CS 225

Data Structures

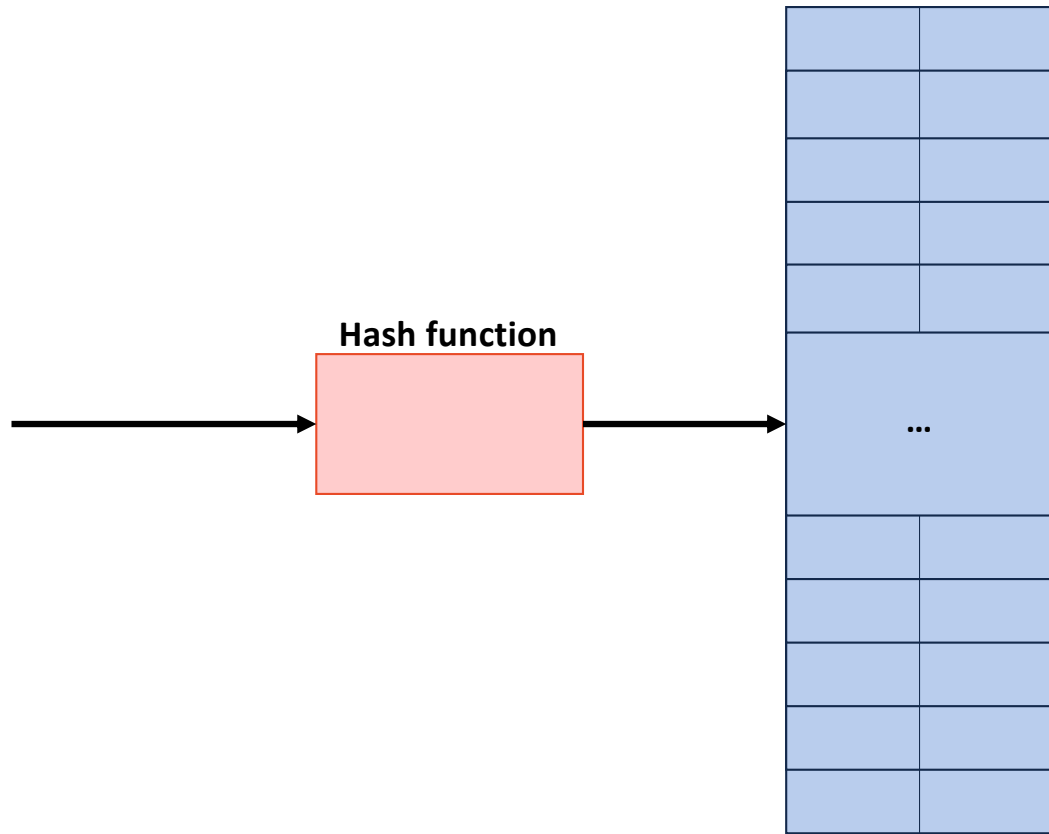*October 20 – Hashing*
G Carl Evans

Hashing

Goals:

We want to define a **keyspace**, a (mathematical) description of the keys for a set of data.

 …use a function to map the **keyspace** into a small set of integers.

Hashing

Hash function

A Hash Table based Dictionary

Client Code:

```
1  Dictionary<KeyType, ValueType> d;
2  d[k] = v;
```

A **Hash Table** consists of three things:

1. A hash function, f(k)

2. An array

3. Something to handle chaos when it occurs!

A Perfect Hash Function

(Angrave, CS 241)
(Bailey, CS 465)
(Challen, CS 124)
(Davis, CS 101)
(Evans, CS 225)
(Fagen-Ulmschneider, CS 240)
(Gunter, CS 464)
(Herman, CS 233)

Hash function

Key	Value

A Perfect Hash Function

Keyspace:
Rolling 5 dice!
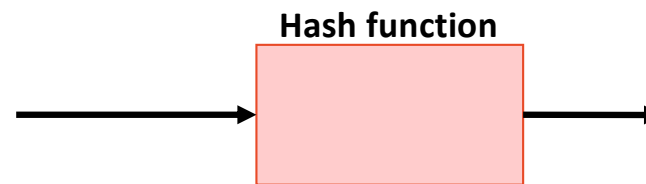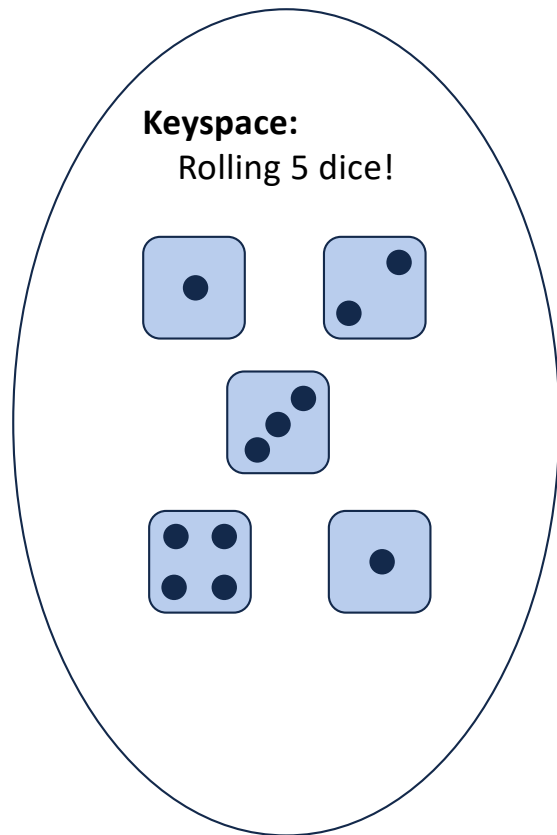
Hash function

Key	Value
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Hash Function

Our **hash function** consists of two parts:
- A **hash**:

- A **compression:**

Choosing a good hash function is tricky…
- Don't create your own (yet*)
- Very smart people have created very bad hash functions

Hash Function

Characteristics of a good hash function:

1. Computation Time:

2. Deterministic:

3. Satisfy the SUHA:

General Purpose Hash Function

Keyspaces

Easy to create if: **|KeySpace| ~ N**

General Purpose Hash Function

Keyspaces

Easy to create if: **|KeySpace| ~ N**

Difficult to Create:

General Purpose Hash Function

Keyspaces

Easy to create if: **|KeySpace| ~ N**

Difficult to Create:
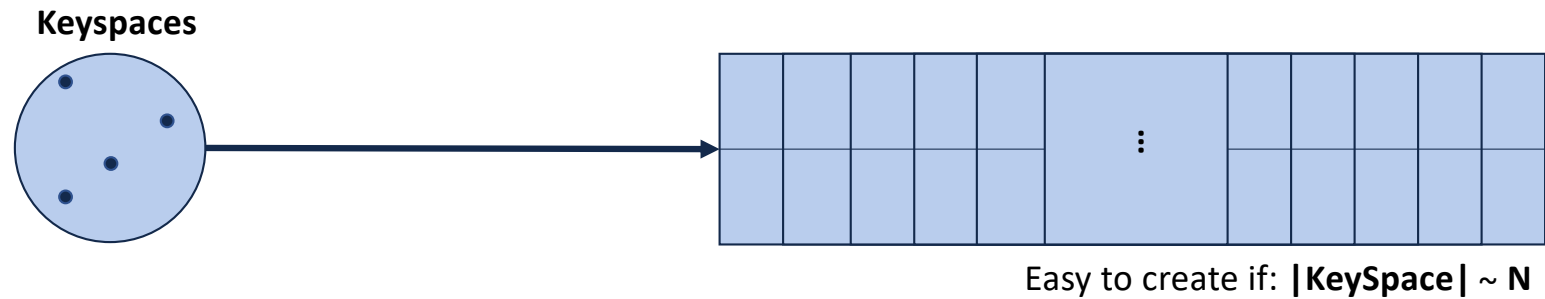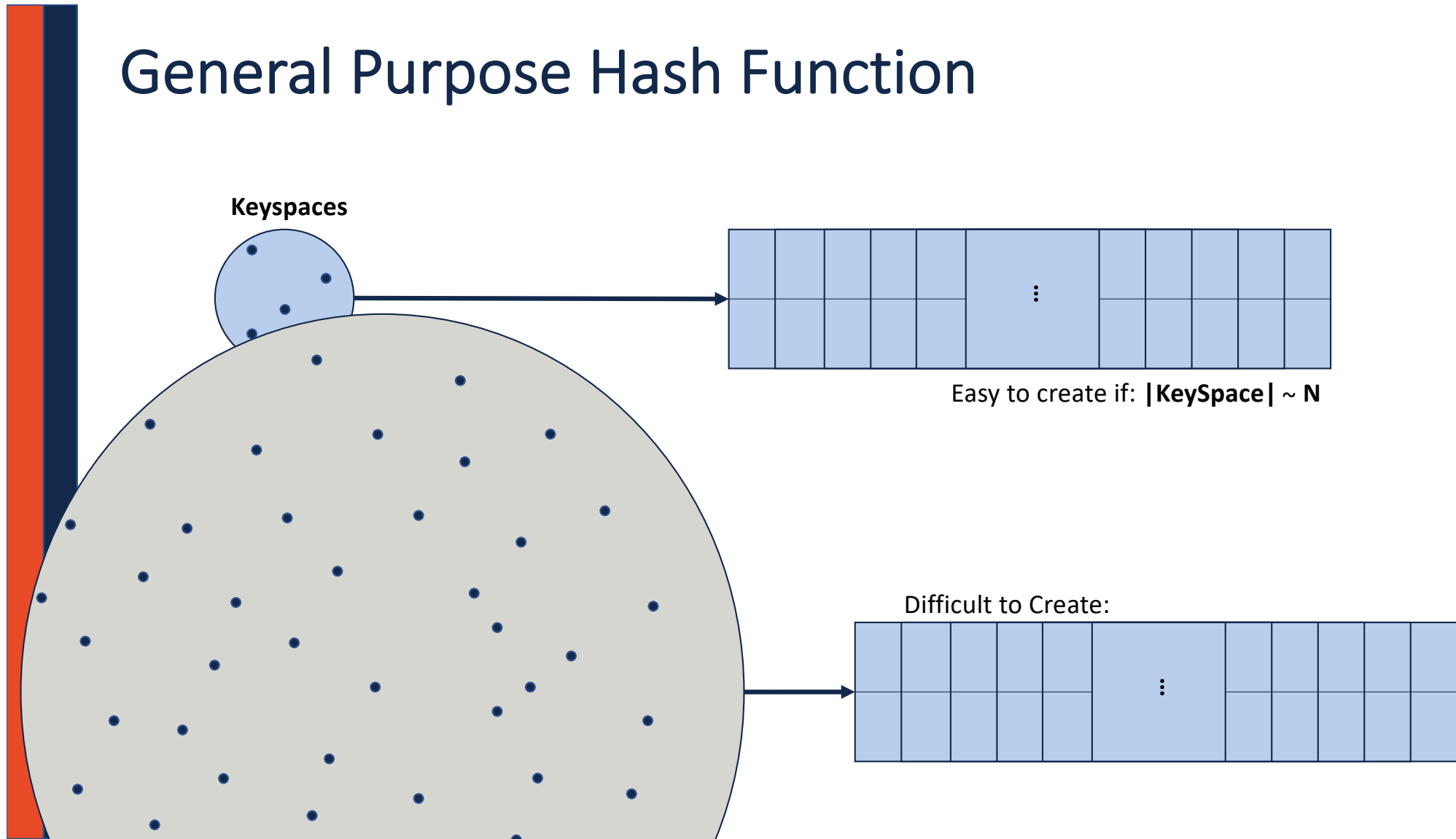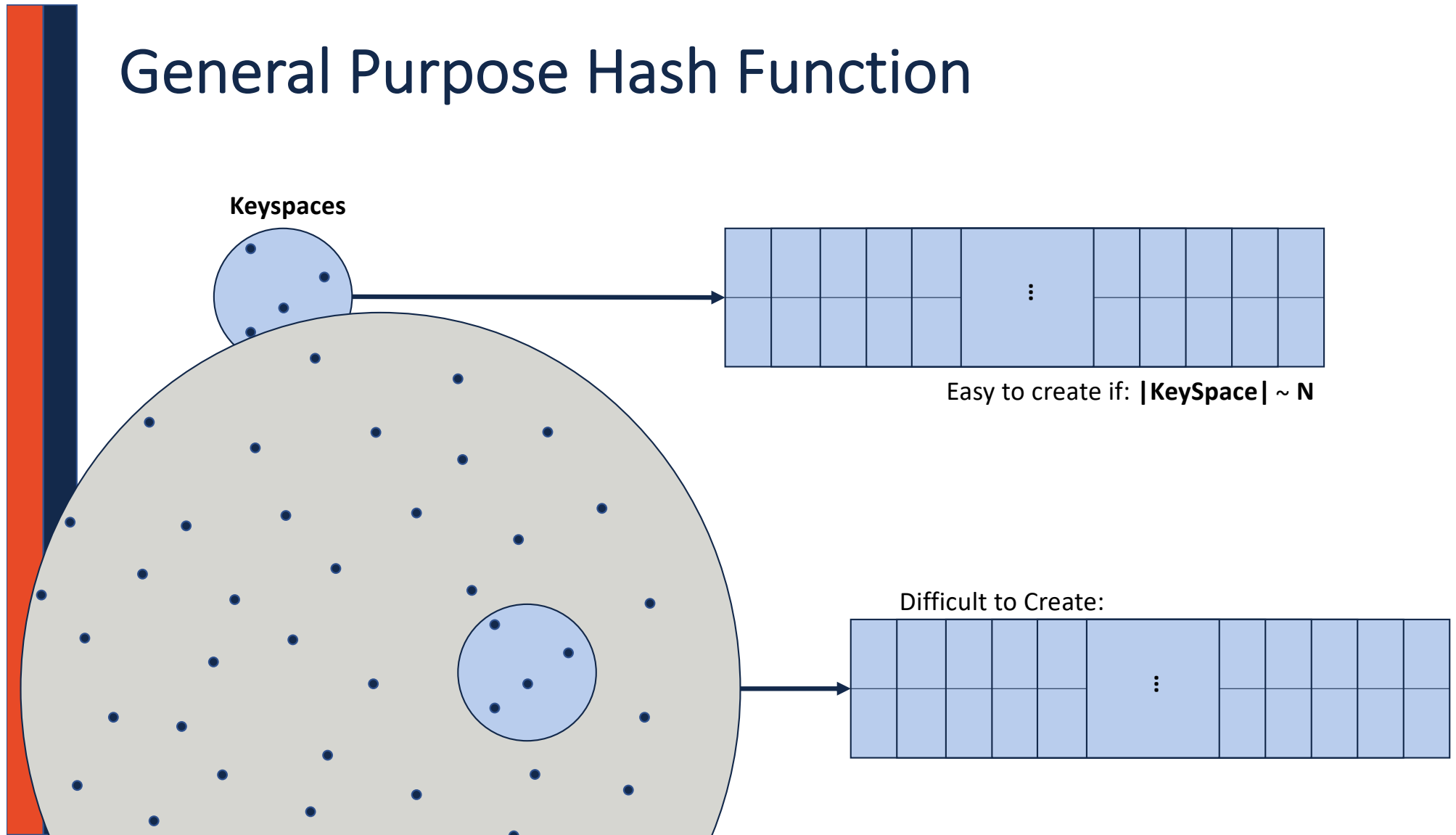
illinois1867 · Follow

illinois1867 Serious #ILLINOIShomecoming question... how do you say "I-L-L" in dog language?

thejordanbarry Omg @emily_tyndorf your puppy is so famous

tessafurlong @emily_tyndorf WHAT IS HAPPENING

tyndorfanne Rosy will be hosting a "meet and greet" for all that are interested😂 #unofficialIllinimascot❤️

idesigner3 @meg733 정말 우리 다람이 닮았다

frantastic2021 @elise_marie28 !!!!

meg733 @idesigner3 나이가 있어보이네

merdive_m12 😂 🍊 💥

allison_nichols4 @emily_tyndorf why am i not surprised that Rosy made the Illinois page😂

1,691 likes

OCTOBER 11

Log in to like or comment.

917037_15005
87793583844_
407241692_n.
png

923679_16398
85792957394_
663562891_n.
png

924439_46820
8916668835_2
077452412_n.p
ng

924849_96117
1243949976_8
99310604_n.p
ng

927447_25968
7470868691_2
035903376_n.
png

929178_15452
81665768987_
841080237_n.
png

929215_35264
3904900366_8
12094193_n-9
-0.png

929215_35264
3904900366_8
12094193_n-9
-1.png

929215_35264
3904900366_8
12094193_n-9
-2.png

929215_35264
3904900366_8
12094193_n-9
-3.png

929215_35264
3904900366_8
12094193_n-9
-4.png

929215_35264
3904900366_8
12094193_n-9
-5.png

929215_35264
3904900366_8
12094193_n-9
-6.png

929215_35264
3904900366_8
12094193_n-9
-7.png

929215_35264
3904900366_8
12094193_n-9
-8.png

929215_35264
3904900366_8
12094193_n-9
-9.png

929215_35264
3904900366_8
12094193_n-9
-10.png

929215_35264
3904900366_8
12094193_n-9
-11.png

929215_35264
3904900366_8
12094193_n-9
-12.png

929215_35264
3904900366_8
12094193_n-9
-13.png

929215_35264
3904900366_8
12094193_n-9
-14.png

929215_35264
3904900366_8
12094193_n-9
-15.png

929215_35264
3904900366_8
12094193_n-9
-16.png

929215_35264
3904900366_8
12094193_n-9
-17.png

929215_35264
3904900366_8
12094193_n-9
-18.png

929215_35264
3904900366_8
12094193_n-9
-19.png

929215_35264
3904900366_8
12094193_n-9
-20.png

929215_35264
3904900366_8
12094193_n-9
-21.png

929215_35264
3904900366_8
12094193_n-9
-22.png

929215_35264
3904900366_8
12094193_n-9
-23.png

929215_35264
3904900366_8
12094193_n-9
-24.png

929215_35264
3904900366_8
12094193_n-9
-25.png

929215_35264
3904900366_8
12094193_n-9
-26.png

929215_35264
3904900366_8
12094193_n-9
-27.png

929215_35264
3904900366_8
12094193_n-9
-28.png

929215_35264
3904900366_8
12094193_n-9
-29.png

929215_35264
3904900366_8
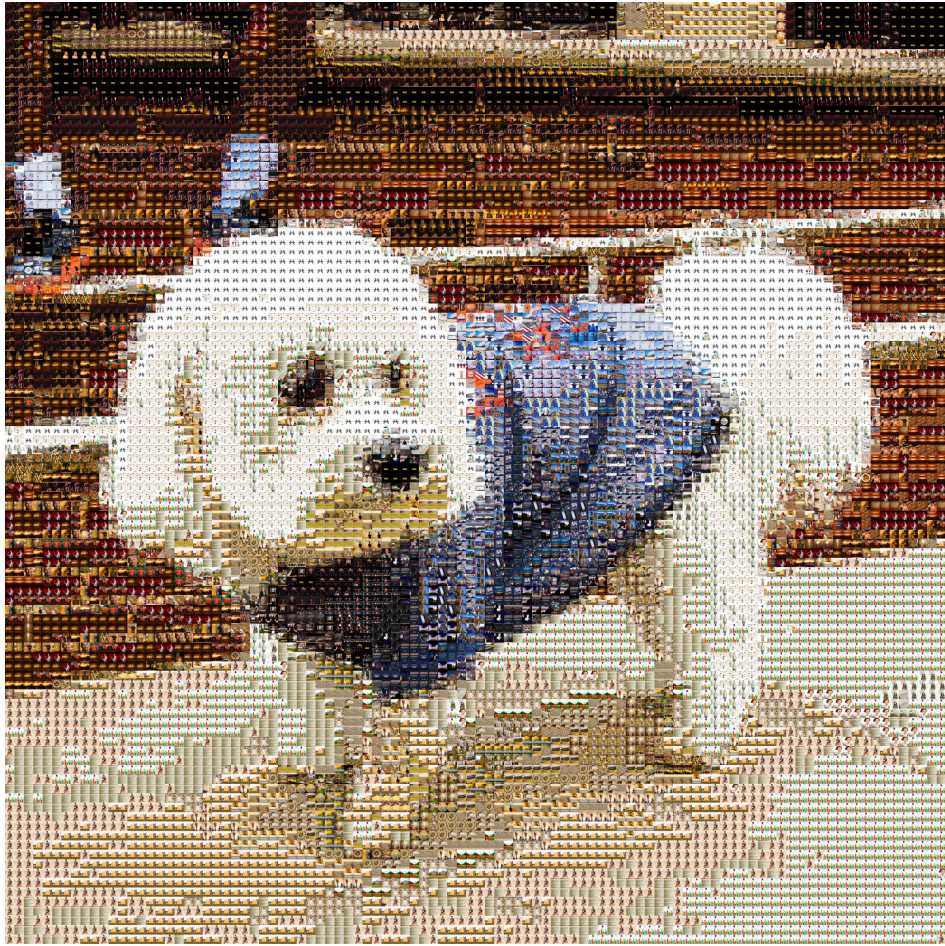12094193_n-9
-30.png

929215_35264
3904900366_8
12094193_n-9
-31.png

929215_35264
3904900366_8
12094193_n-9
-32.png

929215_35264
3904900366_8
12094193_n-9
-33.png

929215_35264
3904900366_8
12094193_n-9
-34.png

929215_35264
3904900366_8
12094193_n-9
-35.png

929215_35264
3904900366_8
12094193_n-9
-36.png

929215_35264
3904900366_8
12094193_n-9
-37.png

929215_35264
3904900366_8
12094193_n-9
-38.png

929215_35264
3904900366_8
12094193_n-9
-39.png

929215_35264
3904900366_8
12094193_n-9
-40.png

929215_35264
3904900366_8
12094193_n-9
-41.png

929215_35264
3904900366_8
12094193_n-9
-42.png

929215_35264
3904900366_8
12094193_n-9
-43.png

929215_35264
3904900366_8
12094193_n-9
-44.png

929215_35264
3904900366_8
12094193_n-9
-45.png

929215_35264
3904900366_8
12094193_n-9
-46.png

929215_35264
3904900366_8
12094193_n-9
-47.png

929215_35264
3904900366_8
12094193_n-9
-48.png

929215_35264
3904900366_8
12094193_n-9
-49.png

929215_35264
3904900366_8
12094193_n-9
-50.png

929215_35264
3904900366_8
12094193_n-9
-51.png

929215_35264
3904900366_8
12094193_n-9
-52.png

929215_35264
3904900366_8
12094193_n-9
-53.png

929215_35264
3904900366_8
12094193_n-9
-54.png

929215_35264
3904900366_8
12094193_n-9
-55.png

929215_35264
3904900366_8
12094193_n-9
-56.png

929215_35264
3904900366_8
12094193_n-9
-57.png

929215_35264
3904900366_8
12094193_n-9
-58.png

929215_35264
3904900366_8
12094193_n-9
-59.png

929215_35264
3904900366_8
12094193_n-9
-60.png

929215_35264
3904900366_8
12094193_n-9
-61.png

929215_35264
3904900366_8
12094193_n-9
-62.png

929215_35264
3904900366_8
12094193_n-9
-63.png

929215_35264
3904900366_8
12094193_n-9
-64.png

929215_35264
3904900366_8
12094193_n-9
-65.png

929215_35264
3904900366_8
12094193_n-9
-66.png

929215_35264
3904900366_8
12094193_n-9
-67.png

929215_35264
3904900366_8
12094193_n-9
-68.png

929215_35264
3904900366_8
12094193_n-9
-69.png

929215_35264
3904900366_8
12094193_n-9
-70.png

929215_35264
3904900366_8
12094193_n-9
-71.png

929215_35264
3904900366_8
12094193_n-9
-72.png

929215_35264
3904900366_8
12094193_n-9
-73.png

929215_35264
3904900366_8
12094193_n-9
-74.png

929215_35264
3904900366_8
12094193_n-9
-75.png

929215_35264
3904900366_8
12094193_n-9
-76.png

929215_35264
3904900366_8
12094193_n-9
-77.png

929215_35264
3904900366_8
12094193_n-9
-78.png

929215_35264
3904900366_8
12094193_n-9
-79.png

929215_35264
3904900366_8
12094193_n-9
-80.png

929215_35264
3904900366_8
12094193_n-9
-81.png

929215_35264
3904900366_8
12094193_n-9
-82.png

929215_35264
3904900366_8
12094193_n-9
-83.png

929215_35264
3904900366_8
12094193_n-9
-84.png

929215_35264
3904900366_8
12094193_n-9
-85.png

929215_35264
3904900366_8
12094193_n-9
-86.png

929215_35264
3904900366_8
12094193_n-9
-87.png

929215_35264
3904900366_8
12094193_n-9
-88.png

929215_35264
3904900366_8
12094193_n-9
-89.png

929215_35264
3904900366_8
12094193_n-9
-90.png

929215_35264
3904900366_8
12094193_n-9
-91.png

929215_35264
3904900366_8
12094193_n-9
-92.png

929215_35264
3904900366_8
12094193_n-9
-93.png

929215_35264
3904900366_8
12094193_n-9
-94.png

929215_35264
3904900366_8
12094193_n-9
-95.png

929215_35264
3904900366_8
12094193_n-9
-96.png

929215_35264
3904900366_8
12094193_n-9
-97.png

929215_35264
3904900366_8
12094193_n-9
-98.png

929215_35264
3904900366_8
12094193_n-9
-99.png

929215_35264
3904900366_8
12094193_n-9
-100.png

929215_35264
3904900366_8
12094193_n-9
-101.png

929215_35264
3904900366_8
12094193_n-9
-102.png

929215_35264
3904900366_8
12094193_n-9
-103.png

929215_35264
3904900366_8
12094193_n-9
-104.png

929215_35264
3904900366_8
12094193_n-9
-105.png

929215_35264
3904900366_8
12094193_n-9
-106.png

929215_35264
3904900366_8
12094193_n-9
-107.png

929215_35264
3904900366_8
12094193_n-9
-108.png

929215_35264
3904900366_8
12094193_n-9
-109.png

929215_35264
3904900366_8
12094193_n-9
-110.png

929215_35264
3904900366_8
12094193_n-9
-111.png

929215_35264
3904900366_8
12094193_n-9
-112.png

929215_35264
3904900366_8
12094193_n-9
-113.png

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

929215_35264
3904900366_8

Hash Function

Given: Easy to create a hash function of strings of length 8.

Idea: Map 40 character things to length 8:

```
Alice was beginning to get very tired of
 sitting by her sister on the bank, and
of having nothing to do: once or twice s
he had peeped into the book her sister w
as reading, but it had no pictures or co
nversations in it, 'and what is the use
of a book,' thought Alice 'without pictu
res or conversations?'  So she was consi
dering in her own mind (as well as she c
ould, for the hot day made her feel very
 sleepy and stupid), whether the pleasur
e of making a daisy-chain would be worth
 the trouble of getting up and picking t
he daisies, when suddenly a White Rabbit
 with pink eyes ran close by her.  There
 was nothing so very remarkable in that;
 nor did Alice think it so very much out
 of the way to hear the Rabbit say to it
self, 'Oh dear! Oh dear! I shall be late
!' (when she thought it over afterwards,
 it occurred to her that she ought to ha
```

Idea: Map 40 character things to length 8:

```
https://en.wikipedia.org/wiki/Main_Page
https://en.wikipedia.org/wiki/Battle_of_
https://en.wikipedia.org/wiki/Vector_Gen
https://en.wikipedia.org/wiki/2017_Austr
https://en.wikipedia.org/wiki/19th_Natio
https://en.wikipedia.org/wiki/Japanese_g
```

Hash Function

In CS 225, we focus on **general purpose** hash functions.

Other hash functions exists with different properties
(eg: cryptographic hash functions)

Collision Handling: Separate Chaining

S = { 16, 8, 4, 13, 29, 11, 22 } |S| = n

h(k) = k % 7 |Array| = N

0		
1		
2		
3		
4		
5		
6		

	Worst Case	SUHA
Insert		
Remove/Find		

Collision Handling: Probe-based Hashing

S = { 16, 8, 4, 13, 29, 11, 22 } |S| = n

h(k) = k % 7 |Array| = N

0	
1	
2	
3	
4	
5	
6	

Try h(k) = (k + 0) % 7, if full...
Try h(k) = (k + 1) % 7, if full...
Try h(k) = (k + 2) % 7, if full...
Try ...