Using Terminal Window Graphics in CS1

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The problem

We have many goals for CS1, sometimes conflicting:

- Make it simple
  - *Many students come in with no prior programming experience*
- Make it rigorous
  - Students must master the essential language features, I/O, etc.
- Make it comprehensive
  - Teach the entire language
- Make it fun!
  - Colorful, graphical, interactive
  - A positive experience in CS1 is essential for retaining CS majors

Inspiration

- Stuart Reges, *Back to Basics in CS1 and CS2*, SIGCSE 2006
- The objects early approach is hard to do right
- So, focus on the essentials of procedural programming: types, values, variables, loops, decisions, functions, arrays
  - Move on to OOP once the fundamentals have been mastered
- Our CS1 course uses C
  - Structs + accessor functions = encapsulation
  - Easy transition to Java in CS2

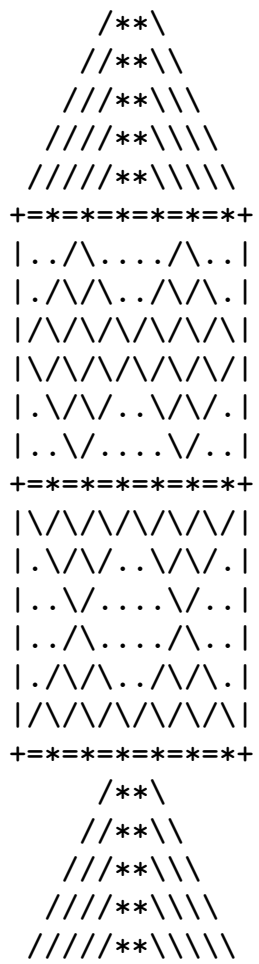
Designing Projects and Labs

How to make the CS1 projects and labs interesting?

- Console I/O: can be boring
  - Oh, another program that reads from `stdin` and writes to `stdout`. Whee.
- GUIs/graphics: complex API, takes time away from teaching essentials
  - Wrapper API can help: e.g., acm.graphics package
  - But wouldn't it be nice if we could somehow do graphics "for free"?

ASCII art

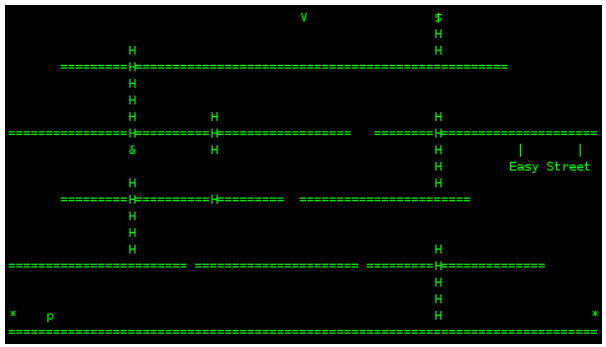
- One of Reges's CS1 projects: draw a rocket using text characters
- Nice!
  - Interesting visual effect
  - Students learn console output on day 1 of course: *no new API to teach*
- Our thought: why not draw *graphics* in the terminal window?
  - Color, animation, etc.
  - The only requirement is that you can move the cursor!



Character graphics: an old idea

Flashback to 1983!

- I was in 6th grade
- Family computer: the Kaypro II
- No bitmapped graphics
- Had two (quite good) animated games
  - CatChum (Pac-Man(tm))
  - Ladder (Donkey Kong(tm))
- Stephen Ostermiller wrote a free clone of Ladder in Java (`ostermiller.org/ladder`)



Terminal Window Graphics

- Treat the terminal window as a (low-res) graphics display
- Move the cursor to put characters at arbitrary positions
- Set foreground/background colors
- Update entire screen, delay, repeat: animation
  - Double buffering to eliminate flicker
- Can be portable
  - `ncurses` on any Unix
  - Win32 console API on Windows
- Open source:
  - `http://libtermgraph.sourceforge.net`

API

```
// Output functions
void cons_clear_screen(void);
void cons_move_cursor(int row, int col);
void cons_change_color(int fg_color, int bg_color);
void cons_printw(const char *fmt, ...);
void cons_update(void);
```

API

```
// Other functions
int cons_get_screen_height(void);
int cons_get_screen_width(void);
int cons_get_keypress(void);
void cons_sleep_ms(int ms);
```

Experience

- We have found that students grasp the idea of moving the cursor fairly easily
  - They already understand that `\n` moves the cursor to the beginning of the next line
- Colors also not too difficult
- Even without having previously seen the API, can introduce it in a lab within 20 minutes or so

Animation

```
struct Scene s =
    create_scene();           // create initial scene

while (true) {
    render_scene(s);          // draw it in hidden buffer
    cons_update();            // copy buffer to screen
    cons_sleep_ms(DELAY);     // pause
    s = update_scene(s);      // update state of scene
}
```

Students write the functions in **bold**. Works for any animation, including video games.

Lab: Bouncing Character

- Animate a character moving diagonally, bouncing when it hits the edge of the window
- Use a struct to keep track of position and direction/velocity of the character

Lab: Bouncing Particles

- Animate a large number of characters bouncing around the window
- Use struct to keep track of state of each particle
- Use floating point variables for position and direction/velocity
- Students write accessor functions taking instances of their particle struct type by reference using pointers
  - If you can model one, you can model any number of them!

Assignment: Sudoku

- Write a program to fill in a Sudoku puzzle
- Essentially, a GUI!
- Uses a 2-D array as the underlying data structure

Demo

Assignment: Planet Simulation

- Simulate a planet orbiting a star
- Compute effect of star's gravity on planet at each time step

Demo

Assignment: Shoot 'Em Up

- Essentially, Space Invaders(tm)
- Use structs to keep track of state of player ship, enemy ships, missiles
  - Manage complexity using accessor functions, encapsulation
- Students write a video game in their first programming course
  - We given them very little skeleton code
  - Hopefully, a confidence-builder

Demo

Assignment: Eat 'Em Up

- Essentially, Pac-Man(tm)
- Just about any 2-D video game could be adapted for terminal window graphics

Demo

Conclusions

- Terminal window graphics is a very lightweight approach to introducing graphics and animation in CS1
- We've received positive feedback from students
- Open source: `http://libtermgraph.sourceforge.net`
  - Links to projects

Questions?