International AI Olympiad

Syllabus

Introduction
Search
Knowledge Representation and Reasoning
Machine Learning
Society, Ethics and Professionalism
Logical Representation and Reasoning
Probabilistic Representation and Reasoning
Planning
Agents
Natural Language Processing
Robotics
Perception and Computer Vision

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About this Syllabus

Each chapter covers one area of the syllabus and lists its units (in bold) and their sub-units. Rows are numbered consecutively across the whole syllabus.

Competition Rounds

Theoretical round

Questions in the theoretical round are based **only on the topics presented in the IAIO webinars**.

Practical round

Tasks in the practical round may benefit from approaches drawn from **all topics in this syllabus**.

Ethics

Ethical concerns should be considered in **all aspects of AI design** and will be taken into account in the evaluation of solutions where appropriate, in addition to questions that specifically address ethical issues.

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Introduction

INTRO

ID	Unit
1	**Overview of AI problems; examples of successful recent AI applications**
2	**Definitions of agents with examples**
3	**What is intelligent behavior?**
4	• The Turing test and its flaws
5	• Multimodal input and output
6	• Simulation of intelligent behavior
7	• Rational vs. non-rational reasoning
8	**Problem characteristics**
9	• Fully vs. partially observable
10	• Single vs. multi-agent
11	• Deterministic vs. stochastic
12	• Static vs. dynamic
13	• Discrete vs. continuous
14	**Nature of agents**
15	• Autonomous, semi-autonomous, mixed-initiative autonomy
16	• Reflexive, goal-based, and utility-based
17	• Decision making under uncertainty and with incomplete information
18	• The importance of perception and environmental interactions
19	• Learning-based agents
20	• Embodied agents
21	• Sensors, dynamics, effectors
22	**AI applications, growth, and impact**
23	**Practice identifying problem characteristics in example environments**
24	**Philosophical issues**
25	**History of AI**

Search

SEARCH

ID	Unit
26	**State space representation of a problem**
27	• Specifying states, goals, and operators
28	• Factoring states into representations (hypothesis spaces)
29	**Problem solving by graph search**
30	• Graphs as a space, and tree traversals as exploration of that space
31	• Dynamic construction of the graph (not given upfront)
32	**Uninformed graph search for problem solving**
33	• Breadth-first search
34	• Depth-first search
35	• Depth-first search with iterative deepening
36	• Uniform cost search
37	**Heuristic graph search for problem solving**
38	• Heuristic construction and admissibility
39	• Hill-climbing
40	**Local minima and the search landscape**
41	• Local vs. global solutions
42	• Greedy best-first search
43	• Implementation of A* search
44	**Space and time complexities of graph search algorithms**
45	**Beam search**
46	**Two-player adversarial games**
47	• Minimax search
48	• Alpha-beta pruning
49	• Ply cutoff
50	• The horizon effect
51	• Opening playbooks / endgame solutions
52	• What it means to “solve” a game
53	**Understanding the search space**
54	• Constructing search trees
55	• Dynamic search spaces
56	• Combinatorial explosion of search space
57	• Search space topology (ridges, saddle points, local minima, etc.)
58	**Local search**
59	**Constraint satisfaction**
60	**Tabu search**
61	**Variations on A***
62	**Implementation of minimax search, beam search**

ID	Unit
63	**Expectimax search (MDP-solving) and chance nodes**
64	**Stochastic search**
65	• Simulated annealing
66	• Genetic algorithms
67	• Monte Carlo tree search

Knowledge Representation and Reasoning

KRR

ID	Unit
68	**Types of representations**
69	**Symbolic, logical**
70	• Creating a representation from a natural language problem statement
71	**Learned subsymbolic representations**
72	**Graphical models**
73	**Review of probabilistic reasoning, Bayes' theorem**
74	**Bayesian reasoning**
75	• Bayesian inference, including more complex examples
76	**Random variables and probability distributions**
77	• Axioms of probability
78	• Probabilistic inference
79	• Bayes' rule (derivation)
80	**Independence**
81	**Conditional independence**
82	**Markov chains and Markov models**
83	**Utility and decision making**

Machine Learning

ML

ID	Unit
84	**Definition and examples of a broad variety of machine learning tasks**
85	**Supervised learning**
86	• Classification
87	• Regression
88	• Linear regression
89	• Logistic regression
90	• Decision trees
91	• Nearest-neighbor classification and regression
92	• Learning simple neural networks / multi-layer perceptrons
93	• Support vector machines (SVMs) and kernels
94	• Gaussian processes
95	**Unsupervised learning and clustering**
96	• Clustering
97	• K-means
98	• DBSCAN
99	• Gaussian mixture models
100	• Expectation maximization (EM)
101	• Self-organizing maps
102	**Dimensionality reduction**
103	• Principal component analysis (PCA)
104	• t-distributed stochastic neighbor embedding (t-SNE)
105	• Uniform manifold approximation and projection (UMAP)
106	**Semi-supervised learning**
107	**Reinforcement learning**
108	• Exploration vs. exploitation trade-off
109	• Markov decision processes
110	• Value and policy iteration
111	• Policy gradient methods
112	• Deep reinforcement learning
113	**Fundamental ideas**
114	• No free lunch principle and consequences of design decisions
115	• Sources of error and undecidability in machine learning
116	**Simple statistical-based supervised learning**
117	• Focus on usage and intuition without optimization math details
118	**General statistical-based learning, parameter estimation**
119	**Formulation of simple machine learning as an optimization problem**
120	• Objective function

ID	Unit
121	• Gradient descent
122	**The overfitting problem / controlling solution complexity**
123	• The bias (underfitting) – variance (overfitting) trade-off
124	• The curse of dimensionality
125	• Regularization: mathematical formulation, L1 and L2
126	**Working with data**
127	**Data preprocessing**
128	• Importance and pitfalls of preprocessing
129	**Handling missing values**
130	• Implications of imputing vs. flag-as-missing
131	**Encoding categorical variables (one-hot), encoding real-valued data**
132	**Normalization / standardization**
133	**Emphasis on real data, not textbook examples**
134	**Representations**
135	• Hypothesis spaces and complexity
136	• Manually crafted representations
137	• Simple basis feature expansion (e.g., squaring univariate)
138	• Learned feature representations (e.g., deep neural networks)
139	**Machine learning evaluation and experimental design**
140	• Partitioning data: stratification, train, validation, test splits
141	• Estimation of test performance on held-out data
142	• Tuning the parameters of a machine learning model via validation set
143	• Biases (e.g., algorithmic, search)
144	• Understanding what your model is actually doing and its pitfalls
145	**Performance evaluation**
146	• Performance metrics for classifiers: error, precision, recall, F1
147	• Confusion matrix
148	• ROC curve and area under ROC curve
149	• Performance metrics for regressors (MSE, MAE, R^2)
150	**Cross-validation**
151	• Parameter tuning (grid / random search, via cross-validation)
152	**Basic neural networks**
153	• Fundamentals of the training process
154	• Basic introduction to generative neural networks (LLMs, etc.)
155	**Deep learning**
156	• Deep feed-forward networks
157	• Neural tangent kernel and network training understanding
158	• Convolutional neural networks
159	• Autoencoders
160	• Recurrent networks, transformers, other architectures

ID	Unit
161	• Adversarial training and generative adversarial networks
162	• Representations and knowledge transfer
163	• Visualization of learned feature representations from deep nets
164	**Bayesian learning**
165	• Naive Bayes and its relationship to linear models
166	• Bayesian networks
167	• Prior / posterior
168	• Generative models
169	**Ensembles of models**
170	• Simple weighted majority combination
171	• Boosting / bagging
172	• Random forest
173	• Gated ensemble
174	**Graph analysis**
175	**Learning theory**
176	• General overview of learning theory / why learning works
177	• VC dimension
178	• Generalization bounds
179	**Explainable / interpretable machine learning**
180	• Understanding feature importance (e.g., LIME, Shapley values)
181	• Interpretable models and representations
182	**Recommender systems**
183	**Hardware for machine learning**
184	**Applications of machine learning algorithms**
185	• Medicine and health
186	• Economics
187	• Education
188	• Vision
189	• Natural language
190	• Robotics
191	• Game play
192	• Data mining

Society, Ethics and Professionalism

SEP

ID	Unit
193	**Applications of AI to a broad set of problems and diverse fields**
194	• Formulating and evaluating a specific application as an AI problem
195	**Data availability and cleanliness**
196	• Basic data cleaning and preprocessing
197	• Dataset bias
198	• Algorithmic bias
199	• Evaluation bias
200	**Deployed deep generative models**
201	• Overview of deep image generative models (DALL-E, Midjourney, etc.)
202	• Overview of large language models (ChatGPT, Gemini, etc.)
203	**Societal impact of AI**
204	• Ethics
205	• Fairness
206	• Trust / explainability
207	• Privacy and usage of training data
208	• Human autonomy and oversight
209	• Sustainability
210	**Ethics for machine learning**
211	• Focus on real data, real scenarios, and case studies
212	• Dataset / algorithmic / evaluation bias
213	• Privacy
214	• Fairness
215	• Trust / explainability

Logical Representation and Reasoning

LRR

ID	Unit
216	**Review of propositional and predicate (first-order) logic**
217	**Resolution and theorem proving**
218	• Forward chaining, backward chaining
219	**Knowledge representation issues**
220	• Description logics
221	• Ontology engineering
222	**Semantic web**
223	**Non-monotonic reasoning**
224	**Argumentation**
225	**Reasoning about action and change**
226	**Temporal and spatial reasoning**
227	**Logic programming**
228	• Prolog, Answer Set Programming
229	**Rule-based expert systems**
230	**Semantic networks**
231	**Model-based and case-based reasoning**

Probabilistic Representation and Reasoning

PROB

ID	Unit
232	**Knowledge representations for reasoning under uncertainty**
233	**Bayesian networks**
234	• Exact inference and its complexity
235	• Markov blankets and d-separation
236	• Randomized sampling (Monte Carlo) methods
237	**Markov networks**
238	**Relational probability models**
239	**Hidden Markov models**
240	**Decision theory**
241	• Preferences and utility functions
242	• Maximizing expected utility
243	• Game theory

Planning

PLAN

ID	Unit
244	**Planning operators and state representations**
245	**Total-order planning**
246	**Partial-order planning**
247	**Plan graphs and GraphPlan**
248	**Hierarchical planning**
249	**Planning languages and representations**
250	• PDDL
251	**Multi-agent planning**
252	**MDP-based planning**
253	**Interconnecting planning, execution, and dynamic replanning**
254	• Conditional planning
255	• Continuous planning
256	• Probabilistic planning

Agents

AGENTS

ID	Unit
257	**Agent architectures**
258	**Agent theory**
259	**Rationality, game theory**
260	**Decision-theoretic agents**
261	• Markov decision processes (MDP)
262	• Bandit algorithms
263	**Software agents, personal assistants, and information access**
264	• Collaborative agents
265	• Information-gathering agents
266	• Believable agents (synthetic characters, emotional modeling)
267	**Learning agents**
268	**Cognitive architectures**
269	• Capabilities (perception, decision, prediction, etc.)
270	• Knowledge representation, utilization, refinement
271	• Applications and evaluation of cognitive architectures
272	**Multi-agent systems**
273	• Collaborating agents
274	• Agent teams
275	• Competitive agents (e.g., auctions, voting)
276	• Swarm systems and biologically inspired models
277	• Multi-agent learning
278	**Human-agent interaction**
279	• Communication methodologies (verbal and non-verbal)
280	• Practical issues
281	**Applications**
282	• Trading agents, supply chain management

Natural Language Processing

NLP

ID	Unit
283	**Deterministic and stochastic grammars**
284	**Parsing algorithms**
285	• CFGs and chart parsers (e.g., CYK)
286	• Probabilistic CFGs and weighted CYK
287	**Representing meaning / semantics**
288	• Logic-based knowledge representations
289	• Semantic roles
290	• Temporal representations
291	• Beliefs, desires, and intentions
292	**Corpus-based methods**
293	**N-grams and HMMs**
294	**Smoothing and backoff**
295	**Examples of use: POS tagging and morphology**
296	**Information retrieval**
297	**Vector space model**
298	• TF and IDF
299	• Precision and recall
300	**Information extraction**
301	**Language translation**
302	**Text classification, categorization**
303	• Bag of words model
304	**Deep learning for NLP**
305	• RNNs
306	• Transformers
307	• Multimodal embeddings (e.g., images + text)
308	• Generative language models

Robotics

ROBO

ID	Unit
309	**Overview: problems and progress**
310	• State-of-the-art robot systems and sensor processing overview
311	• Robot control architectures (deliberative vs. reactive)
312	• World modeling and world models
313	• Inherent uncertainty in sensing and in control
314	**Sensors and effectors**
315	• Sensors: LIDAR, sonar, vision, depth, event cameras, etc.
316	• Effectors: wheels, arms, grippers, etc.
317	**Coordinate frames, translation, and rotation**
318	**Configuration space and environmental maps**
319	**Interpreting uncertain sensor data**
320	**Localization and mapping**
321	**Navigation and control**
322	**Forward and inverse kinematics**
323	**Motion path planning and trajectory optimization**
324	**Joint control and dynamics**
325	**Vision-based control**
326	**Multiple-robot coordination and collaboration**
327	**Human-robot interaction**
328	• Shared workspaces
329	• Human-robot teaming and physical HRI
330	• Social assistive robots
331	• Motion / task / goal prediction
332	• Collaboration and explicit vs. implicit communication
333	• Trust

Perception and Computer Vision

VISION

ID	Unit
334	**Computer vision**
335	• Image acquisition, representation, processing and properties
336	• Shape representation, object recognition, and segmentation
337	• Motion analysis
338	• Generative models
339	**Audio and speech recognition**
340	**Touch and proprioception**
341	**Other modalities**
342	**Modularity in recognition**
343	**Approaches to pattern recognition**
344	• Classification algorithms and measures of quality
345	• Statistical techniques
346	• Deep learning techniques