The three subsystems of the Model Human Processor are the Perceptual System, Emotional System, and Motor System
   ***F** – Cognitive System*
4) The Recognize-Act cycle is a key component of Soar.
   ***T** – this is the core engine in a production system, which in turn is the basis in all Newell-inspired architectures, included Soar*
5) Fitt's law states that the time it takes to move a hand to an object is proportional to the size of the object.
   ***F** – inverse proportional*
6) ACT-R is an architecture that connects mental functions to anatomical regions of the brain.
   ***T** – a focus in ACT-R*
7) The central processor of ACT-R is a production system.
   ***T** – as for 4)*
8) In ICARUS , the knowledge of actions and the skills to perform them are closely integrated into one module.
   ***F** – they are clearly separated, but cooperating*
9) In Brook's layered architecture, a higher layer can control the layers below.
   ***T** – the layers can operate independent of each other, but upper layers can control lower ones (subsumption).*
10) In Brook's layered architecture, all inputs will be received by the highest layer, which will activate the others.
   ***F** – in contrast to previous question*
11) In a biological neuron, the cell nucleus transmits signals to the dendrites that activate the axons.
   ***F** – dendrites recieve signals from axons, which in turn activate other cell's dendrites*
12) A Perceptron can only learn features that have linearly separable input values.
   ***F/T** – erroneous question, should be "… with respect to the classes", or just "linearly separable classes"*
13) In the CBR system Creek the case knowledge and general domain knowledge are separated in two different knowledge bases.
   ***F** – tightly integrated within one knowledge base.*
14) The systematicity principle in analogy reasoning states that 2nd order relationships are more important than 1st order relationships.
   ***T** – higher order relations more important than lower order.*
15) Membership in a fuzzy set can be both True and False at the same time.
   ***T** – a person can be both young and not-young. Many **F** accepted with a good explanation*
16) Fuzzy set theory is a type of statistical probability theory.
   ***F** – not probability theory, but possibility theory*
17) Bayes formula gives the likelihood of a hypothesis given the input parameters by using a formula where the probability of the input parameters given the hypothesis is an important element.
   ***T** – this is the idea of the formula*
18) The three levels of Endsley's model of situation awareness are – slightly rephrased:
   i) perception of the present situation, ii) understanding the current situation, iii) projection of future status.
   ***T** – fig. 1.1 in the paper*

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19) The main focus within Artificial General Intelligence is to build systems that surpass human intelligence.
***F** – main focus is to get closer to (approximate) human intellgence, without ruling out the possibility of beyond human intelligence*

20) An explainable model for a neural network can be built by giving the network different combinations of input parameters and observing the output for each combination.
***T** – this is one of the models described in the DARPA paper, called «model induction»*

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