GLOSSARY

A B C D E F G H I J L M N O P Q R S T U W

A

- **Alpha-beta pruning**: A search-based algorithm for the implementation of deterministic two-player zero-sum games of perfect information. It seeks to cut off paths in a state space graph of a game if a particular move is considered to be detrimental. By performing cut-offs, the algorithm improves the search efficiency.
- **Alpha-cut-off**: A type of cut-off performed by alpha-beta pruning. It cuts off paths that lead to moves that are not beneficial for the maximiser player.
- **Alpha number:** A numerical value assigned in alpha-beta pruning to nodes of a state space graph of a game that correspond to states from which the maximiser makes moves. This defines the best move that can be made to maximise the result of the game. Hence, this value should not decrease, since this would represent a bad move for the maximiser.
- **Arc of a state space graph:** A constituent part of a state space graph. This represents a directed connection between two nodes in the state space graph, and thus indicates a transition between problem-solving states, or, in other words, an executable action in a problem-solving process.
- **Artificial general intelligence:** An approach to artificial intelligence that treats intelligence as a general capability that can be copied/replicated, and is therefore associated with the development of computer systems that are capable of solving a wide range of tasks and controlling themselves autonomously.
- **Artificial narrow intelligence:** An approach to artificial intelligence that develops computer systems that perform a single narrow task like playing chess, driving a car, etc.
- **Artificial super intelligence:** An approach to artificial intelligence in which the aim is to develop an artificial intelligence that is much smarter than the best human minds, and is able to outperform humans in practically every field, including scientific creativity, general wisdom and social skills.

B

- **Backtracking:** A general search strategy for systematically trying different paths through a state space graph and avoiding problems such as struggling in cycles and repeatedly considering the same nodes. It is based on the idea that if the search goal node is not reached by the current path, then it is necessary to backtrack to the most recent node

on the path with unexamined descendants/ancestors (depending on the search direction) and to try another path.

- **Backward chaining:** See Goal-driven search.
- **Beam search:** A heuristic graph search algorithm that considers a limited number of the best nodes in each iteration, based on a defined parameter called a beam width.
- **Beam width:** A numerical parameter used in a beam search that defines the number of the best nodes examined at each iteration of the search.
- **Best-first search:** A heuristic graph search algorithm that keeps track of all of the nodes found previously but considers only one best node at each iteration. This means that the algorithm does not discard a problem solution if the heuristic evaluation function is not well-defined.
- **Beta-cut-off:** A type of cut-off performed in alpha-beta pruning. This cuts off paths that lead to moves that are not beneficial for the minimiser player.
- **Beta number:** A numerical value that is assigned in alpha-beta pruning to nodes of a state space graph for a game corresponding to states from which the minimiser makes moves. It defines the best move that can be made to minimise the result of the game. This value should not increase, since this would represent a bad move for the minimiser.
- **Bidirectional search:** An uninformed graph search algorithm that performs a search simultaneously in both directions of a state space graph (a data-driven search and a goal-driven search), until it finds a point of contact in both directions. It explores a state space graph in the manner of the breadth-first search algorithm.
- **Branching factor:** A numerical factor that is used to characterise the complexity of a state space graph. It is the average number of arcs per node, and is calculated by dividing the sum of the direct descendants of all nodes by the total number of nodes in the state space graph.
- **Breadth-first search:** An uninformed graph search algorithm that considers the nodes of a state space graph in a levelwise manner (sequentially at the same level, before going deeper) and finds the first (usually the shortest) path that leads to the search goal node.

C

- **CLOSED list:** A data structure that is used in the implementation of uninformed and heuristic graph search algorithms. It contains nodes that have been already expanded (the so-called ‘closed’ nodes) while searching for a solution in a state space graph.
- **Closed node:** A node acquired in a search process of a state space graph for which the descendants/ancestors (depending on the search direction) have already been generated by a search algorithm.
- **Complete state space graph:** A state space graph that includes all states, from the initial state of the problem (represented by the root node of the graph), to all goal states of the problem (represented by leaf nodes).

- **Complexity of a state space graph:** A property of a state space graph that is typically associated with the total number of nodes in the search. It is calculated based on the branching factor and the depth of the state space graph.

D

- **Data-driven search:** A type of search performed in a state space graph. It starts from the given data for a problem and proceeds toward a goal. In other words, the search process starts from a root node and proceeds in a forward direction in the state space graph until it reaches the defined leaf node.
- **Depth-first search:** An uninformed graph search algorithm that traverses a state space graph in a depthward manner (by going deeper and deeper into the state space graph while expanding nodes), and finding the first path that leads to the search goal node.
- **Depth-limited search:** An uninformed graph search algorithm that traverses a state space graph in a depthward manner (by going deeper and deeper into the state space graph, while expanding nodes) until it reaches a pre-defined depth limit.
- **Depth limit:** A numerical parameter used by a depth-limited search to define how deeply the state space graph can be explored. The algorithm does not consider nodes located below this depth limit.
- **Depth of the state space graph:** A numerical factor used to characterise the complexity of a state space graph. It is usually the length of the longest path in the state space graph.
- **Deterministic two-player zero-sum game of perfect information:** A type of game that is characterised by the following aspects:
    - The players make alternate moves until the end of the game (i.e. the first player moves, the second player moves, the first player moves, and so on);
    - Both players have access to complete information about the course of the game (including past moves, future moves, and the available objects (e.g. cards or figures) used in the game). Hence, no information is hidden from either player;
    - Randomness factors (e.g. the use of a die) are not involved in these types of games;
    - One player's loss is equal to another player's gain, giving a total sum of zero.

E

- **Expert task of artificial intelligence:** A type of task that is attributed to artificial intelligence. This denotes a specialised task that needs a particular expertise, for example, engineering (design, fault-finding,

manufacturing planning), scientific analysis, medical diagnosis, or financial analysis.

F

- **Formal representation**: A problem representation technique that uses mathematical concepts to represent objects from the real world and their behaviour in such a way that they can easily be transformed into computational objects.
- **Formal specification**: See Formal representation.
- **Formal task of artificial intelligence**: A type of task that is attributed to artificial intelligence. It denotes a task that can be described mathematically, for example a game (chess, checkers, etc.), geometry, logic, integral calculus, and others.
- **Forward chaining**: See Data-driven search.
- **Fully available state space graph**: See Complete state space graph.

G

- **Game result**: A numerical value assigned to the root node of a state space graph of a game when using algorithms such as Minimax and alpha-beta pruning. It reflects the result of the game if both players play rationally, without making mistakes, and with the aim of winning the game.
- **Goal-driven search**: A type of search performed in a state space graph. It starts from a given goal and proceeds back to the data. In other words, the search process starts from a leaf node of a state space graph, and proceeds in a backward direction in the state space graph.
- **Goal state of the problem-solving process**: A state that one wants to achieve in a problem-solving process.

H

- **Heuristic evaluation function**: A mathematical function used by a heuristic search algorithm to evaluate the quality of nodes in a state space graph. It usually represents heuristic knowledge used by an intelligent computer and helps a heuristic search algorithm to determine the direction of the location of the search goal node.
- **Heuristic knowledge**: Experience-based rules that allow people to solve problems, make decisions, and reason in a more effective way.
- **Heuristic measure**: A numerical value allocated by a heuristic evaluation function to represent the quality of a specific node in a state

space graph, in terms of the costs associated with reaching the search goal node.

- **Heuristic search**: A type of search that uses not only the state space graph (that is, its nodes and arcs) but also additional information about the quality of the nodes.
- **Heuristics**: See Heuristic knowledge.
- **Hill climbing**: A heuristic graph search algorithm that considers only one (the best) node in the state space graph in each iteration of the search process.
- **Horizon effect**: An effect caused by the depth limitation of a search algorithm. It can lead to negative manifestations such as an inability to find the search goal node.

I

- **Initial state of the problem-solving process**: The state from which one starts solving a problem.
- **Internal node of a state space grap**h: A node in a state space graph that corresponds to an intermediate state of a problem-solving process. From a structural viewpoint, it is a node that has both ancestors and descendants.
- **Iterative deepening**: A search strategy used in the implementation of a deterministic two-player zero-sum game of perfect information in which a time limit is imposed on making the next move in the game. It traverses the state space graph in a levelwise manner, increasing the depth of exploration of the graph for as long as the time limit allows.

J

- **John Searle's Chinese room argument**: A famous example of criticism of the symbolic paradigm of artificial intelligence and the Turing test. It claims that the manipulation of symbols is a fundamentally unintelligent process.

L

- **Leaf node of a state space graph**: A node in a state space graph that corresponds to a goal state of a problem-solving process. From a structural viewpoint, it is a node that has no descendants.
- **List**: A type of data structure that stores a set of data elements in sequential order.

- **Local maximum problem**: A shortcoming of the hill-climbing algorithm that manifests in an inability of the algorithm to reach the search goal node, as the algorithm finds a node that has a better heuristic measure than the heuristic measures of its descendants/ancestors (depending on the search direction). This shortcoming comes into play only when the heuristic evaluation function used by the algorithm is not well-defined.

M

- **Maximiser**: A label used in a game algorithm such as Minimax or alpha-beta pruning to denote a player whose playing strategy is to win the game.
- **Minimax algorithm**: A search-based algorithm for the implementation of a deterministic two-player zero-sum game of perfect information in which the quality of each node in a state space graph of the game is evaluated to find the optimal next move.
- **Minimiser**: A label used in a game algorithm such as Minimax or alpha-beta pruning to denote a player whose playing strategy is to do everything possible to prevent the maximiser from winning the game, by trying to lead the game into a state that is the worst outcome for the maximiser.
- **Mundane task of artificial intelligence**: See Routine task of artificial intelligence.

N

- **N-ply look ahead**: A search strategy used in the implementation of a deterministic two-player zero-sum game of perfect information that can be represented only by a partial state space graph, due to insufficient computational resources. To find the next move, it explores a limited number of levels of the state space graph.
- **New artificial intelligence**: An approach to artificial intelligence based on the assumption that true intelligence involves the ability to function in a real-world environment, and in which the focus is on studying and imitating the intelligence not only of humans but of a wider range of organisms, processes, and phenomena that occur at multiple spatial and temporal scales, for example the behaviour of fish and birds.
- **Node of a state space graph**: A component of a state space graph that corresponds to a discrete state of a problem-solving process.
- **Node level**: A typical part of a state space graph created for a deterministic two-player zero-sum game. Each node level contains one or more nodes that display states of the game from which only one of the two players can make a move.
- **Nouvelle artificial intelligence**: See New artificial intelligence.

O

- **OPEN list**: A data structure used in the implementation of an uninformed and heuristic graph search algorithm. It contains nodes that have been already generated in the search process (the so-called ‘open’ nodes) for which the ancestors/descendants (depending on the search direction) have not yet been generated.
- **Open node**: A node acquired in a search process of a state space graph. It represents a node that has already been generated, but for which the descendants/ancestors have not yet been generated.

P

- **Parameters characterising states in the game**: A set of properties of a game and its course that are used in a computer implementation of a game. The values of the properties change after making a move during the course of the game, and this allows the players to track the course of the game, since they determine a specific state in the game at a specific moment in time. The values of these parameters should be represented at each node of the state space graph. The parameters depend on the game and thus may differ widely; for example, they may include the scores for each player, the current game board, or both the scores of the players and the current game board.
- **Partly available state space graph**: A state space graph generated to the specified depth allowed by the available computational resources. It is a sub-graph of the complete state space graph, and usually includes states between a specific node and a predefined depth.
- **Partial state space graph**: See Partly available state space graph.
- **Physical symbol system**: A concept used to define the physical symbol system hypothesis, which forms the basis of the symbolic paradigm of artificial intelligence. It refers to a system that is characterised by the following aspects:
    - Symbols that correspond to meaningful physical patterns that could represent any form of knowledge, experience, concepts, and causality
    - Symbolic structures consisting of symbols that are connected in some physical way. These symbolic structures represent the essential aspects of a problem domain
    - Operations (construction, copying, modification, and destruction) that are used to manipulate existing symbolic structures and to create new ones
    - The operations can themselves be represented by symbols and symbolic structures within the system.
- **Physical symbol system hypothesis**: The hypothesis underlying the symbolic paradigm of artificial intelligence. “A physical symbol system

has the necessary and sufficient means for general intelligent action" (Newell & Simon, 1976).

- **Plateau problem**: A shortcoming of the hill climbing algorithm that manifests in the inability of the algorithm to continue the search in the case where all descendants/ancestors (depending on the search direction) have the same heuristic measures as the current node. This shortcoming comes into play only when the heuristic evaluation function used by the algorithm is not well-defined.
- **Priority queue**: A data structure in which the sequence of storing and processing data elements depends on the priorities associated with them; elements with high priority are stored and processed before those with low priority.

Q

- **Queue**: A linear data structure that operates on the "first in, first out" principle, in which the first data element that entered the queue is the first to be processed.

R

- **Root node of a state space graph**: A node in a state space graph that corresponds to an initial state of a problem-solving process. From a structural viewpoint, it is a node that does not have ancestors.
- **Routine task of artificial intelligence**: A type of task that is attributed to artificial intelligence. It denotes a task that humans do every day and that could be done by an intelligent computer system, such as perception (visual, speech), natural language processing (understanding, generation, and translation), common sense reasoning, and robot contro.

S

- **Search algorithm:** An algorithm that processes a state space graph to find a solution to a problem based on known input data. The task of any search algorithm is to find a solution path, if such a path exists in the state space graph.
- **Search goal node**: A particular node in the state space graph that should be reached when searching for a solution using a search algorithm.

- **Search start node**: A particular node in the state space graph that serves as a starting point when searching for a solution using a search algorithm.
- **Solution path**: A path through the state space graph from a given search start node to a given search goal node. It is the output expected from a search algorithm, as it corresponds to an ordered sequence of actions that lead to the solution to the problem.
- **Stack**: A linear data structure that operates on the “last in, first out” principle, in which the last data element that entered in the stack is the first to be processed.
- **State**: A set of values for the properties of a given object or phenomenon at a specified time.
- **State space graph**: A formal representation of a problem-solving process. It is a mathematical structure consisting of nodes, which represent discrete states of the problem-solving process, and directed arcs, which represent actions in the problem-solving process.
- **Strong artificial intelligence**: See Artificial general intelligence.
- **Strong methods of artificial intelligence**: These are methods used in the development of intelligent computer systems. They incorporate and process large amounts of knowledge about a problem under consideration, and take into account the problem-solving context. Strong methods typically use weak methods of artificial intelligence.
- **Symbolic paradigm of artificial intelligence**: A paradigm of thought used in artificial intelligence that is based on the physical symbol hypothesis, in which information processing involves rule-governed transformations and the manipulation of symbol-based physical structures.

T

- **Terminal node of a state space graph**: See Leaf node of a state space graph.
- **The total Turing test**: A variation of the Turing test developed by Harnad in 1991 that considers not only the verbal behaviour of an intelligent computer system but also its capabilities to perceive and manipulate objects.
- **The Turing test**: One of the methods of enquiry used in artificial intelligence to test a computer’s ability to exhibit intelligent behaviour that is similar to or indistinguishable from that of a human. The test was developed by Alan Turing in 1950, and is mainly based on testing the verbal behaviour of an intelligent computer system.

U

- **Uninformed search**: A type of search that uses only the state space graph, or, in other words, its nodes and arcs. This kind of search is also called a brute force or blind search, as it explores the state space graph sequentially. Algorithms in this category are unable to determine whether one node is better than another by taking into account the costs of reaching the search goal node.

W

- **Weak artificial intelligence**: See Artificial narrow intelligence.
- **Weak methods of artificial intelligence**: Methods used in the development of intelligent computer systems that are based on general methods (such as general-purpose searches, logic, syntax-based calculations, automatic reasoning, etc.) which could be applied to a broad set of problems. They do not incorporate and process knowledge about a problem under consideration.
- **Winning path**: A path identified at the end of the application of a game implementation algorithm such as Minimax or alpha-beta pruning in the case where the complete state graph is used. It is not a path that definitely leads to a win by a particular player, but instead shows the course of the game that is most likely to be undertaken. Winning paths are identified based on the results of the game. A winning path is one that starts at the root node and reaches a leaf node while satisfying the following conditions:
    - All nodes on the winning path are closely related
    - All nodes on the winning path have the heuristic measures, which are equal to the game result.