```cpp
//
//  BinaryChop.cpp
//  Return index of element
//
//  Created by Stewart Bracken on 12/8/13.
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//

#include <stdio.h>
#include <vector>
#include <thread>

#include "BinaryChop.h"
#include "FunctionalVector.h"

#include "MathUtil.h"

// My progression for better binary search functions.
// Chop6 should be the fastest.

//Iterative approach. Pretty fast, not as fast as chop2.
// O(nlogn) -- if lucky search hit, can return before nlogn.
int BinaryChop::chop1(int to_find, const std::vector<int>& data){
    int len = static_cast<int>(data.size()),
        low = 0;
    if(len == 0) return NOT_FOUND;
    int i, curr_data;

    while( len > 0 ){
        i = len/2 + low;
        curr_data = data[i];
        if( curr_data == to_find ){
            return i;
        }else if( to_find > curr_data ){
            //Need to search farther down array
            low = i+1;
            len = (len-1)/2;
        }else{ //to_find < curr_data
            //Search again at a smaller index.
            len = div_ceil( len-1, 2 );
        }
    }
    return NOT_FOUND;
}
```



```cpp
//Helper tail recursive function for chop2
static int chop2_rec(int& to_find, const std::vector<int>& data,
                     int& length, int& low){
    if(length == 0)
        return NOT_FOUND;
    int i = length/2 + low;
    int curr_data = data[i];
    if( curr_data == to_find ){
        return i;
    }else if( to_find > curr_data ){
        low = i+1;
        length = (length-1)/2;
    }else{
        length = div_ceil(length-1, 2);
    }
    return chop2_rec(to_find, data, length, low);
}

// Tail recursive chop.
// O(nlogn) -- if lucky search hit, can return before nlogn.
int BinaryChop::chop2(int to_find, const std::vector<int>& data){
    int length = static_cast<int>(data.size());
    int low = 0;
    return chop2_rec(to_find, data, length, low);
}


//Functional style array slicing binary chop
// O(nlogn) -- if lucky search hit, can return before nlogn.
int BinaryChop::chop3(int to_find, const std::vector<int>& data){
    FunctionalVector<int> fun_data(data); //copy data
    size_t i;
    int curr_data;
    while( fun_data.size() > 0 ){
        i = fun_data.size()/2;
        curr_data = fun_data[i];
        if( curr_data == to_find ){
            return static_cast<int>(fun_data.index_at(i));
        }else if( to_find > curr_data ){
            //Need to search farther down array
            fun_data.slice(i+1, (fun_data.size()-1)/2);
        }else{ //to_find < curr_data
            //Search again at a smaller index.
            fun_data.slice(0, div_ceil( static_cast<int>(fun_data.size()-1), 2) );
        }
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        }
        return NOT_FOUND;
    }

    //thread function for doing work on data.
    void chop4_thread(int to_find, const std::vector<int> &data, int low, int length,
    int* result){
        int i = length/2 + low;
        int curr_data = data[i]; //thread-safe read

        if(curr_data == to_find){
            *result = i;
            return;
        }else if( to_find > curr_data ){
            low = i+1;
            length = (length-1)/2;
        }else{
            length = div_ceil(length-1, 2);
        }

        if(length == 0)
            return;

        std::thread continue_search(chop4_thread, to_find, data, low, length, result);
        continue_search.join();
    }

    void chop4_thread_spawn(int to_find, const std::vector<int> &data, int low, int
    length, int* result){
        if(length == 0) return;
        if(to_find < data[low] || to_find > data[low+length-1]) return;
        std::thread continue_search(chop4_thread, to_find, data, low, length, result);
        continue_search.join();
    }

    //very slow. binary search wan't really meant to be multithreaded.
    // O(nlogn) -- if lucky search hit, can return before nlogn.
    int BinaryChop::chop4( int to_find, const std::vector<int> &data ){
        int result = NOT_FOUND; //The thread which finds it sets result to idx
        int half = static_cast<int>(data.size())/2;
        std::thread left(chop4_thread_spawn, to_find, data, 0, half, &result);
        std::thread right(chop4_thread_spawn, to_find, data, half,
    div_ceil(static_cast<int>(data.size()), 2), &result);
        left.join();
        right.join();
```



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        return result;
    }

    //Iterative approach 2. Attempting to be faster than tail recursion.
    // This ends up being just as fast as tail recursion.
    // Wow, it turns out I overengineered all my other solutions.
    // This one is much more simple and elegant. Nice dice.
    // θ(nlogn) -- bound above and below nlogn due to deferred equality.
    int BinaryChop::chop5( int to_find, const std::vector<int>& data ){
        int imax = static_cast<int>( data.size()-1 ),
            imin = 0,
            imid;
        if( imax < 0 ) return NOT_FOUND;

        while( imin < imax ){
            imid = (imin + imax)/2;
            if( to_find > data[imid] ){
                imin = imid+1;
            }else{ //to_find < curr_data
                imax = imid;
            }
        }
        if( imin == imax && data[imin] == to_find ){
            return imin;
        }
        return NOT_FOUND;
    }

    //Helper tail recursive function for chop6
    static int chop6_rec( int& to_find, const std::vector<int>& data,
                          int& imin, int& imax ){
        if( imin == imax ){
            if( data[imin] == to_find ){
                return imin;
            } else {
                return NOT_FOUND;
            }
        }

        int imid = ( imin + imax )/2;

        if( to_find > data[imid] ){
            imin = imid+1;
        }else{
            imax = imid;
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        }

        return chop6_rec( to_find, data, imin, imax );
    }

    // Θ(nlogn) -- bound above and below nlogn due to deferred equality.
    int BinaryChop::chop6( int to_find, const std::vector<int>& data ){
        int imax = static_cast<int>( data.size()-1 );
        int imin = 0;
        if( imax < 0 )
            return NOT_FOUND;
        return chop6_rec( to_find, data, imin, imax );
    }
```