CSE 421
Algorithms

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Lecture 16, Winter 2019
Dynamic Programming

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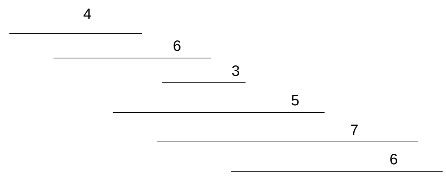
Intervals sorted by end time

Dynamic Programming

- Weighted Interval Scheduling
- Given a collection of intervals $I_1,\ldots,I_n$ with weights $w_1,\ldots,w_n$, choose a maximum weight set of non-overlapping intervals



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Intervals sorted by end time

Optimality Condition

- Opt[j] is the maximum weight independent set of intervals $I_1, I_2, \ldots, I_j$
- Opt[j] = max(Opt[j – 1], w_j + Opt[p[j]])
  - Where p[j] is the index of the last interval which finishes before I_j starts

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Algorithm

MaxValue(j) =
  if j = 0 return 0
  else
    return max(MaxValue(j-1),
        w_j + MaxValue(p[j]))

Worst case run time: 2^n

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A better algorithm

M[j] initialized to -1 before the first recursive call for all j

MaxValue(j) =
  if j = 0 return 0;
  else if M[j] != -1 return M[j];
  else
    M[j] = max(MaxValue(j-1), w_j + MaxValue(p[j]));
    return M[j];

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Iterative Algorithm

Express the MaxValue algorithm as an iterative algorithm

MaxValue {

}

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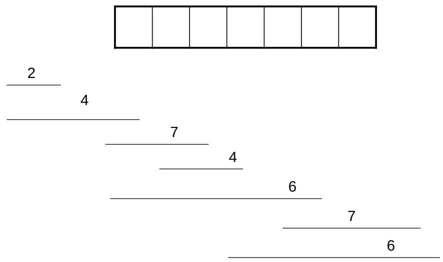
Fill in the array with the Opt values

Opt[j] = max (Opt[j – 1], w_j + Opt[p[j]])



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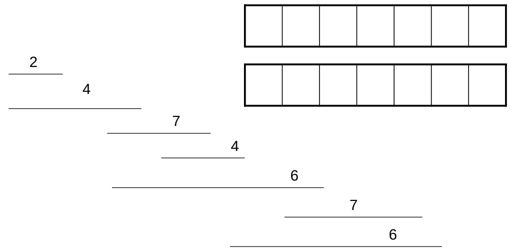
Computing the solution

Opt[j] = max (Opt[j – 1], w_j + Opt[p[j]])

Record which case is used in Opt computation



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Dynamic Programming

- The most important algorithmic technique covered in CSE 421
- Key ideas
  - Express solution in terms of a polynomial number of sub problems
  - Order sub problems to avoid recomputation

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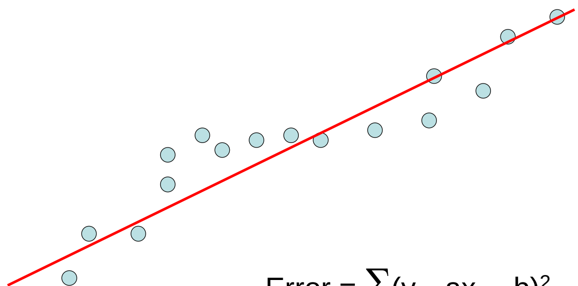
Optimal linear interpolation



Error = $\sum(y_i - ax_i - b)^2$

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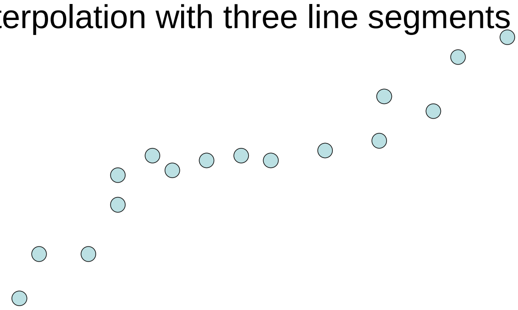
What is the optimal linear interpolation with three line segments



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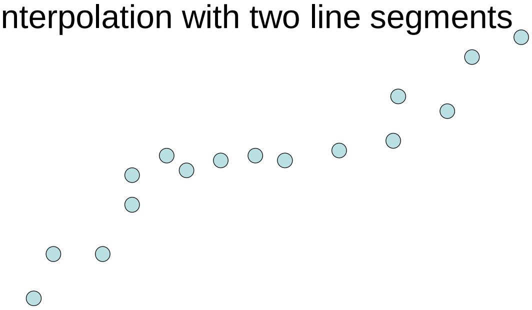
What is the optimal linear interpolation with two line segments



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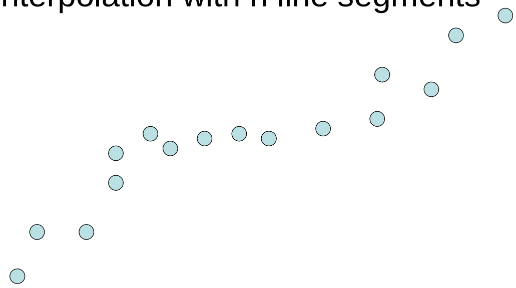
What is the optimal linear interpolation with n line segments



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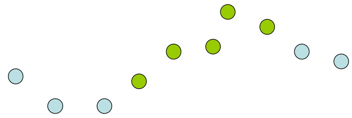
Notation

- Points $p_1, p_2, \ldots, p_n$ ordered by x-coordinate ($p_i = (x_i, y_i)$)
- $E_{i,j}$ is the least squares error for the optimal line interpolating $p_i, \ldots p_j$



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Optimal interpolation with two segments

- Give an equation for the optimal interpolation of $p_1,\ldots,p_n$ with two line segments
- $E_{i,j}$ is the least squares error for the optimal line interpolating $p_i, \ldots p_j$

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Optimal interpolation with k segments

- Optimal segmentation with three segments
  - $\text{Min}_{i,j}\{E_{1,i} + E_{i,j} + E_{j,n}\}$
  - $O(n^2)$ combinations considered
- Generalization to k segments leads to considering $O(n^{k-1})$ combinations

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$\text{Opt}_k[\,j\,]$: Minimum error approximating $p_1 \ldots p_j$ with k segments

How do you express $\text{Opt}_k[\,j\,]$ in terms of $\text{Opt}_{k-1}[1],\ldots,\text{Opt}_{k-1}[\,j\,]$?

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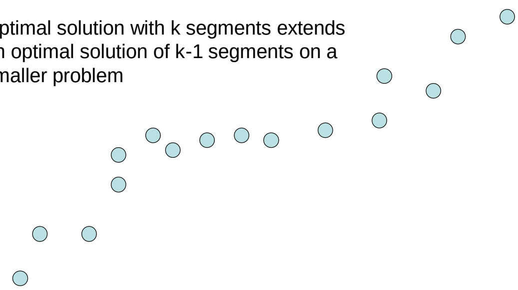
Optimal sub-solution property

Optimal solution with k segments extends an optimal solution of k-1 segments on a smaller problem



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Optimal multi-segment interpolation

Compute Opt[k, j] for $0 < k < j < n$

```
for j := 1 to n
   Opt[ 1, j] = E_{1,j};
for k := 2 to n-1
   for j := 2 to n
       t := E_{1,j}
       for i := 1 to j -1
          t = min (t, Opt[k-1, i ] + E_{i,j})
       Opt[k, j] = t
```

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Determining the solution

- When Opt[k,j] is computed, record the value of i that minimized the sum
- Store this value in a auxiliary array
- Use to reconstruct solution

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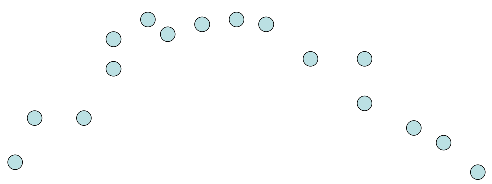
Variable number of segments

- Segments not specified in advance
- Penalty function associated with segments
- Cost = Interpolation error + C x #Segments



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Penalty cost measure

- Opt[j] = $\min(E_{1,j}, \min_i(\text{Opt}[i] + E_{i,j} + P))$

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