

# CS325 - Project 1

Group #6

William Jernigan, Alexander Merrill, Sean Rettig

October 16, 2014

## Correctness

### Proof of Claim 2: Direct Proof

Claim 2: If  $\{y_{j_1}, y_{j_2}, \dots, y_{j_t}\}$  is the visible subset of  $\{y_1, y_2, \dots, y_{i-1}\}$  ( $t \leq i-1$ ) then  $\{y_{j_1}, y_{j_2}, \dots, y_{j_k}, y_i\}$  is the visible subset of  $\{y_1, y_2, \dots, y_i\}$  where  $y_{j_k}$  is the last line such that  $y_{j_k}(x^*) \geq y_i(x^*)$  where  $(x^*, y_{j_k}(x^*))$  is the point of intersection of lines  $y_{j_k}$  and  $y_{j_{k-1}}$ .

Let  $V = \{y_{j_1}, y_{j_2}, \dots, y_{j_t}\}$  be the visible subset of  $A = \{y_1, y_2, \dots, y_{i-1}\}$ .

Let  $V^+ = \{y_{j_1}, y_{j_2}, \dots, y_{j_k}, y_i\}$  be the visible subset of  $A^+ = \{y_1, y_2, \dots, y_i\}$ .

**Prove that  $y_i \in V^+$**

Let  $A^+ = A \cup \{y_i\}$ .

Because  $m_i > m_n$  for all  $n < i$ ,  $y_i$  is visible by the Claim 1 proof in the "Visible Line Notes" handout. Since  $y_i$  is visible and  $y_i \in A^+$ ,  $y_i$  must also be in  $V^+$ , the visible subset of  $A^+$ .

**Prove that  $y_{j_k} \in V^+$**

Let  $(x^*, y_{j_k}(x^*))$  be the point of intersection of the lines  $y_{j_k}$  and  $y_{j_{k-1}}$ .

Since  $y_{j_k}(x^*) \geq y_i(x^*)$  by definition,  $y_{j_k}$  is visible with respect to  $y_i$ .

Since  $y_{j_k}$  was already in  $V$ , it is defined to be visible with respect to all other elements.

$\therefore y_{j_k} \in V^+$ .

**Prove that  $y_{j_n} \in V^+, 0 < n < k$**

Because  $y_{j_n} \in V$ , it is defined to be visible with respect to all other elements in  $V$ .

So we must show that  $y_{j_n}$  is visible with respect to  $y_i$  as well.

Let  $(x_n^*, y_{j_n}(x_n^*))$  be the point of intersection of the lines  $y_{j_n}$  and  $y_{j_{n+1}}$ .

By definition,  $m_{j_n} < m_{j_{n+1}}$ , so  $\forall x_n < x_n^*, y_{j_n}(x_n) \geq y_{j_{n+1}}(x_n)$ .

$\therefore y_{j_1}(x_{1,2}^*) = y_{j_2}(x_{1,2}^*) \geq y_{j_3}(x_{1,2}^*), y_{j_2}(x_{2,3}^*) = y_{j_3}(x_{2,3}^*) \geq y_{j_4}(x_{2,3}^*), \dots, y_{j_{n-1}}(x_{n-1,n}^*) = y_{j_n}(x_{n-1,n}^*) \geq y_{j_{n+1}}(x_{n-1,n}^*), \dots, y_{j_{k-1}}(x_{k-1,k}^*) = y_{j_k}(x_{k-1,k}^*) \geq y_{j_i}(x_{k-1,k}^*)$

$\therefore y_{j_n}$  is visible with respect to  $y_i$ .

$\therefore y_{j_n} \in V^+$ .

**Prove that  $y_{j_p} \notin V^+, k < p < i$**

$y_{j_p} \notin V$  if  $t < p < i$  or  $y_{j_p} \in V$  if  $k < p < t$ .

We must show that  $y_{j_p}$  is not visible with respect to  $y_i$  as well.

**0.0.1  $y_{j_p} \notin V$  if  $t < p < i$**

If  $y_{j_p}$  was not visible in  $V$  then it cannot be visible in  $V^+$  by the Proof of Claim 1 given in class.

**0.0.2**  $y_{j_p} \in V$  if  $k < p \leq t$

Let  $(x_p^*, y_{j_p}(x_p^*))$  be the point of intersection of the lines  $y_{j_{p-1}}$  and  $y_{j_p}$ .

By definition,  $m_{j_{p-1}} < m_{j_p}$ , so  $\forall x_{p-1} < x_p^*, y_{j_{p-1}}(x_{p-1}) > y_{j_{p+1}}(x_p)$ .

$\therefore y_{j_1}(x_{1,2}^*) = y_{j_2}(x_{1,2}^*) \geq y_{j_3}(x_{1,2}^*), y_{j_2}(x_{2,3}^*) = y_{j_3}(x_{2,3}^*) \geq y_{j_4}(x_{2,3}^*), \dots, y_{j_{p-1}}(x_{p-1,p}^*) = y_{j_p}(x_{p-1,p}^*) \geq$

$y_{j_{p+1}}(x_{p-1,p}^*), \dots, y_{j_{k-1}}(x_{k-1,k}^*) = y_{j_k}(x_{k-1,k}^*) \geq y_{j_i}(x_{k-1,k}^*)$

Since  $y_{j_p}$  was already in  $V$ , it is defined to be visible with respect to all other elements.

$\therefore y_{j_p} \in V^+$ .

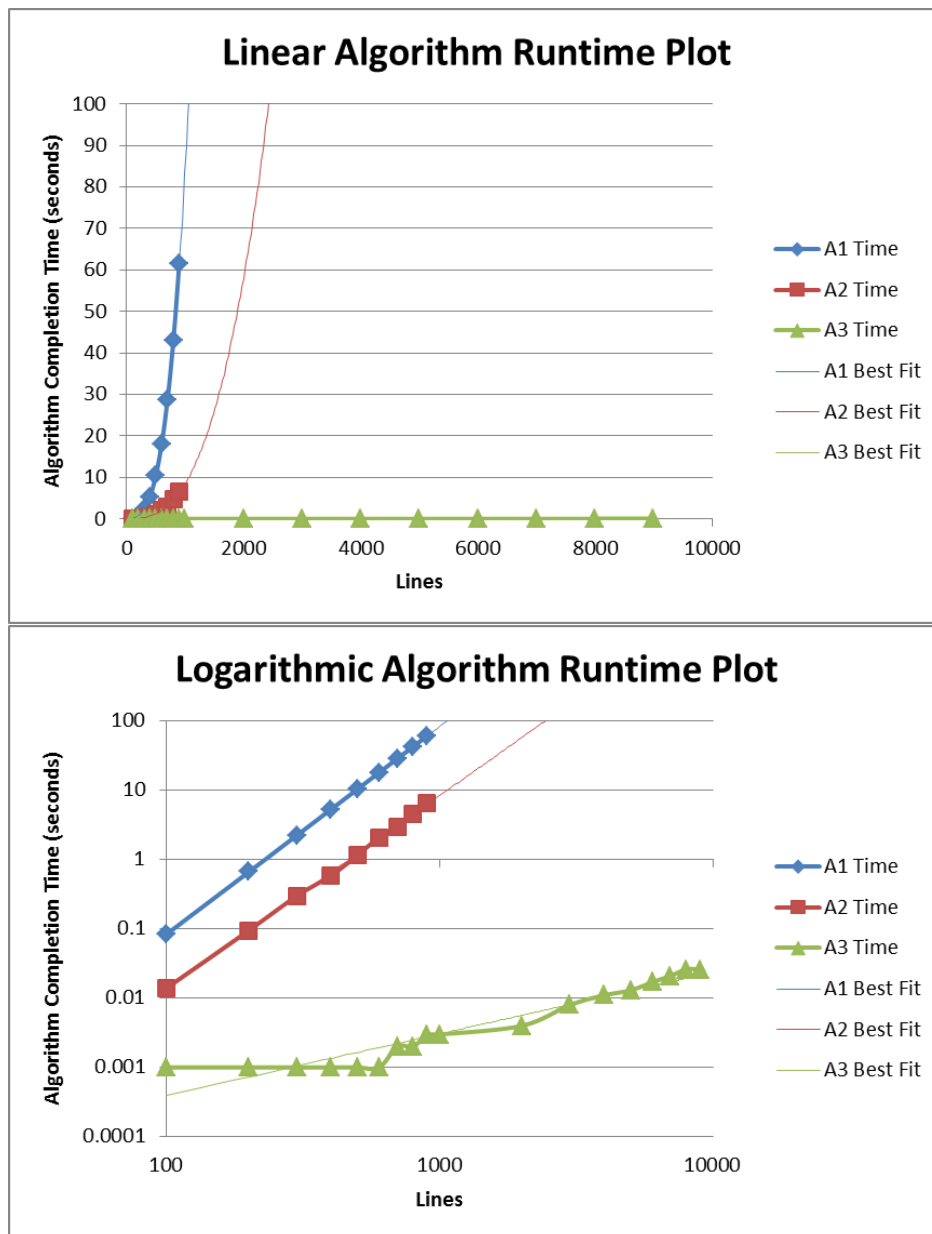
## Proof of Algorithm 3: Direct Proof

## Experimental and Asymptotic Run Time Analysis

### Experimental Run Time Data

Lines	A1 Time	A2 Time	A3 Time
100	0.084	0.014	0.001
200	0.665	0.095	0.001
300	2.246	0.300	0.001
400	5.324	0.588	0.001
500	10.414	1.163	0.001
600	18.104	2.100	0.001
700	28.801	2.989	0.002
800	42.930	4.628	0.002
900	61.510	6.617	0.003
1000			0.003
2000			0.004
3000			0.008
4000			0.011
5000			0.013
6000			0.017
7000			0.021
8000			0.026
9000			0.026

## Experimental Run Time Plots



## Experimental Run Time Analysis

Algorithm 1:  $y = 8 \times 10^{-8}x^{3.0026}$

Algorithm 2:  $y = 4 \times 10^{-8}x^{2.7892}$

Algorithm 3:  $y = 7 \times 10^{-6}x^{0.8868}$

Given these equations, we can use both the slopes and our code to analyze the run times of the algorithms.

## Asymptotic Run Time Analysis

Algorithm 1:  $\Theta(n^3)$

Algorithm 1 iterates over the set of lines in a triple-nested loop.

Algorithm 2:  $\Theta(n^3)$

Similar to Algorithm 1, Algorithm 2 still has the triple-nested loop—it simply bypasses some unnecessary calculations within the triple-nested loop to speed it up.

Algorithm 3:  $\Theta(n)$

Algorithm 3 only iterates over the set of lines once. Though the `removeCovered` function can recurse several times, it does not scale with the size of the input list.

## Discrepancies

We note that the slopes from our experimentally-derived equations are close to  $\Theta(n^3)$ ,  $\Theta(n^3)$ , and  $\Theta(n)$ , but not exact. These discrepancies have many possible contributing factors, including a small sample size, a low timing resolution (particularly for Algorithm 3), and randomness in run time present in Algorithms 2 and 3 (which unlike Algorithm 1, do not simply perform a fixed number of operations, but rather change what operations they run depending on the input lines given. This randomness is likely to be the primary cause, as the experimental running time for Algorithm 1 is by far the closest to our asymptotic estimation.

## Estimated Number of Lines Per Hour

Algorithm 1:  $\sim 3,532$

Algorithm 2:  $\sim 8,460$

Algorithm 3:  $\sim 7,919,210,000$

## Pseudocode

```
algorithm1(lines):
    for j in lines[0 ... n]:
        for i in lines[j+1 ... n]:
            for k in lines[i+1 ... n]:
                Xjk, Yjk = intersection(j, k)
                Yi = i.slope * Xjk + i.intercept
                if Yjk > Yi:
                    i.visible = False
    return lines

algorithm2(lines):
    for j in lines[0 ... n]:
        for i in lines[j+1 ... n]:
            for k in lines[i+1 ... n]:
                if i.visible:
                    Xjk, Yjk = intersection(j, k)
                    Yi = i.slope * Xjk + i.intercept
                    if Yjk > Yi:
                        i.visible = False
    return lines

algorithm3(lines):
    vlines = []
    for i in lines:
        vlines.append(i)
        removeCovered(vlines)
    return lines

removeCovered(vlines):
    if len(vlines) < 3: # All lines are visible if there are only 1 or 2.
        return vlines
    else:
        a, b, c = vlines[n-2 ... n]
        Xab, Yab = intersection(a, b)
        Yc = c.slope * Xab + c.intercept
        if Yc > Yab: # If line b is covered, remove it and recurse.
            b.visible = False
            vlines.remove(b)
            return removeCovered(vlines)
        else: # If line b is still visible, do nothing.
            return vlines
```