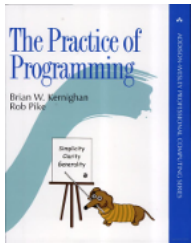
Design

Kurt Schmidt

Dept. of Computer Science, Drexel University

October 29, 2016

Examples are taken from Kernighan & Pike, *The Practice of Programming*, Addison-Wesley, 1999



Intro

Design and Implementation

Objectives:

- To design and impelement a program for a small yet reasonably complicated problem
- To introduce and review a variety of implementation languages and to have students review the pros and cons of different implementation choices and languages.

> *Show me your flowcharts and conceal your tables, and I shall continue to be mystified. Show me your tables, and I won't usually need your flowcharts; they'll be obvious.*
>
> *— Frederick P. Brooks, The Mythical Man Month*

Markov

Case Study

Problem Generate random English text that reads well

Program Some data comes in, some data goes out, and the processing depends on a little ingenuity

Implementations C, C++, Java

Approaches

- Failed attempts:
  1. Generate random letters (10,000 monkeys typing at 10,000 typewriters)
     - Weighted choices, given letter frequency
  2. Choose random words from a dictionary
- We need a statistical model with more structure
  - Frequency, given some context

The Markov Algorithm (Learn)

Learn from input:

1. Look at all n-word phrases (prefixes)
   - Consider the word that follows each each prefix
   - The same prefix might appear more than once, maybe with a different suffix
2. Store the (prefix, suffix list) in a dictionary
   - The key is the prefix
   - The satellite data (value) associated w/each prefix is the list of suffixes

Note, we're creating a multi-map.

- Each prefix can have several possible suffixes

Example

The following example uses a subset of Prof. Brooks' quote.

- Prefix length of 2 words
- We won't strip punctuation
- We won't worry about capitalisation
  - So, "We" and "we" are different strings
- We will use a special `(null, null)` prefix to indicate the start

Markov Algorithm – Build (Learn)

1. Set w_1 and w_2 to the sentinel values
2. Read next word into tok
3. Add (prefix, suffix) pair to table (dictionary)
4. Replace (w_1, w_2) with (w_2, s)
5. Back to 2

Example Markov Table

A subset of the states, parsing Brooks' quote.

Prefix	**Suffix List**
(null) (null)	Show
(null) Show	me
Show me	your your
me your	flowcharts tables,
your flowcharts	and
flowcharts and	conceal
your tables,	and and
wil be	mystified. obvious.
be obvious.	(null)
be mystified.	Show
mystified. Show	me

Notes

- Store duplicate suffixes
  - E.g., "and" must be a good word to follow "Your tables"
  - The statistical bit. "and" is more likely to be chosen
- Use (null) to mark the end of a story

Markov Algorithm – Generate

1. Set w_1 and w_2 to the sentinel values
2. Look up prefix in table, get suffix list
3. Randomly choose suffix s
   - If s is sentinel, exit
   - Else, print s
4. Replace (w_1, w_2) with (w_2, s)
5. Back to 2

Impelementation

- See the lecture outline for links to different implementations
  - C (see Makefile)
  - C++
  - Java
  - Python
  - Perl
- What are the pros and cons of the different implementations?

Data Structures

The Data Structures

- Python and Perl have everything we need built in
- Java and C++ provide appropriate containers in their standard libraries
- in C We'll need to roll these things ourselves

The Data Structures – Python

- The dictionary (`dict`) is given to us
- The prefixes, the keys in the dictionary, will be stored in 2-element `tuple`s (immutable)
- The satellite data, list of suffixes, will be stored in a `list` (a vector)
  - If a prefix doesn't already exist in the table, we insert it, with an empty `list`, `[]`
  - Append the new suffix onto the end of this list

Hash Table in C

We'll make an open hash table of size M to store our table:

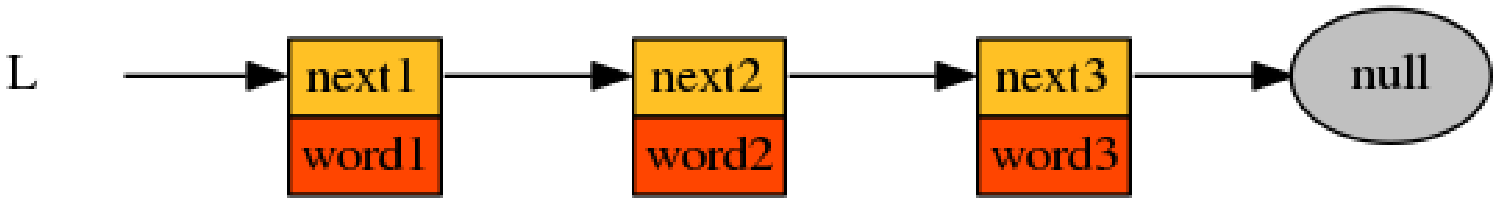
- The prefix (key) is *hashed*
  - Returns a value on $[0, M-1]$
- Each entry in the table is a bucket of keys
  - Distinct keys that have the same hash value (collision)
  - We'll use a linked list
- Each prefix is associated with a list of suffixes

The Satellite Data – Suffix List

- An entry might have several associated data
- Store values in a linked list
- Each `Suffix` is a node in a linked list
  - `word`, (a pointer to) the suffix
  - `next`, pointer to the rest of the list

```
typedef struct Suffix* Suffix ;
struct Suffix {
   char* word ;
   Suffix* next ;
} ;
```

Figure: List of Suffixes



The Prefix (State)

Each `state` stores

- The prefix of $NPREF$ words
- The list of suffixes
- Pointer to next `State` in bucket

```
typedef struct State* State ;
struct State {
   State* next ;
   char* pref[NPREF] ;
   Suffix* suf ;
} ;
```

Figure: A Single State ($NPREF = 2$)

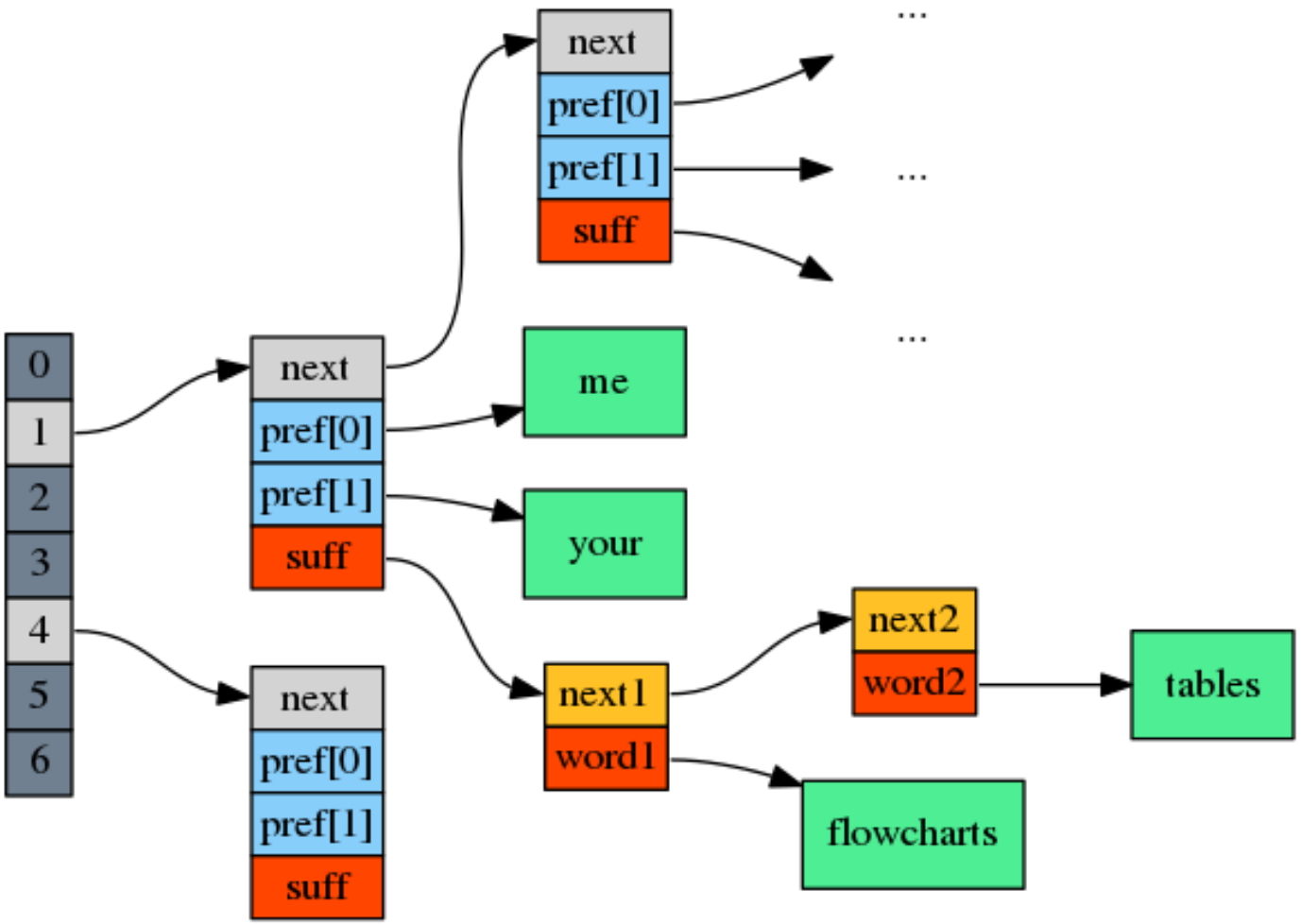
The Hash Table


```
State* statetab[NHASH] ;
```

- The table itself
- An array of pointers to States
- Again, use lists of States (buckets) to handle collisions

The Hash Table

Figure: Sample State Table



Other C Code – eprintf

- Print an error message to `stderr`, then exit:

```
void eprintf( char*, ... ) ;
```

- Print a warning message to `stderr` (don't exit):

```
void weprintf( char*, ... ) ;
```

- Call `strdup( s )`, exits if it fails

```
char* estrdup( char *s ) ;
```

Other C Code – eprintf (cont.)

- Call `malloc( n )`, exits if it fails

```
void* emalloc( size_t n ) ;
```

- Call `realloc( p, n )`, exits if it fails

```
void* erealloc( void* p, size_t n ) ;
```

- Store program name in a static global

```
void setprogname( char* ) ;
```

- Retrieve stored name:

```
char* progname( void ) ;
```

Other C Code – memmove


```
memmove( t, s, n ) ;
```

- Moves (low-level) a block of memory
- Reads n bytes, starting at s, and writing at t
- Okay if regions overlap
- Given prefix $(w_1, \ldots, w_{n-1})$, with suffix $suffix$:

```
memmove( prefix, prefix+1, (NPREF-1)*sizeof( prefix[0] )) ;
prefix[NPREF-1] = suffix ;
```

- Slides everybody down (left) 1, appends the current suffix
- $prefix$ is now $(w_2, \ldots, w_{n-1}, suff)$

Performance

Performance

On Linux 4.4 (64-bit) with an i7 quad core @ 2GHz:

Language	**Time** (sec)	**Lines of Code**
C	0.023	203
C++	0.274	58
Java	0.135	87
Python	0.050	54
Perl	0.056	19