SIMULATED ANNEALING

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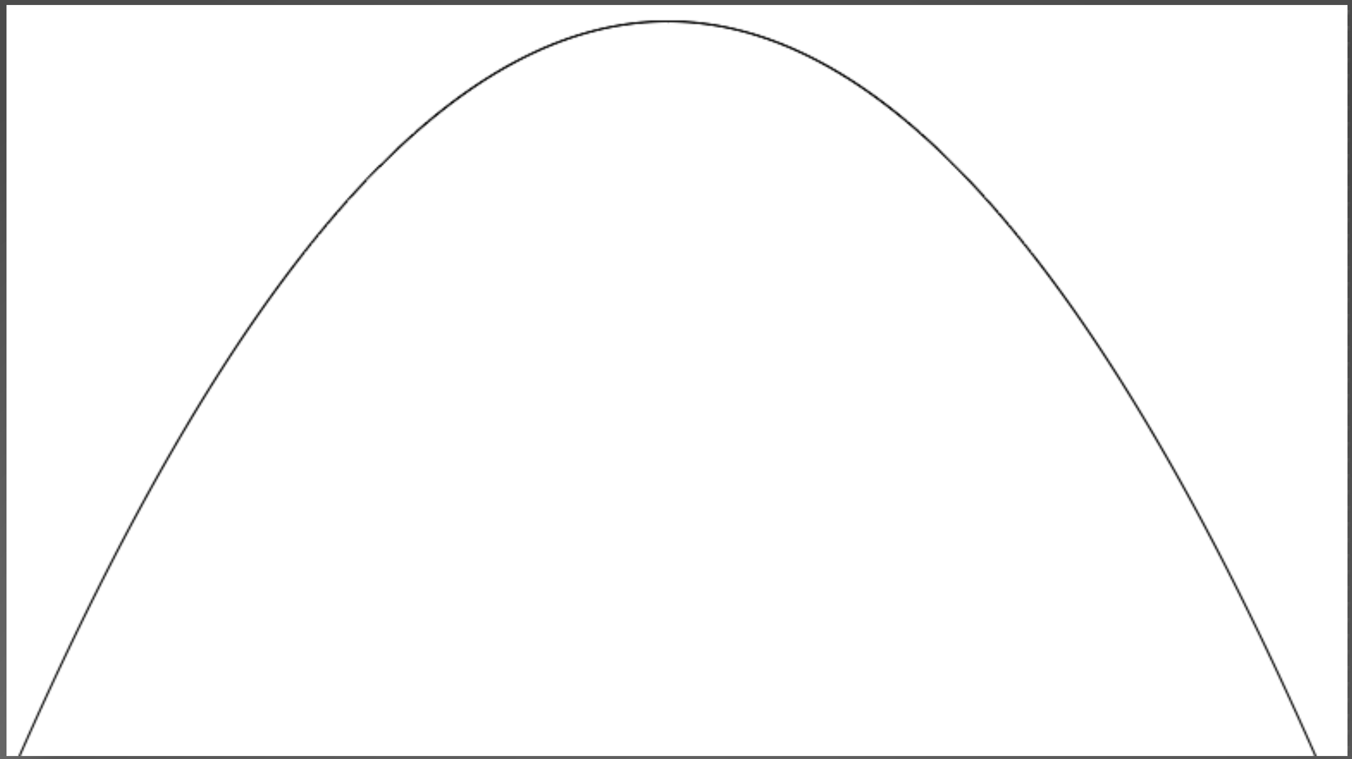
OUTLINE

- Traditional Descent
- Problems with Traditional Descent
- Introduction to Simulated Annealing
- General Annealing
- Key points
- Algorithm
- Uses
- Traveling Salesperson
- TSP Uses

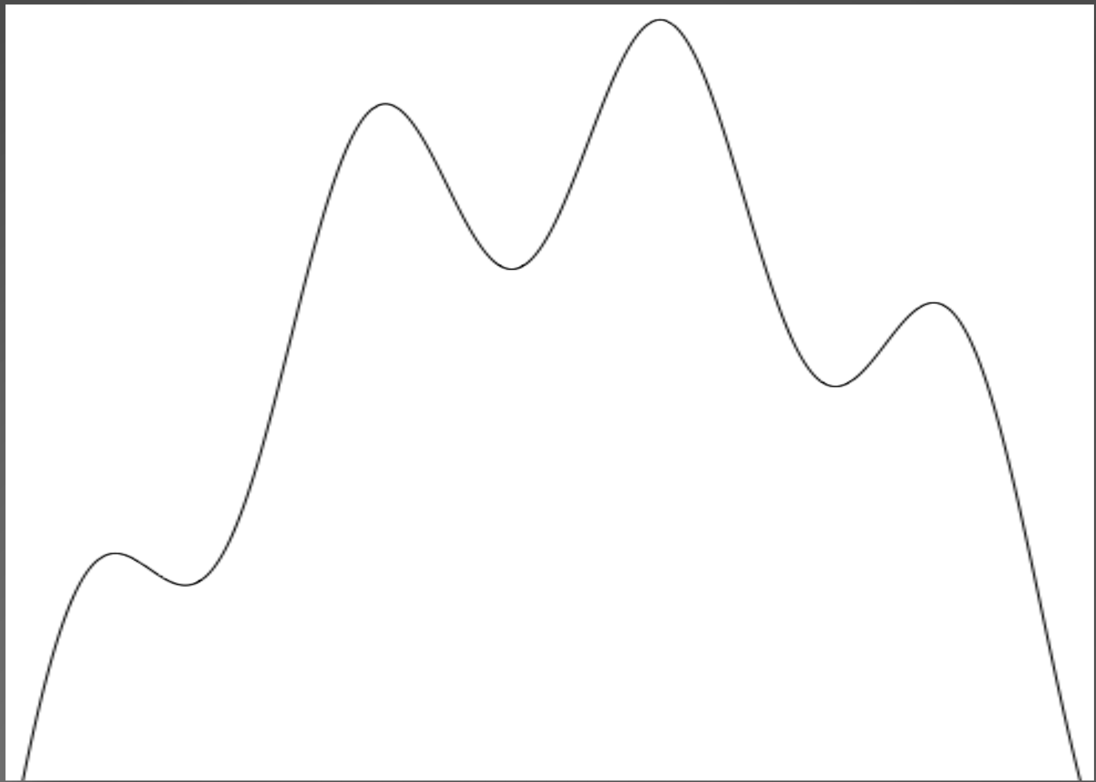
TRADITIONAL DESCENT

- Randomly select initial state
- Iterate through solutions
- Find extremes through iteration
  - Steepest Descent
  - Random Descent
- Minimums or Maximums

FOR EXAMPLE



BUT WHAT ABOUT?



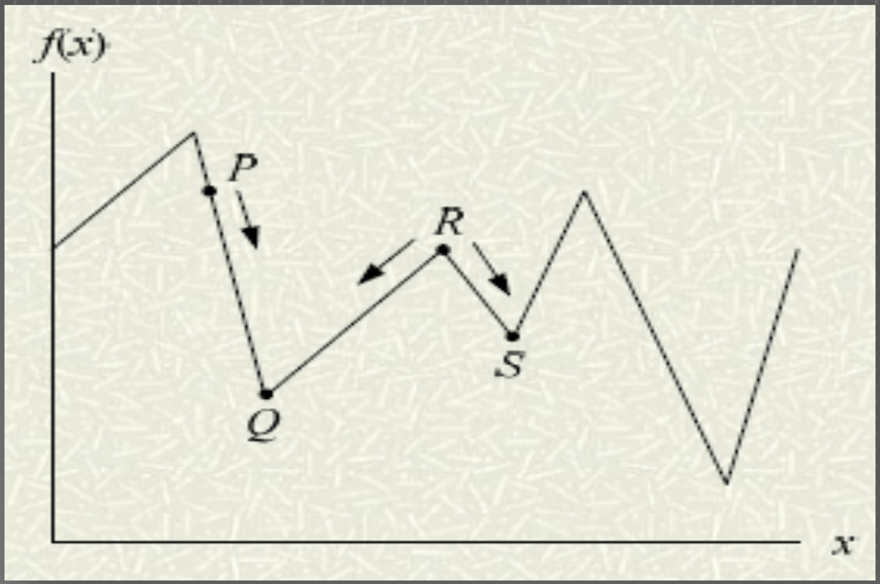
TO CLARIFY

- You need to find the highest hill
- But there is a dense fog

How do you know you are there?

LOCAL EXTREMA

Traditional descent stops at local extremes



SOLUTION

- Simulated Annealing
- Genetic Algorithm
- Ant Colony Algorithm
- . . .

SIMULATED ANNEALING

- Basic idea comes from metallurgy
- Very similar to Traditional Descent

BASIC IDEA OF ANNEALING

- Solid > Melting point > Solid
- Structural properties of the cooled solid depends on the rate of cooling

KEY POINTS

- Temperature decreases over time
- Temperature continues to decrease until the system “freezes” into a steady state

Thermodynamic simulation	Combinatorial optimization
System states Energy Change of state Temperature Frozen State	Feasible solutions Cost Neighboring solution Control parameter Heuristic solution

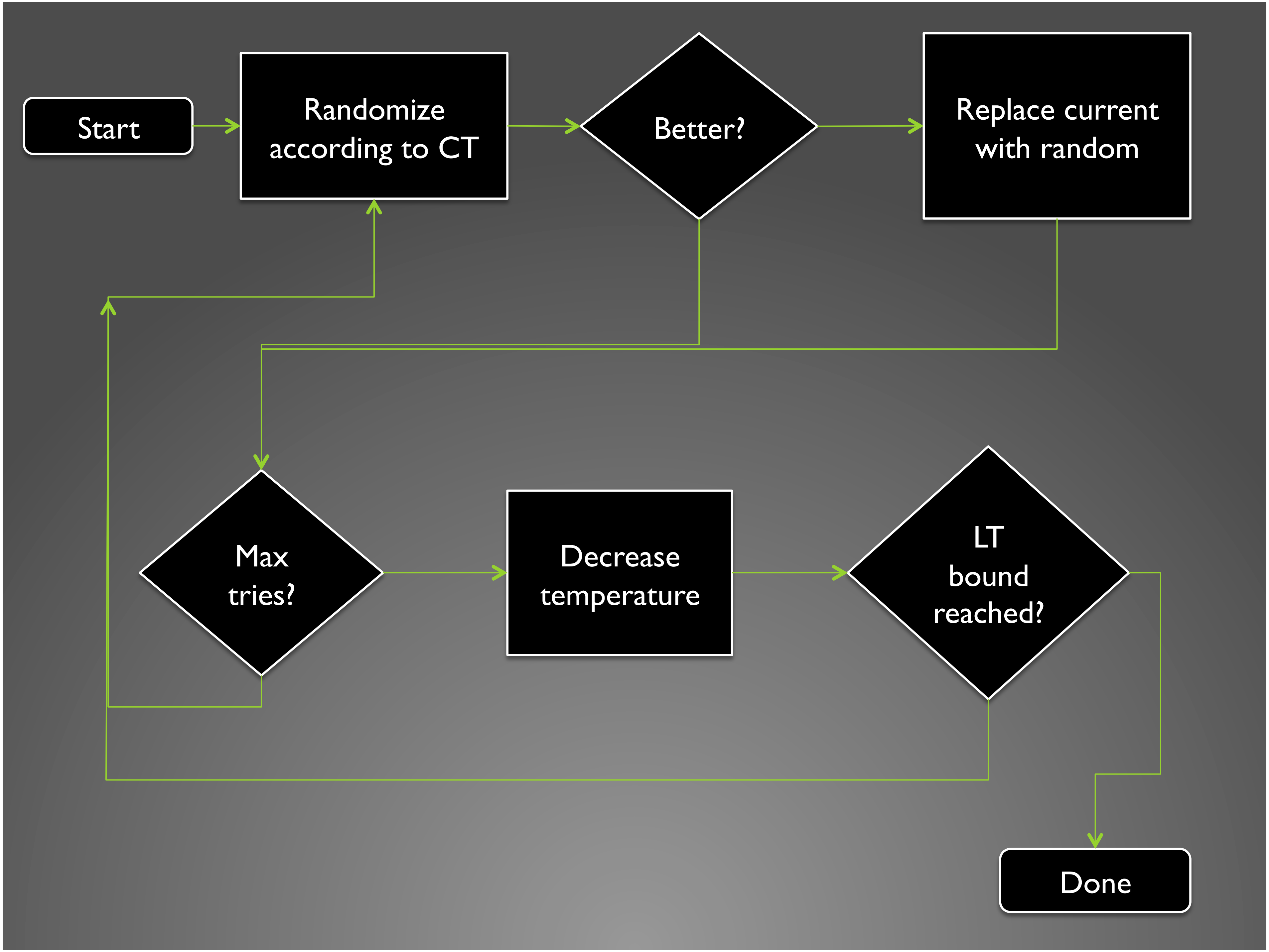
MORE KEY POINTS

- Simulated Annealing can make less than optimal choices
- No single algorithm

ALGORITHM

Given: initial state s0, maximum iterations maxK, maximum allowable energy maxEnergy

```
state ← s0;    energy ← calculateEnergy(state);
bestState ← state;     bestEnergy ← energy
k ← 0
while k < maxK and energy > maxEnergy
    newState ← neighbor(state); newEnergy ← calculateEnergy(newState)
    if newEnergy < bestEnergy then
        bestState ← newState; bestEnergy ← newEnergy
    if P(energy, newEnergy, temp(k/kmax)) > random() then
        state ← newState; energy ← newEnergy
    k ← k + 1
return bestState
```


Start
Randomize according to CT
Better?
Replace current with random
Max tries?
Decrease temperature
LT bound reached?
Done

TEMPERATURE

- The key to the whole algorithm

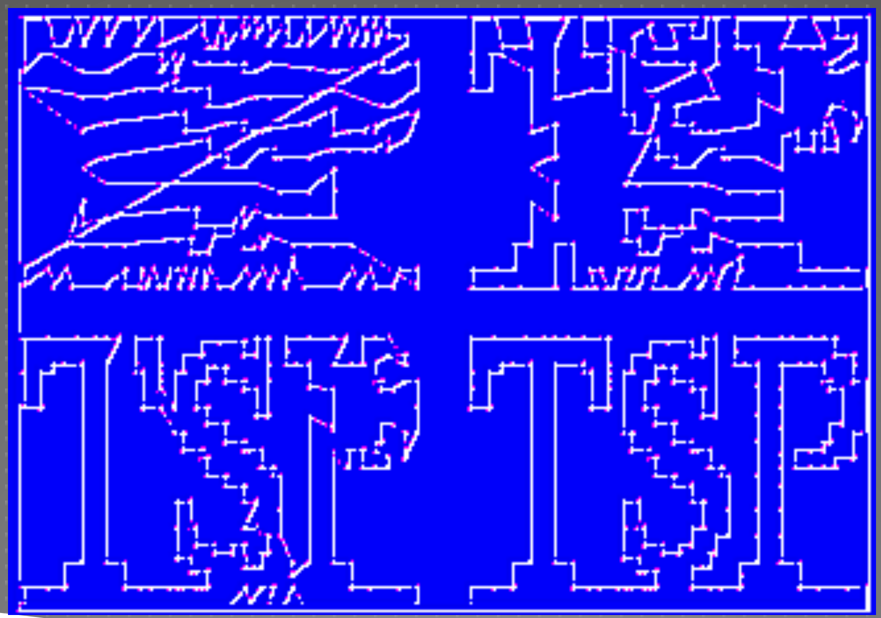
$$e^{-\Delta D/T} > R(0,1)$$

USES

- Traveling Salesman Problem (TSP)
- N-Queens Problem
- Knapsack Problem
- …

TRAVELING SALESMAN

- Simple problem
  - A salesperson is trying to visit a set of cities
  - For maximum profit, he needs to save gas money



TSP USES

- Route Optimization
- Manufacturing
  - Drilling
  - Welding
- Astronomy