Public-Service Announcement I

“Are you an engineer, designer, or entrepreneur? Come check out Mobile Developers of Berkeley. We create end-to-end solutions with a diverse breath of skills. Our members hone their skills in frontend, backend, design, and engineering while developing an understanding of topics such as software architecture, databases, operating systems, and networking. We build apps targeting a wide range of industries while leveraging the latest technologies in IOT, AI, fintech, ML, AR, and more. Join us for our showcase tonight, Wednesday 9/6. Our members will show you our apps and what it took to make them. Free food, fidget spinners & swag will also be there.

See https://www.mobiledevsberkeley.org/ for further information.”
Public-Service Announcement II

“Introducing Political Computer Science @ Berkeley! PCS harnesses students’ intellectual capabilities and potential in CS and Government affairs to address current issues within the United States legal and political systems.

We already have an Amazon Alexa Skill called Political Pundit that is about to be published; it is able to give responses to inquiries about politics/government.

To view the many other projects that we have in the works (pertaining to gerrymandering, campaign finance, Alexa, and more), visit our website: pcsberkeley.wixsite.com/pcsberkeley

We’re now accepting applications for the 2017-2018 school year (it only takes 5 minutes to complete)! Apply on our website!”

Recreation

What is the sum of the coefficients of

\[(1 - 3x + 3x^2)^{743}(1 + 3x - 3x^2)^{744}\]

after expanding and collecting terms?
CS61B Lecture #6: Arrays

• An array is a structured container whose components are
  - **length**, a fixed integer.
  - a sequence of **length** simple containers of the same type, numbered from 0.
  - (.length field usually implicit in diagrams.)

• Arrays are anonymous, like other structured containers.

• Always referred to with pointers.

• For array pointed to by A,
  - Length is A.length
  - Numbered component \(i\) is \(A[i]\) (\(i\) is the index)
  - Important feature: index can be any integer expression.
A Few Samples

Java

```java
int[] x, y, z;
String[] a;
x = new int[3];
y = x;
a = new String[3];
x[1] = 2;
y[1] = 3;
a[1] = "Hello";

int[] q;
q = new int[] { 1, 2, 3 };
// Short form for declarations:
int[] r = { 7, 8, 9 };
```

Results

```
x: 0 3 0
    |
    v
y:  
    |
    v
z:
    |
    v
a: Hello
    |
    v
```
```
q: 1 2 3
    |
    v
r: 7 8 9
    |
    v
```

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Example: Accumulate Values

Problem: Sum up the elements of array A.

```java
static int sum(int[] A) {
    int N;
    N = 0;
    for (int i = 0; i < A.length; i += 1)
        N += A[i];
    return N;
}
```

// New (1.5) syntax
```java
for (int x : A)
    N += x;
```

// For the hard-core: could have written
```java
int N, i;
for (i=0, N=0; i<A.length; N += A[i], i += 1)
    { }
```

// or just ;

// But please don’t: it’s obscure.
Example: Insert into an Array

Problem: Want a call like `insert(A, 2, "gnu")` to convert (destructively)

```
A: — — — — — — — — — —
    bear  gazelle  hartebeest  skunk

A: — — — — — — — — — —
    bear  gazelle  gnu  hartebeest
```

```java
/** Insert X at location K in ARR, moving items K, K+1, ... to locations K+1, K+2, .... The last item in ARR is lost. */
static void insert (String[] arr, int k, String x) {
    for (int i = arr.length-1; i > k; i -= 1) // Why backwards?
        arr[i] = arr[i-1];
    /* Alternative to this loop:
       System.arraycopy(arr, k, arr, k+1, arr.length-k-1);*/
    arr[k] = x;
}
```
(Aside) Java Shortcut

• **Useful tip:** Can write just *arraycopy* by including at the top of the source file:

```java
import static java.lang.System.arraycopy;
```

• This means “define the simple name arraycopy to be the equivalent of java.lang.System.arraycopy in the current source file.”

• **Can do the same for out so that you can write**

```java
out.println(...);
```

  in place of

```java
System.out.println(...);
```

• **Finally, a declaration like**

```java
import static java.lang.Math.*;
```

  means “take all the (public) static definitions in java.lang.Math and make them available in this source file by their simple names (the name after the last dot).”

• **Useful for functions like sin, sqrt, etc.**
Growing an Array

Problem: Suppose that we want to change the description above, so that \( A = \text{insert2} \ (A, 2, \ "gnu") \) does not shove “skunk” off the end, but instead “grows” the array.

A: bear
gazelle
hartebeest
skunk

A: bear
gazelle
gnu
hartebeest
skunk

/** Return array, \( r \), where \( r\.length = ARR\.length+1 \); \( r[0..K-1] \) the same as \( ARR[0..K-1] \), \( r[k] = x \), \( r[K+1..] \) same as \( ARR[K..] \). */
static String[] insert2(String[] arr, int k, String x) {
    String[] result = new String[arr.length + 1];
    arraycopy(arr, 0, result, 0, k);
    arraycopy(arr, k, result, k+1, arr.length-k);
    result[k] = x;
    return result;
}

Why do we need a different return type from insert2??
Example: Merging

**Problem:** Given two sorted arrays of ints, A and B, produce their **merge:** a sorted array containing all items from A and B.

A: 0 2 3 6 9 11  
B: 1 4 5 7 8  

result: 0 1 2 3 4 5 6 7 8 9 11
Example: Merging Program

Problem: Given two sorted arrays of ints, A and B, produce their *merge*: a sorted array containing all from A and B.

Remark: In order to solve this recursively, it is useful to *generalize* the original function to allow merging *portions* of the arrays.

```java
/** Assuming A and B are sorted, returns their merge. */
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0);
}

/** The merge of A[L0..] and B[L1..] assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1) {
    int N = A.length - L0 + B.length - L1;
    int[] C = new int[N];
    if (L0 >= A.length) arraycopy(B, L1, C, 0, N);
    else if (L1 >= B.length) arraycopy(A, L0, C, 0, N);
    else if (A[L0] <= B[L1]) {
        C[0] = A[L0]; arraycopy(merge(A, L0+1, B, L1), 0, C, 1, N-1);
    } else {
        C[0] = B[L1]; arraycopy(merge(A, L0, B, L1+1), 0, C, 1, N-1);
    }
    return C;
}
```

What is wrong with this implementation?
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);
}

/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k){
    ...
}

This last method merges part of A with part of B into part of C. For example, consider a possible call merge(A, 3, B, 1, C, 2)
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);
}

/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k) {
    if (L0 >= A.length) /* ? */
    else if (L1 >= B.length) /* ? */
    else if (A[L0] <= B[L1]) {
        C[k] = A[L0]; /* ? */
    } else {
        C[k] = B[L1]; /* ? */
    }
    return C;
}
A Tail-Recursive Solution

```java
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);
}

/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k) {
    if (L0 >= A.length) /* ? */
    else if (L1 >= B.length) /* ? */
    else if (A[L0] <= B[L1]) {
        C[k] = A[L0];
        /* ? */
    } else {
        C[k] = B[L1];
        /* ? */
    }
    return C;
}
```
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);
}

/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k){
    if (L0 >= A.length) arraycopy(B, L1, C, k, B.length-L1);
    else if (L1 >= B.length) arraycopy(A, L0, C, k, A.length-L0);
    else if (A[L0] <= B[L1]) {
        C[k] = A[L0];
        /* ? */
    } else {
        C[k] = B[L1];
        /* ? */
    }
    return C;
}
A Tail-Recursive Solution

```java
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);
}

/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k){
    if (L0 >= A.length) arraycopy(B, L1, C, k, B.length-L1);
    else if (L1 >= B.length) arraycopy(A, L0, C, k, A.length-L0);
    else if (A[L0] <= B[L1]) {
        C[k] = A[L0];
        merge(A, L0+1, B, L1, C, k+1);
    } else {
        C[k] = B[L1];
        merge(A, L0, B, L1+1, C, k+1);
    }
    return C;
}
```
Iterative Solution

In general, we don’t use either of the previous approaches in languages like C and Java. Array manipulation is most often iterative:

```java
public static int[] merge(int[] A, int[] B) {
    int[] C = new int[A.length + B.length];
}
```
public static int[] merge(int[] A, int[] B) {
    int[] C = new int[A.length + B.length];
    int L0, L1;
    L0 = L1 = 0;
    for (int k = 0; k < C.length; k += 1) {
        if (L0 >= A.length) {
            C[k] = B[L1]; L1 += 1;
        } else if (L1 >= B.length) {
            C[k] = A[L0]; L0 += 1;
        } else if (A[L0] <= B[L1]) {
            C[k] = A[L0]; L0 += 1;
        } else {
            C[k] = B[L1]; L1 += 1;
        }
    }
    return C;
}
Alternative Solution: Removing k

Claim: An invariant of the loop is that k=L0+L1.

```java
public static int[] merge(int[] A, int[] B) {
    int[] C = new int[A.length + B.length];
    int L0, L1;
    L0 = L1 = 0;
    while (L0 + L1 < C.length) {
        if (L0 >= A.length) {
            C[L0 + L1] = B[L1]; L1 += 1;
        } else if (L1 >= B.length) {
            C[L0 + L1] = A[L0]; L0 += 1;
        } else if (A[L0] <= B[L1]) {
            C[L0 + L1] = A[L0]; L0 += 1;
        } else {
            C[L0 + L1] = B[L1]; L1 += 1;
        }
    }
    return C;
}
```
Multidimensional Arrays

What about two- or higher-dimensional layouts, such as

\[ A = \begin{array}{cccc}
2 & 3 & 4 & 5 \\
4 & 9 & 16 & 25 \\
8 & 27 & 64 & 125 \\
\end{array} \]
Multidimensional Arrays in Java

These are not primitive in Java, but we can build them as arrays of arrays:

```java
int[][] A = new int[3][];
A[0] = new int[] {2, 3, 4, 5};
A[2] = new int[] {8, 27, 64, 125};
```

// or
```java
int[][] A;
A = new int[][] {
    {2, 3, 4, 5},
    {4, 9, 16, 25},
    {8, 27, 64, 125}
};
```

// or
```java
int[][] A = {
    {2, 3, 4, 5},
    {4, 9, 16, 25},
    {8, 27, 64, 125}
};
```

// or
```java
int[][] A = new A[3][4];
for (int i = 0; i < 3; i += 1)
    for (int j = 0; j < 4; j += 1)
        A[i][j] = (int) Math.pow(j + 2, i + 1);
```
Exotic Multidimensional Arrays

- Since every element of an array is independent, there is no single "width" in general:

  ```java
  int[][] A = new int[5][];
  A[0] = new int[] {};
  A[1] = new int[] {0, 1};
  A[3] = new int[] {6, 7, 8};
  ```

- What does this print?

  ```java
  int[][] ZERO = new int[3][];
      new int[] {0, 0, 0};
  ZERO[0][1] = 1;
  System.out.println(ZERO[2][1]);
  ```
Exotic Multidimensional Arrays

- Since every element of an array is independent, there is no single “width” in general:

```java
int[][] A = new int[5][];
A[0] = new int[] {};
A[1] = new int[] {0, 1};
A[3] = new int[] {6, 7, 8};
```

- What does this print?

```java
int[][] ZERO = new int[3][];
ZERO[0] = ZERO[1] = ZERO[2] = new int[] {0, 0, 0};
ZERO[0][1] = 1;
System.out.println(ZERO[2][1]);
```