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18. Artificial Intelligence techniques

a. Expert systems: definitions, knowledge base, data base, inference mechanisms.

b. ANN architectures and design problems, application examples.

c. Fuzzy logic in power system protection: fuzzy criteria signals, fuzzy settings, fuzzy comparison.

d. Genetic algorithms: genetic modifications of individuals, genetic optimization rules, application examples.

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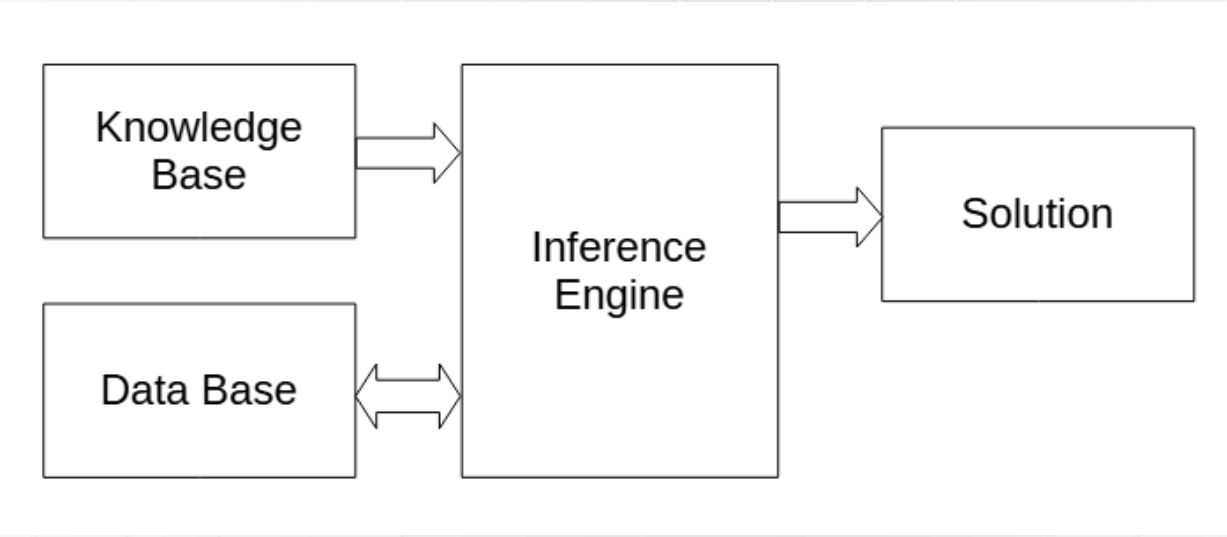
Expert Systems (ES)

Software that in certain way expresses and simulates the reasoning of a human expert by solving tasks from given knowledge domain.



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Expert Systems (ES)

Components

- Knowledge Base – Contains the knowledge about the system, its functioning, rules of problem solving, etc.
- Data Base – Includes the facts, which generally describe the domain and the state of the problem to be solved.
- Inference Engine – Reasoning principles and conflict resolution strategies. There are two types of inference methods:
  - Forward Chaining - Known facts are used to test all the hypotheses.
  - Backward Chaining - Proposed hypotheses must be proven using facts.

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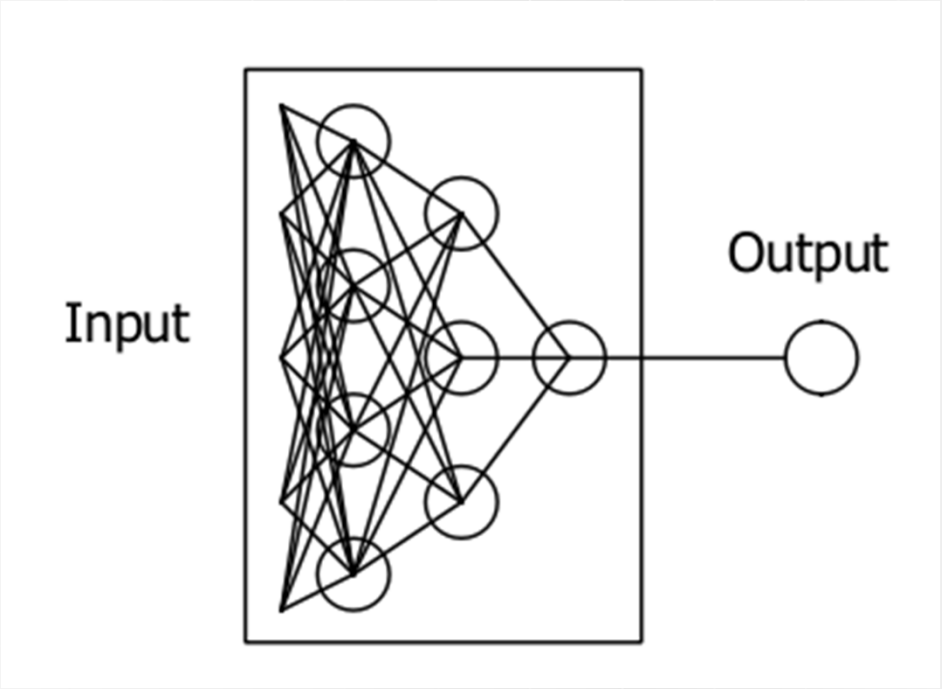
Artificial Neural Networks (ANN)



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Artificial Neural Networks (ANN)

ANN is a set of processing units that perform linear or non-linear operations. There are several neural network types. The most frequently applied are the following (in brackets the frequency of application for power system protection tasks):

- Multilayer perceptron networks (81%) – Three- or four-layer feed-forward networks, networks with radial basis function.
- Hoppfield networks (6%) – Bolzmann machines, Gauss networks, chaotic networks.
- Kohonen networks (8%) – Two- or three-dimensional grid nets.
- Support Vector Machines (5%)

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Artificial Neural Networks (ANN)

Design problems

Overfitting (Memorization) – Occurs when our model becomes good at being able to classify or predict on data that was included in the training set, but is not as good at classifying data that it wasn't trained on.

Cross validation - When training a model, it is important not to overfit or underfit it. Your choice of training set and test set are critical in reducing this risk. Is a technique used to assess a machine learning model and test its or accuracy.

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Artificial Neural Networks (ANN)

The next examples of the ANN applications for power system protection and control tasks are:

- Protection of transmission and distribution lines (fault detection and classification, fault direction discrimination, auto reclosing and fault location functions).
- Power transformer monitoring, protection functions (e.g. stabilization against inrush conditions).
- Generator protection (e.g. out-of-step)

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Fuzzy Logic (FL)

Fuzzy logic is a set of mathematical principles for knowledge representation based on degrees of membership.

Fuzzy Logic structure

- Fuzzification - Real input signals are converted into their fuzzy counterparts (fuzzy numbers).
- Fuzzy reasoning - Fuzzy criteria signals are processed and, after comparison with fuzzy settings, some fuzzy decision/output signals are generated.
- Defuzzification - Conversion of the fuzzy outputs into crisp numbers (real output signal or decision).

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Fuzzy Logic (FL)

In power system protection

- Fuzzy criteria signals compensate the inaccuracy during transients of classical approach.
- Fuzzy settings compensate for the trade-offs in relay settings (thresholds) e.g. a fuzzy curve.
- Multi-criteria decision-making improves security and dependability (several protection criteria used in parallel).

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Fuzzy Logic (FL)

Application of fuzzy logic in power systems, and especially in power system protection and control, one can enumerate the following:

- Identification of fault type in transmission lines.
- Fault location on a line.
- Fuzzy multi-criteria protection of power transformer.

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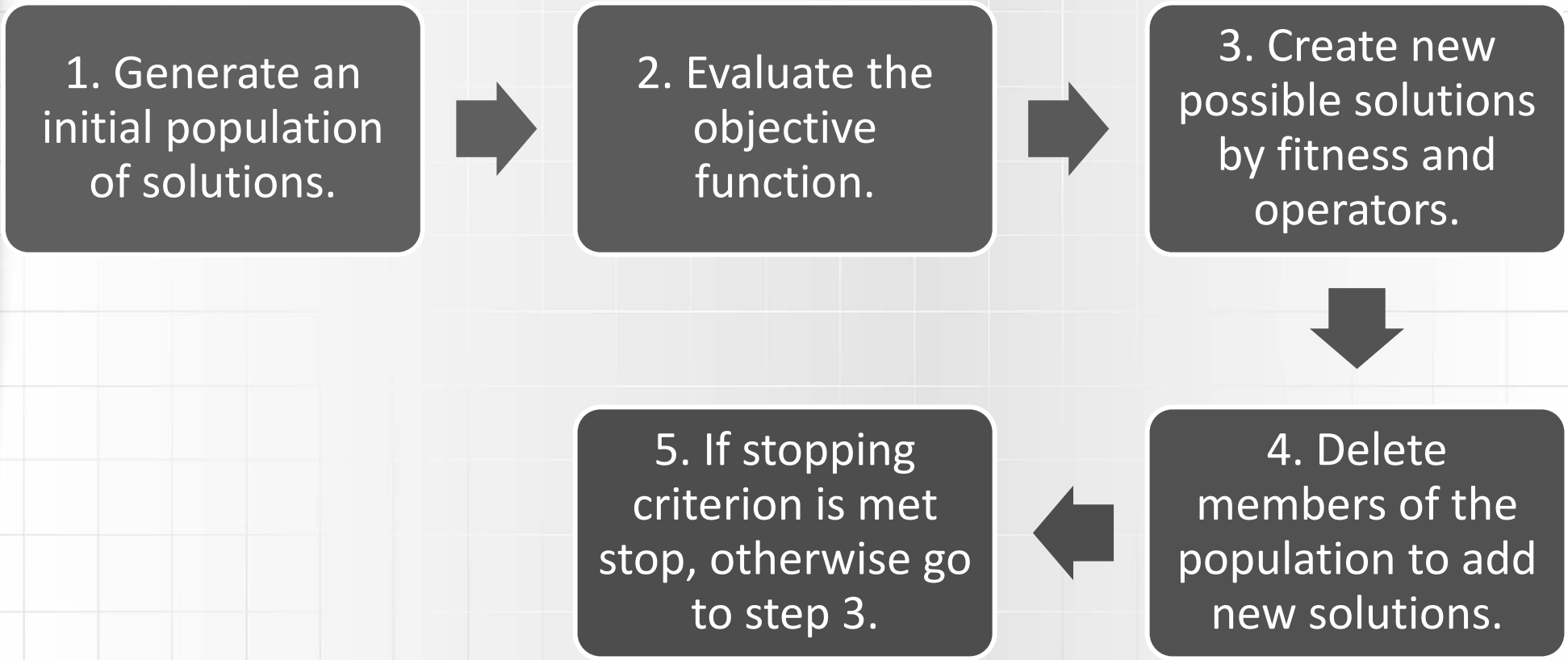
Genetic Algorithms (GA)

Genetic optimization iteratively improves the quality of solutions until an optimal, or at least feasible, solution is found.



Genetic Algorithms (GA)

Fitness

Optimization algorithms require objective functions or cost functions to provide a measure of the quality of the solution in the solution space. GAs require the best solution to have the highest chance of being selected by the selection procedure.

Ranking methods

In fitness ranking, the individuals are sorted according to their objective value and the fitness is calculated from the position of the individual in the sorted list.

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Genetic Algorithms (GA)

Selection methods

- Wheel of roulette – Individuals are ordered according to their fitness.
- Stochastic universal sampling – N parents are selected from the ranking
- Truncation selection - Percentage of individuals are selected.
- Tournament selection – Pairs of individuals compete.

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GA Operators

Crossover

Is used to recombine or exchange parts of the selected parents to produce new offspring.

Mutation

Introduces an element of chance by modifying heuristically elements of existing solutions. The simplest mutation that is considered as being a traditional mutation operator is that of binary mutation.

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GA Operators

Application examples of genetic algorithms in power systems:

- Current transformer saturation detection with genetically optimized neural networks.
- Genetic optimization of settings of the overcurrent protection relays.