

**supervised learning**: distinguish input and output, interest in prediction, minimize prediction error

**unsupervised learning**: no distinct variables, look for data structure, minimize compression rate, reconstruction error

**reinforcement learning**: agent interacts with an environment, learn policy, action is rewarded, maximize total reward

**optimal solution** for a set of solutions for a certain formula; could be formulas, or graphs, or salesman-like problems. graph:

1) min  $f(x) = \max \{-f(x)\}$  2) E.g.,  $X = \mathbb{R}^D$ ,  $x = \{0,1\}^D$  3) Optimal solution:  $\forall x \in X, f(x^*) \leq f(x)$  and  $\forall c \in \{x^* - \epsilon, x^* + \epsilon\}$

**Blind search**: depth first(dive down), breadth first (left to right, rows). vs **heuristic** → estimate closeness to goal state. Convex/non-convex(always approaching lowest), deterministic/stochastic (same result for input), constrained/unconstrained (rules algo has to adhere to),

continuous/discrete(does environment change?), global/local(individual prediction vs entire problem).

**0th order**: derivative-free (hill, iterated local), 1st order, gradient-based (descent, adam), hessian based; 2nd order(newton's). **Gradient** goes towards the lower point (negative derivative in certain points). Step size importance: too low, too slow, too high, bounce around. **Stuck local**, only continuous, function has to be smooth and differentiable, not differentiable when: objective function unknown, discrete search space. **Random** → fails high-dimensional, high evaluation count. **Local search** can help; find the best in a certain area, then go from best. Similar to gradient in essence. All about exploitation vs exploration. Population based; multiple solutions, pick best. Derivative slow, many eval, no guarantees. **Probabilistic learning**

bernoulli distribution:  $p(c|x) = (x^c)^c(1-x)^{1-c}$ . Chance 1 thing happens depending on other observation odds.  $\mathcal{D} = \{c_1, c_2, \dots, c_N\}$  - iid observations (data) EXAMPLE:  $\mathcal{D} = \{0,0,1,1,0,1,1\}$ . The likelihood function:  $N p(\mathcal{D}|x) = \prod p(c_n|x)_{n=1}$ . We want to minimize the log-likelihood function,  $\min -\log p(\mathcal{D}|x)_{x \in [0,1]}$ . Negative because easier to minimize, lowest negative is the highest maximum.

logarithm; Because:  $\log \prod = \sum \log$  and optimum is the same.

1) Determine  $p(y|x)$ . 2) Determine  $p(\mathcal{D}|x)$ . 3) Check constraints. 4) Find the best solution by minimizing  $-\log p(\mathcal{D}|x)$ .

**Sampling methods**: perform a lot to see relative frequencies. Used to estimate  $\pi$ . Problem with sampling: curse of dimensionality → grid on unit interval  $(10^2$  points). If  $2d \rightarrow (10^4)$ . Scales insanely fast, unsustainable. So, a sample based on the past (**markov chain**), proposal distribution  $q(x|xt-1)$  makes a chain corresponding to sample original distribution. Has to be irreducible and aperiodicity. Positive probability of visiting all states and not getting trapped in a cycle. **Metropolis Hastings algo**. Work with acceptance probability. Sample only if it gets picked. Too small → omission, large → low accept. Simulated annealing improves, set  $T_{t+1}$  according to the cooling schedule. SLOWly accept less over time. Version with sampling is stochastic, the best current is deterministic. **Evolutionary algo 1**. Improve performance, search through multiple candidate solutions. Use info about quality to speed up optimization? example; multiple chains diff temperature. Generate options through probability distributions, or transform candidates previous solutions. Take insp from nature; genotype, gene.

**Genetic algorithm**: fitness for each option. 2 parents, have crossover points (take digits from the other parent) and mutate 1 thing. **Evo algo 2**: selection operator.

Evolve free structured programs (function set, terminal set), symbolic regression, LISP. (encode program in string). **Distribution algorithm** The general scheme; 1. (init) Initialize a population of solutions,  $\mathcal{P}_1 := \mathcal{P}_0$ , and evaluate. 2.Repeat until STOP: (i) (Modeling) Learn a distribution  $p_t(x, f)$  using  $\mathcal{P}_t$ . (ii) (Generate) Generate new solutions,  $\mathcal{P}_{t+1}$ , by sampling from  $p_t(x, f)$ . (iii) (Evaluate) Evaluate new solutions. (iv)(Select) Set  $\mathcal{P}_{t+1}$  to  $\mathcal{P}_t+1$ . With linear dynamic scaling, we can **adapt fitness function**:  $f_t(x) = \alpha f(x) + (1-\alpha) f_{t-1}(x)$  :  $x^* \in \mathcal{P}_t$ . Issues; dominance (individual surpasses all), crowding: dense population in few regions, vanishing selective pressure (difference too small, may fail to improve solution). Selection mechanisms either build upon survivors or recombination of parents.

$p = f(x) / \sum f(x)$  (Assume maximization). **Mutation**: Transformation depends on representation. Change integers, bits, graphs/trees? Flipping bits is the easiest example. integers; random resetting (sample mask/integers). Mutate continuous: random perturbation (gaussian, cauchy, uniform). Perturb:  $x' = x+y$ . Differential; sample two individuals, perturb:  $x' = x+a*(x1-x2)$ . Permutations mutate; swap, insert, scramble, inverse. For trees; crossover point at intersection. **Parents-evol**: n-point crossover. Uniform; every other digit. Arithmetic; simple; change part, single arith; single position, whole; change all. In trees, select two points where the other tree is continuous and the other way around. **Collective intel**. Ants and bees work based on others. decentralized, distributed, self-organization, emergence, bottom-up, agent-based, irreducibility. Artificial ants pick a data object with a probability inversely proportional to the number of similar objects around, and drop the object with the probability proportional to the number of similar objects around. **Neural network** Fully connect; input → hidden → output (all nodes connected). Recurrent; hidden points to itself. convolutional; feature extraction phase+classification with fully connected. Convolution and pooling first. This makes a convolutional network. In a neuron;  $z = x1w1+x2w2+b$ . **Sigmoid neuron**; converters to numbers based on formula;  $(1/1+\exp(-z))$ . **Fully connected neural net**: Linear layer;  $a: Wx = \sum w_j x_j$ , j times. After linear layer → nonlinearity. Make it so the line can curve. These nonlinearities are: sigmoid, tanh, relu, leaky relu. Sigmoid is good for the last layer. **Multiclass sigmoid** → softmax, sums probabilities up to 1. **tanh**; converts numbers into probability between -1,1, centering around 0. **RELU** → 0 if negative, else z (g(z) = max(0,z)). Zero gradient though. **Leaky relu**;  $g(z) = \max(\epsilon z, z)$  with  $\epsilon < 1$ . Fast computation and no more zero gradient! **Logistic regression** model y with Bernoulli distribution.  $p(y|x, \theta) = \text{Bern}(y|\text{sigmoid}(\theta^T x))$ . We make use of sigmoid → can model probabilities. Make it so we find the best set of parameters for O with a line. Either analytical ( $\delta/\delta\theta = 0$ ), or gradient (sum over the earlier formula (bern) for each node). Use mini batches if n is large during gradient. **neural 2**: parameters of distribution:  $\mathcal{D} = \{(\theta_i, y_i)\}_{i=1}^N$ .

	Genetic Algorithms	Genetic Programming	Evolution Strategies	Differential Evolution	Estimation of Distribution Algorithms
Representation	Binary strings	Tree-structured programs	Real-valued	Real-valued	Real-valued
Encoding length	Fixed	variable	Fixed	Fixed	Fixed
Operators	Selection, crossover, mutation	Selection, crossover, mutation	Selection, mutation	Selection, crossover, mutation	Selection, (modeling, mutation)
Self-Adaptation	None	None	Standard deviations and covariance	None	Standard deviations

# Comp Intel Modelling Control 1

**WJ Hussar**



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