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Reading List for the Qualifying Examination in Artificial Intelligence

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Abstract

This report contains the reading list for the Qualifying Examination in Artificial Intelligence. Areas covered include search, representation, reasoning, planning and problem solving, learning, expert systems, vision, robotics, natural language, perspectives and AI programming. An extensive bibliography is also provided.

Overview

This document is the reading list for the Qualifying Examination in Artificial Intelligence at Stanford University, commencing with the Winter examination in 1989. The reading list is divided into 11 sections, each corresponding to a major area of AI. Every section contains a list of required readings covering the fundamental material that a graduate student in AI ought to know. In addition, there is a selection of recommended readings. Students should be familiar with many of the latter references. The required readings are marked by a bullet (•), the recommended readings by a circle (o).

1 Search

- Pearl and Korf, ***Search techniques.***
  An excellent survey of the field. Korf's survey ***in Exploring Artificial Intelligence*** is not as comprehensive, but does contain references to some interesting recent developments (notably in chess).

- Winston, ***Artificial Intelligence.***
  Chapter 3, pages 79-84: dependency-directed backtracking.
  Chapter 4: search methods.

- Nilsson, ***Principles of Artificial Intelligence.***
  Sections 2.4.1-2.4.4: on A*.
  Sections 3.1 and 3.2: AND/OR trees and AO*.

- Mackworth, ***Consistency in networks of relations.***
  Read sections 1-5. The important concepts are constraint-satisfaction problems, backtracking, and arc-consistency.

o Berliner, ***The B* tree search algorithm: A best-first proof procedure.***
  Skim this paper to understand the two bounds and how they are used. The main problem with this approach is that it requires that the static evaluator be modified.

2 Representation

- ***The Handbook of Artificial Intelligence,*** Volume 1, Chapter 3.
  Sections A, B, C2, C5.
  Section A introduces some basic issues in knowledge representation while Section B provides an overview of several major formalisms. Sections C2 and C5 cover procedural and direct representations. Also look at the summary of the benefits and drawbacks of logical representations given on pages 170-l 71.

- Genesereth and Nilsson, ***Logical Foundations of Artificial Intelligence,*** Chapters 1, 2.
  Chapter 1 is more motivational than anything else, although Section 1.1 does provide a nice summary of some important historical information. Take note of the ***Physical Symbol Systems Hypothesis*** on page 5; although previously uncontroversial, the validity of this hypothesis is currently being questioned by the Connectionists. Section 2

presents the basics of predicate logic, as well as discussing other kinds of declarative representations.

- Rich, ***Artificial Intelligence,*** Section 7.2.
  Summaries of conceptual dependency, semantic nets, frames, and scripts. This material is covered ***in The Handbook*** *of* ***Artificial Intelligence,*** but Rich's presentation is somewhat more complete.

- Buchanan and Shortliffe, ***Rule-based Expert Systems,*** Chapter 2.
  An overview of production systems.

- Winston, ***Artificial Intelligence,*** pages 21-24, 41-42.
  Some desiderata for good representations.

- Levesque, ***Knowledge representation and reasoning.***
  An excellent overview of the knowledge representation area and its interactions with work on reasoning.

- Winograd, ***Frame representations and the declarative/procedural controversy.***
  Read Sections l-3 for the main issues in this controversy, which commanded much attention throughout the 1970's.

- Hayes, ***The logic*** *of* ***frames.***
  In this paper, Hayes shows that frames can be translated into logic.

- ***Newell, The knowledge level.***
  Skim this for an understanding of what constitutes a knowledge level description.

- Forbus, ***Qualitative physics: past, present and future.***
  Sections l-3 provide a good introduction to the area of qualitative physics. You might also want to glance at the remainder of the paper, which is more detailed and technical.

- Genesereth and Nilsson, ***Logical Foundations*** *of* ***Artificial Intelligence.***
  Chapter 9 (except sections 9.3, 9.6, 9.11-9.13).
  An introduction to some of the issues in formalizing knowledge and belief. Ignore the details of proofs.

- Laird, Newell and Rosenbloom, ***SOAR: An architecture*** *for* ***general intelligence.***
  The important ideas in SOAR are problem solving as search (a CMU tradition), universal subgoaling, and chunking. Section 2 contains a detailed description of the system; feel free to skip sections that seem too dense. The sections on chunking (2.6 and 3.3) are covered in the references for learning.

- Amarel, ***On representations*** *of* ***problems*** *of* ***reasoning about actions.***
  Successive reformulations of the missionaries and cannibals problem are shown to result in improved problem solving efficiency. Little progress has been made to date on automating reformulation, although there are several research projects in this area underway.

- Shoham and Goyal, ***Temporal reasoning.***
  A survey of the various formalisms for temporal reasoning. A nice summary of problems with ***change based*** approaches (such as the situational calculus) is provided in the first section, as well as concise definitions of the ***frame, qualification,*** and ***ramification*** problems. Skip Sections 3.2 and 3.3.

- Brachman, Fikes and Levesque, ***KRYPTON: a functional approach to knowledge representation.***
  The first part of this paper outlines some deficiencies of frame-based representations. The second part describes KRYPTON, a system that combines a frame-based language for describing terms with a logical language for making assertions.

- Hayes, ***Some problems and non-problems in representation theory,***
  Hayes stresses the importance of an ***interpretation*** for a knowledge representation formalism, as well as outlining several interesting representational challenges.

- Hayes, ***The second naive physics manifesto.***
  An interesting expose of the difficulties involved in formalizing commonsense reasoning. The paper is somewhat long; skim it for an understanding of the naive physics enterprise.

- Marr, ***Vision,*** pages 19-29.
  Read for an understanding of Marr's three levels of description.

3 Reasoning

- Genesereth and Nilsson, ***Logical Foundations of Artificial Intelligence.***
  Chapters 3, 4, 5. (Skip Section 5.8 and the proofs in 4.10.)
  Logical inference, resolution and resolution strategies.

- ***The Handbook of Artificial Intelligence,*** Volume 3, Chapter 12.
  Skim section A for an overview of deduction. Read sections C (non-resolution theorem proving) and D (the Boyer-Moore theorem prover).

- ☼♏♓♦♏❐ , ***Nonmonotonic Reasoning.***
  A good technical overview of the field of nonmonotonic reasoning.

- Genesereth and Nilsson, ***Logical Foundations of Artificial Intelligence.***
  Chapter 8, Sections **1-3.**
  The basics of probabilities, Bayes' rule, and standard expert systems techniques for uncertain reasoning are covered.

- Pearl, ***Probabilistic Reasoning in Intelligent Systems.***
  Chapter **1:** uncertainty in AI systems.
  Chapter 9, pages 415-421: Dempster-Shafer theory.
  The material in Chapter 9 should be read first; it briefly describes the Dempster-Shafer model. Chapter 1 presents a nice overview of some higher-level issues in reasoning with uncertainty.

- Charniak and McDermott, ***Introduction to Artificial Intelligence.***
  Sections 8.1, 8.2, 8.4.
  Skim for an overview of abduction from both a logical and a statistical perspective.

- Rich, ***Artificial Intelligence,*** Section 6.2.2.
  The basic functionality of Doyle's Truth Maintenance System (TMS) is described.

- de Kleer, ***An assumption-based TMS.***
  Read Section 1 to understand the basic ideas. The ATMS explores the classic tradeoff of using space (for storing contexts) to save time (needed to backtrack). Note that in contrast to Doyle's TMS, the ATMS is completely monotonic.

- ***Nii, Blackboard systems.***
  An overview of the blackboard approach to problem solving.

o Reiter, On ***closed world databases.***
The effects of the closed world assumption on database queries are examined. Examples and statements of theorems are of particular importance.

o Genesereth and Nilsson, ***Logical Foundations*** *of* ***Artificial Intelligence,*** Chapter 10.
Read sections 10.1-10.6 for an understanding of metalevel representation and reasoning. Section 10.7 introduces bilevel reasoning; you should be familiar with the issues, but details are unnecessary.

o Kowalski, ***Algorithm = Logic + Control.***
Kowalski presents the view that an algorithm can be separated into a ***logical component*** corresponding to the knowledge used to solve a problem, and the ***control component,*** which describes problem solving strategies. He argues that such a separation will make it easier to design algorithms that are both correct and modifiable.

o Weyhrauch, ***Prolegomena to a theory*** *of* ***mechanized formal reasoning .***
Sections l-9 except 9.1 and 9.2. The key ideas are simulation structures along with the related notion of procedural attachment, and the use of metatheories.

o Bledsoe and Hodges, ***A survey*** *of* ***automated deduction.***
This paper provides some historical perspective on automated deduction, but more importantly surveys current work in the field. Skim it to get a feel for the state of the art in theorem proving as well as current research areas.

4 Planning and Problem Solving

- Nilsson, ***Principles*** *of* ***Artificial Intelligence,*** Chapter 7.
  A summary of classical planning techniques and STRIPS. Some references are made to terminology introduced in previous chapters; the meanings of these terms should be clear from the context, or can easily be looked up.

- ***The Handbook*** *of* ***Artificial Intelligence,*** Volume 1, Chapter 2.
  Section D1: the Logic Theorist.
  Section D2: GPS.

Section D6: AB S TRIPS .

The Logic Theorist is primarily of historical interest. It and GPS were two of the earliest attempts at automated problem solving, and both adopt a search-oriented approach. **A** better explanation of means-ends analysis is provided by some of the other references, but D2 is still worth reading. The ABSTRIPS program should be learned well.

- ***The Handbook of Artificial Intelligence,*** Volume 3, Chapter 15.

  This reference outlines more classical planning work. Skip the STRIPS and AB-STRIPS sections — the other references for these systems are better. The remainder of the chapter should be read carefully.

- Fikes, Hart and Nilsson, ***Learning and executing generalized robot plans.***

  Sections 1, 3-6.

  A good overview of triangle tables and STRIPS. It also presents some of the earliest work on execution monitoring.

- Waldinger, ***Achieving several goals simultaneously.***

  A very clear exposition of goal regression and the problem of interacting subgoals.

- Winston, ***Artificial Intelligence,*** Chapter 3.

  This chapter covers ***constraints*** in detail. The first half deals primarily with Waltz's algorithm for propagating labels for the interpretation of line drawings. The remainder covers numeric constraints and backtracking. All of this material is quite important and should be read carefully.

- Swartout, ***DARPA Santa Cruz workshop on planning.***

  A good survey of current work and issues in planning. As the article makes clear, much recent planning research has focused on developing systems that work in domains that are unpredictable and have real-time constraints.

- Rich and Waters, ***Readings in Artificial Intelligence and Software Engineering.***

  Read the the introduction for an overview of automatic programming.

o Lifschitz, ***On the semantics of STRIPS.***

Lifschitz points out that the STRIPS representation of actions as ADD/DELETE rules is highly sensitive to seemingly minor modifications. A semantic characterization of these rules is given, which delineates the acceptable applications of STRIPS-style rules.

o Chapman, ***Planning for conjunctive goals.***

Read Section 1. Skim Section 2 and the start of Section 3, looking at how the planning problem is formalized and at the theorems (especially the complexity results). You may also want to look at TWEAK's solution to the Sussman anomaly (Section 2.4), and the historical perspective on planning (Sections 3.3-3.4).

o Manna and Waldinger, ***A deductive approach to program synthesis.***

Non-clausal resolution, induction and transformation rules are used to synthesize programs within a theorem proving framework.

5 Learning

- ***The Handbook** of **Artificial Intelligence,*** Volume 3, Chapter 14.
  A comprehensive introduction to work on learning, though a bit dated. Skip sections D3 (the Encyclopedia of Artificial Intelligence reference provides a more compact presentation of this material) and D5e (on grammatical inference). You need only understand Mostow's operationalizer and Waterman's poker players at a very high level; reading the first few paragraphs of sections C2 and D5b should suffice.

- ***The Encyclopedia** of **Artificial Intelligence,*** Machine Learning, pages 464-485.
  A review of more recent work in machine learning. Read the sections on the history of learning (page 464), learning concepts from examples (465–473), learning by analogy (476–479), and discovering quantitative laws (484).

- Laird, Newell and Rosenbloom, ***SOAR: An architecture** for **general intelligence.***
  Read Sections 2.6 and 3.3 for an explanation of chunking, the mechanism by which SOAR's performance improves over time.

- Valiant, ***A theory** of **the learnable.***
  This paper has spawned a cottage industry of work on inferring concepts with high probability. The work is closely linked with complexity theory.

- Paul Utgoff, *Shift of **bias** for **inductive concept learning.***
  Read pages 107-113 for a definition of bias.

- Mitchell ***Generalization as search.***
  Concept formation is considered as a search problem.

6 Expert Systems

- ***The Handbook** of **Artificial Intelligence,*** Volume 2.
  Read sections 7A, 8A, 9A, 9B for overviews of this area. You should be familiar with the Prospector system; also take a look at the sections on Macsyma, Teirisias, Casnet, Internist, Sophie, Buggy, Guidon and Excheck.

- Buchanan and Feigenbaum, ***Dendral and Meta-Dendral: Their applications dimenston.***
  A concise overview of the Dendral and Meta-Dendral programs. See the Handbook for more details (if desired).

- Buchanan and Shortliffe, ***Rule-based Expert Systems.***
  Chapter 1 (Introduction and 1.1): the historical context of Mycin.
  Chapter 4: the structure of Mycin.
  Chapter 15 (omit Section 3): the Emycin shell.
  Chapter 36, Section 3: a good summary of the goals and results of the Mycin project.

- Buchanan and Smith, ***Fundamentals** of **expert systems.***
  Of greatest interest in this paper are the tables on pages 28-29 and 52-53. The first presents a list of expert systems that have actually been used; the second outlines

open problems in expert systems research. The description of what characterizes an expert system given in the introduction is worth some thought.

- John McDermott, ***Rl: An expert in the computer systems domain.*** R1 was the first expert system to be successfully applied in industry. Read enough to understand what it does and how it works.

- Davis and Hamscher, ***Model-based reasoning: troubleshooting.*** Read Sections l-3 for an application of model-based reasoning.

- Shortliffe, ***Consultation systems for physicians.*** A discussion of the human engineering requirements for increasing the acceptability of medical computing systems. Many of the observations apply to more general forms of 'intelligent assistants'.

7 Vision

- Winston, ***Artificial Intelligence,*** Chapter **10** (omit the last section). Introductory reading that is essential for understanding the references that follow.

- Hildreth and Ullman, ***The Computational Study of*** Vision, Sections 1, 2.1 and 3.1. Section 1 is introductory material. Section 2.1 contains a nice presentation of edge detection, one of the best-understood problems in low-level vision. The remainder of Section 2 is also very readable, although somewhat incomplete in its coverage. Section 3.1 provides a good discussion of some current approaches to high-level vision.

- ***The Handbook of Artificial Intelligence,*** Volume 3, Chapter 13.
  Section A: overview.
  Sections C3, C5: early vision.
  Sections D1, D2, D3, D5, D6: scene representations.
  Sections El, E2: vision algorithms.
  Sections F1, F3: overviews of important systems.
  You may also wish to skim Section B if you are not already familiar with vision work in microworlds. (A very concise description of the microworlds work is given in the survey by Brady cited below.)

- Binford, ***Survey of model-based image analysis systems.*** Presents the state of the art (circa 1982) of model-based vision systems and describes principles for the design of general. vision systems.

- Brady, ***Computational approaches to image understanding.*** A dense paper that covers a large amount of vision work. Of possible interest to the more mathematically inclined reader and a good source for finding additional references.

8 Robotics

- ***The Encyclopedia of Artificial Intelligence,*** Robotics, pages 923-956. A cultural overview of the basic issues in robotics.

- Lozano-Perez, ***Task planning.***
  This paper describes task-level robot programming languages and the use of task planners to convert high-level goal descriptions for a robot into low-level commands for the robot's manipulators. Mathematical details are unimportant.

- o Latombe, ***Robot Motion Planning.***
  An overview of basic problems, methods and complexity issues in robot motion planning.

- o Brooks, ***A robust layered control system for a mobile robot.***
  Brooks presents ***his subsumption architecture*** for building mobile robots. Much recent work at MIT has followed this approach, which challenges (among other things) the use of run-time planning to obtain goal-directed behavior.

9 Natural Language

- Rich, ***Artificial Intelligence,*** Chapter 9, pages 302-305 (up to Section 9.2.1)
  Some basic ideas in natural language work including context, lexical disambiguation, and the syntax/semantics/pragmatics distinction.

- ***The Handbook*** of ***Artificial Intelligence,*** Volume 1, Chapter 4.
  Sections A, C, D, F4, F5, F6.
  This reference covers some basic grammatical formalisms and parsing techniques. You should understand both SHRDLU and MARGIE, and have a passing familiarity with SAM and PAM.

- ***The Handbook*** *of* ***Artificial Intelligence,*** Volume 1, Chapter 5.
  This chapter covers the major speech-understanding projects of the 1970's. Be familiar with the approaches employed in the different systems, as well as their advantages and disadvantages.

- o Winograd, ***What does it mean to understand language?***
  Winograd calls into question the whole enterprise of natural language understanding and describes how his own view on the matter has evolved over the years. A more detailed presentation of the ideas ***can*** be found ***in Computers and Cognition,*** cited below.

- o Perrault and Grosz, ***Natural language interfaces .***
  A survey of recent work on natural language interfaces to software systems. Sections 4 and 5 need only be skimmed.

10 Perspectives

- McCarthy, ***Programs*** *with* ***common sense.***
  McCarthy outlines his vision for an 'advice taker' program whose performance could be improved by receiving advice during the course of its actions. He argues for the use of a declarative representation of information in this program. The latter half

of the paper contains an overview of the situation calculus, which is more succinctly presented in references given above.

- McCarthy, ***Epistemological problems*** *of* ***Articial Intelligence.***
  An old (1977) but still relevant paper that outlines several representational challenges, many of which still have not been adequately addressed.

- Lenat, Prakash and Shepherd, ***CYC: using common sense knowledge to overcome brittleness and knowledge acquisition bottlenecks.***
  Read enough to understand the motivations and methodolgy of the CYC project.

- Brooks, ***Intelligence without representation.***
  Brooks argues that intelligent entities can be constructed without using explicit representations of knowledge. You might want to consider the relationship between this approach and connectionism.

- Fahlman and Hinton, ***Connectionist architectures*** *for* ***artificial intelligence.***
  An introduction to the connectionist school of thought. The paper summarizes various connectionist models, but does not describe the challenge that connectionism poses to traditional AI: the connectionist claim that massively parallel networks can learn non-symbolic representations contradicts the Physical Symbol System Hypothesis. This issue is further explored in Hinton's response to McDermott's article ***Critique*** *of* ***Pure Reason*** (cited below). You should have a passing familiarity with the fundamentals of connectionism, both technical and epistemological.

- Drew McDermott, Critique *of* ***Pure Reason.***
  McDermott (a former 'logicist') criticizes the logical approach to AI. Included in the issue of Computational Intelligence where this article appeared are a large number of replies to McDermott, many of which are worth reading. The more thought-provoking 'anti-logic' replies are Hinton's (anti-representational), Rosenschein's (situated automata), and Winograd's (anti-AI). Interesting pro-logic responses are provided by Brachman, Hayes and Nilsson.

- ***The Encyclopedia*** *of* ***Artificial Intelligence,*** Limits of AI, pages 488-503.
  A critical perspective on the state of AI by Jack Schwartz. His summaries of the achievements in several subfields are quite thought-provoking. Schwartz's own research is very mathematical, which motivates many of the criticisms.

- Winograd and Flores, ***Computers and Cognition,*** Chapters ***2, 3.***
  A critical view of the intellectual tradition underlying AI, along with some alternative foundations. You should look at the assumptions of rationalism (beginning in section 2.1) and their criticisms of these assumptions (pages 32-35). Many of their remarks are similar to earlier criticisms by Hubert Dreyfus.

- Simon, ***Sciences*** *of* ***the Artificial,*** pages 63-66.
  The parable of Simon's ant demonstrates that a simple system can exhibit complex behavior when it operates in a complicated environment.

11 AI Programming

You should also be familiar with the LISP and PROLOG programming languages. Below are some recommended sources.

- Clocksin and Mellish, ***Programming in Prolog*** (2nd edition).
- Kowalski, Logic ***for Problem Solving.***
- Sterling and Shapiro, ***The Art*** *of* ***Prolog.***
- Abelson and Sussman, ***Structure and Interpretation*** *of* ***Computer Programs.***
- Winston and Horn, ***LISP*** (third edition).
- Charniak and McDermott, ***An Introduction to Artificial Intelligence,*** Chapter 2.

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