What’s in a file, what’s in a string?

- Characters make up words in English, the type char is used as a basic building block in C++ and other languages
  - The type char represents characters in different languages, encoding depends on the character set used
  - ASCII is common in C++ and other languages, limited to 128 or 256 different characters (8 bits/character)
  - Unicode is an alternative, uses 16 bits so more characters

- Strings are built from char values, essentially as vectors/arrays of characters
  - Strings support catenation, find, read/write
- At a basic level, files are collections of characters
  - Especially true in Unix, other operating systems as well

Basics of the type char

- Values of type `char` use single quotes, not double quotes
    - `’a’` as compared to `"A"`

- The library accessible in `<cctype>` (or `<ctype.h>`) supports character-set independent char operations

```
string s = "HeLLo";
int k;
for(k=0; k < s.length(); k++)
{  char ch=s[k];
   if (isupper(ch))
        cout << tolower(ch) << end;
}
```

- “bool”-like functions return int values, not bool values!!
    - `tolower` “does the right thing” for uppercase values

Char values as integers

- Char values can be compared using <, >, <=, >=, ==, !=
  - < ordering depends on character set; `'A' < 'a'` in ASCII
  - Code should NOT rely on ASCII specifics, use <cctype> version of tolower rather than

```
char tolower(char c)
// post: return lowercase version of c
{
    if ('A' <= c && c <= 'Z')
    {
       return c + 32;
    }
    return c;
}
```

- In practice int values are used in functions like tolower(...)

Files as lines of characters

- **Files are read by both computers and humans**
  - **Text files are composed of lines, lines composed of chars**
    - **Lines are simple for humans to read/process**
  - **Using operator >> to extract strings, ints, etc. doesn't let us read files a line-at-a-time, consider file format below:**

```
Joe 20 30 40
Sam 50 60 30 40
```

  - **How can we read varying number of scores per line?**
    - **What about alternative of using a sentinel end-of-line value?**

- **Use `getline(..)` to read a line-at-a-time, use `istringstream` (`istrstream`) to process the line as a stream**

Using istringstream (istrstream) objects

- “data” file contains lines like: `Joe 20 30 40 60 70`

```
ifstream ifile("data");
string line,name;
int num,count;
double total;
while (getline(ifile,line))
{
  istrstream iline(line.c_str());  // istringstream
  iline >> name;
  total = count = 0;
  while (iline >> num)      // read all numbers on line
  {
      count++;
      total += num;
  }
  cout << count << " average = " << total/count << endl;
}
```

- The variable iline must be defined inside the outer loop, why?

Other file-reading functions

- `getline` has an optional third argument that defines when a “line” ends
  - Process data file

```
The Beatles : Let it Be
The Rolling Stones : Let it Bleed
```

```
string artist,group;
while (getline(ifile,artist,’:’) &&
       getline(ifile,group))
{
    // process artist, group
}
```

- Also can read a file one char at-a-time using input.get(ch)
  - Doesn’t skip white space, reads every character

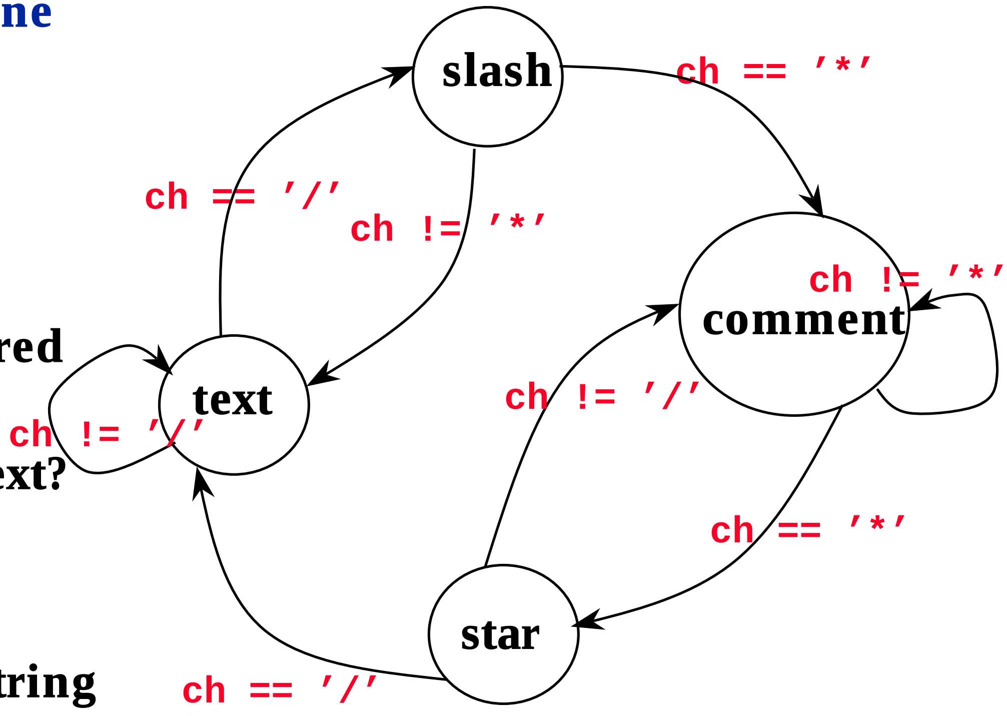
State machines for reading

- Sometimes the “definition” of a word changes (like the definition of a line can change with third argument to getline)
  - Using >> means white-space delimited words
  - What about removing comments? What about using other characters to delimit words, e.g., dashes—as this shows

- Reading is in one of several states, rules for state transitions determine how to change between states
  - In reading // comments there are three states: text, first-slash, comment
  - In reading /* comments how many states are there?

State machine for /* comments */

- Similar to // comment machine
  - ➤Where are characters printed/echoed?
  - ➤Why four states?
- State transition arcs
  - ➤Be sure every char covered in each state
  - ➤In particular, slash-to-text?
  - ➤Start to comment?
- What about “this /* string” ?
  - ➤Is it hard to recognize string literals?
  - ➤What are the issues?



Defining states

- **See the program decomment.cpp for details**
  - ➤ **States can be identified with numbers as labels**

    ```
    const int TEXT = 0;
    const int FIRST_SLASH = 1;
    ```

  - ➤ **Using an enumerated type is the same idea, but gives the labels a type**

    ```
    enum Suit{spades, diamonds, hearts, clubs};
    ```

  - ➤ **Can assign enum to int, but cannot assign int to enum**

    ```
    Suit s = 3;         // illegal
    int k = spades;     // legal
    ```

Using enums to model cards

- **Consider the declaration below from card.h, simulate playing card**

```
class Card
{
  public:

   enum Suit {spades, hearts, diamonds, clubs};

   Card();                     // default, ace of spades
   Card(int rank, Suit s);

   bool SameSuitAs(const Card& c) const;
   int  GetRank()                 const;
   bool IsJoker()                 const;

  private:
   int  myRank;
   Suit mySuit;
};
```

Using class-based enums

- **We can’t refer to `Suit`, we must use `Card::Suit`**
  - **The new type `Suit` is part of the `Card` class**
  - **Use `Card::Suit` to identify the type in client code**
  - **Can assign enum to int, but need cast going the other way**

```
int rank, suit;
tvector<Card> deck;
for(rank=1; rank < 52; rank++)
{
   for(suit = Card::spades;suit <= Card::clubs; suit++)
   {
      Card c(rank % 13 + 1, Card::Suit(suit));
      deck.push_back(c);
   }
}
```

How do objects act like built-in types?

- We've used `Date` and `Bigint` objects, and in many cases used the same operations that we use on `int`s and `double`s
  - We print with operator <<
  - We add using +, +=, and ++
  - We compare using ==, <, >
- In C++ class objects can be made to act like built-in types by *overloading operators*
  - We can overload operator << to print to streams
  - We can overload operator == to compare Date objects
- We'll develop a methodology that allows us to easily implement overloaded operators for classes
  - Not all classes should have overloaded operators
  - Is overloading + to be the union of sets a good idea?

Case study: the class ClockTime

- Represents hours, minutes, seconds, e.g., 1:23:47 for one hour, twenty-three minutes, 47 seconds
  - ClockTime values can be added, compared, printed

```
class ClockTime
{
  public:
    ClockTime();
    ClockTime(int secs, int mins, int hours);
    int     Hours()   const;   // returns # hours
    int     Minutes() const;   // returns # minutes
    int     Seconds() const;   // returns # seconds
```

- How are values represent internally (private), what are some options?
  - Do client program need to know the representation?

Using the class ClockTime

- **The code below shows how the class can be used, what overloaded operators are shown?**

```
int h,m,s;
ClockTime total(0,0,0);
ClockTime max = total;     // zero
while (cin >> h >> m >> s)
{
    ClockTime t(s,m,h);
    total += t;
    if (t > max)
    {   max = t;
    }
}
cout << "total time = " << total << endl;
cout << "max time   = " << max << endl;
```

Design and Implementation Issues

- Converting to a string facilitates writing to a stream
  - We know how to write strings, conversion to a string solves many problems
  - Every class should have a `toString()` method – Java does

- An object could be in a bad state, 1 hour 72 min. 87 sec., How can this happen? How do we prevent bad state?
  - Ignore illegal values
  - Stop the program
  - Convert to something appropriate

- For ClockTime class we'll *normalize*, convert to standard form

Relational operators

- Relational operators are implemented as free functions, not class member functions (Tapestry approach, not universal)
  - ➤ Needed for symmetry in some cases, see Howto E for details
  - ➤ We'll use member function Equals to implement ==
- Print-to-stream operator << must be a free function
  - ➤ We'll use toString to implement <<, avoid using friend functions

```
ostream &  operator << (ostream & os, const ClockTime & ct);
bool operator == (const ClockTime& lhs, const ClockTime& rhs);
```

- These prototypes appear in `clockt.h`, no code just prototype
  - ➤ Code in header file causes problems with multiple definitions at link time

Free functions using class methods

- We can implement == using the `Equals` method. Note that `operator ==` cannot access `myHours`, not a problem, why?

```
bool operator == (const ClockTime& lhs, const ClockTime& rhs)
{
    return lhs.Equals(rhs);
}
```

- We can implement `operator <<` using `toString()`

```
ostream & operator << (ostream & os, const ClockTime & ct)
// postcondition: inserts ct onto os, returns os
{
    os << ct.ToString();
    return os;
}
```

- Similarly, implement + using +=, what about != and < ?

Class or Data invariants

- A ClockTime object must satisfy class invariant to be valid
  - Data invariant true of object as viewed by client program
  - Cannot have minutes or seconds greater than 60
  - What methods can break the invariant, how do we fix this?

- A private, helper function Normalize maintains the invariant

```
void ClockTime::Normalize()
// post: myMinutes < 60, mySeconds < 60, represents same time
{
    myMinutes += mySeconds/60;
    mySeconds %= 60;
    myHours += myMinutes/60;
    myMinutes %= 60;
}
```

Implementing similar classes

- The class `Bigint` declared in `bigint.h` represents integers with no bound on size
  - How might values be stored in the class?
  - What functions will be easier to implement? Why?

- Implementing rational numbers like 2/4, 3/5, or –22/7
  - Similarities to ClockTime?
  - What private data can we use to define a rational?
  - What will be harder to implement?

- What about the Date class? How are its operations facilitated by conversion to absolute number of days from 1/1/1 ?

Niklaus Wirth

- Designed and implemented several programming languages including Pascal, Modula-2, Oberon

  Simple, elegant solutions are more effective, but they are harder to find than complex ones, and they require more time which we too often believe to be unaffordable

- Wrote the paper that popularized the idea of step-wise refinement
  - Iterative enhancement
  - Grow a working program

- Not a fan of C++