Introduction to Datalab

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Recap: operations in C

- And
  - Use 1 to extract, 0 to unset one bit
    - Extract the ith bit: **x & (1 << (i - 1))**
    - Unset the ith bit: **x & ~(1 << (i - 1))**
- Or
  - Use 1 to set, 0 to extract one bit
    - Set the ith bit: **x | (1 << (i - 1))**
- Xor
  - 0 if equal, otherwise 1
    - Flip the ith bit: **x ^ (1 << (i - 1))**
- Not
  - Flip all bits

```
  01101001
& 01010101
----------
  01000001
```

And

A&B = 1 when both A=1 and B=1

&	0	1
0	0	0
1	0	1

```
  01101001
| 01010101
----------
  01111101
```

Or

A|B = 1 when either A=1 or B=1 or both

|	0	1
0	0	1
1	1	1

```
  01101001
^ 01010101
----------
  00111100
```

Exclusive-Or (Xor)

A^B = 1 when A=1 or B=1, but not both

^	0	1
0	0	1
1	1	0

```
~ 01010101
----------
  10101010
```

Not

~A = 1 when A=0

~	0	1
	1	0

Recap: operations in C

- Logic Not
  - View 0 as **false**, otherwise **true**
  - **Always return 0 or 1**
    - **Whether an integer is zero: !x**
    - Whether an integer is not zero: **!!x**
- Add
  - Some magic between x, x + 1 and ~
    - Lowbit(x): **x & (~x+1)**
- << and >>
  - Replace * with <<
    - Multiple x by 8: **x << 3**
  - Combined with |
    - Cat: **(0xFF << 8) | 0xFF = 0xFFFF**

x	z10..0
~x	~z01..1
x + 1	z10..1
~x + 1	~z10..0

Argument x	01100010
<< 3	00010000
Log. >> 2	00011000
Arith. >> 2	00011000

Argument x	10100010
<< 3	00010000
Log. >> 2	00101000
Arith. >> 2	11101000

Datalab: Reminders

- Type
  - **int** and **long** are available
  - cast between int and long is ok, in either direction: **(long)x, (1L << 63)**
- Constant
  - Constant between **0x0 ~ 0xFF (0 ~ 255)** is valid
  - It is ok to concatenate such as **0xFFFF = (0xFF << 8 | 0xFF)**, uses 2 ops (<< and |)
- Operators
  - One operand
    - ! and ~
  - Two operands
    - &, |, ^, +, << and >>
  - **Other operators is invalid**
- Unlimited
  - (), =, and local variables **are always valid and not counted**
- **Important**
  - **Declare all local variables at the beginning of the function**

Some puzzles may have more strict limitations

Datalab: Getting Started

- Method 1:
  - Download datalab-sp25 .tar from course website
    - **cd /path/to/your/download**
  - Upload tar to remote server (if using ics server)
    - **scp datalab-sp25.tar username@x86.ics.xjtu-ants.net:~/datalab-sp25.tar**
  - Decompress
    - **tar -xvf datalab-sp25.tar**
- Method 2 (recommended):
  - Clone from Github repo
    - **git clone [-o remote_name] https://github.com/xjtu-ics/datalab-sp25.git (HTTPS)**
    - **git clone [-o remote_name] git@github.com:xjtu-ics/datalab-sp25.git (SSH)**
- Start
  - **cd /path/to/your/datalab-sp25**
  - **make**

Datalab: Check your code

- btest
  - runs your solutions on random values
- dlc
  - a modified C parser
- driver.pl
  - Runs **./dlc -z** to identify coding rules
  - Runs **./btest -g** to check correctness
  - Runs **./dlc -Z** to check operation counts
  - Print your grade
- Grade
  - Correctness: pass ./**btest** check and ./**dlc -z** check
  - Performance: pass **./dlc -Z** check (use **./dlc -e** to count your operations)
  - We will use **driver.pl** to test your solution

Datalab: Submission

- Upload **bits.c** in a **zip** file to here for submission
  - **make submit**

Datalab: Some tools

- ishow
  - Usage: **./ishow val1 val2 ...**
  - Values may be given in **hex** or **decimal**
  - Examples:

```
ttang in ~/cs/xjtu-ics/ics-labs/datalab/datalab-sp25 on main ● ● λ ./ishow 0x88 88
Hex = 0x00000088,       Signed = 136,   Unsigned = 136
Hex = 0x00000058,       Signed = 88,    Unsigned = 88
```

- printf()
  - Directly used in bits.c (may be some warnings, but it is ok in this lab)
  - **Do not include** <stdio.h> in bits.c, or you will not pass the dlc checker

Datalab: Example

- **Objective:** swap odd and even bits in an integer, where bits are numbered from 0 (least significant) to 31 (most significant)
- **Legal ops: &, |, ^, ~, !, +, <<, >>**
- **10 ops max**

```
/*
 * swapOddEvenBits - Swap odd and even bits
 *   where bits are numbered from 0 (least significant) to 31 (most significant)
 *   Examples: swapOddEvenBits(0b10110101) -> 0b01111010
 *   Legal ops: & | ^ + << >> ~ !
 *   Max ops: 10
 *   Rating: 3
 */
int swapOddEvenBits(int x) {
  return 2;
}
```

Example:

- *0b10110101*
  - *odd: 0b10100000*
  - *even: 0b00010101*
- *0b01111010*

Datalab: Example

correct?	Valid op?	Ops <= 10?

- First attempt:

```
/*
 * swapOddEvenBits - Swap odd and even bits
 *   where bits are numbered from 0 (least significant) to 31 (most significant)
 *   Examples: swapOddEvenBits(0b10110101) -> 0b01111010
 *   Legal ops: & | ^ + << >> ~ !
 *   Max ops: 10
 *   Rating: 3
 */
int swapOddEvenBits(int x) {
  int mask1 = 0x55555555;
  int mask2 = 0xAAAAAAAA;
  return ((x & mask1) << 1) | ((x & mask2) >> 1);
}
```

Datalab: Example

correct?	Valid op?	Ops <= 10?
✗		

- First attempt:
  - **WTF ?**

```
ERROR: Test swapOddEvenBits(-2147483648[0x80000000]) failed...
...Gives -1073741824[0xc0000000]. Should be 1073741824[0x40000000]
```

```c
/*
 * swapOddEvenBits - Swap odd and even bits
 *   where bits are numbered from 0 (least significant) to 31 (most significant)
 *   Examples: swapOddEvenBits(0b10110101) -> 0b01111010
 *   Legal ops: & | ^ + << >> ~ !
 *   Max ops: 10
 *   Rating: 3
 */
int swapOddEvenBits(int x) {
  int mask1 = 0x55555555;
  int mask2 = 0xAAAAAAAA;
  return ((x & mask1) << 1) | ((x & mask2) >> 1);
}
```

Example:

- *x=0b 1000...000*
- *x & mask1: 0b_0...0_0*
- *x & mask2: 0b1_0..._0_*
- ***What if (x & mask2) >> 1?***
  - ***0b 11_0...0_0***
- ***Finally***
- ***0b 1100...00 (0xc0000000)***

Datalab: Example

correct?	Valid op?	Ops <= 10?
✓	✗	

- Second attempt:
  - Correct but invalid

```
10      10      0       swapOddEvenBits
dlc:bits.c:173:swapOddEvenBits: Illegal constant (0x55555555) (only 0x0 - 0xff allowed)
dlc:bits.c:174:swapOddEvenBits: Illegal constant (0xAAAAAAAA) (only 0x0 - 0xff allowed)
dlc:bits.c:177:swapOddEvenBits: Zapping function body!
```

```c
/*
 * swapOddEvenBits - Swap odd and even bits
 *   where bits are numbered from 0 (least significant) to 31 (most significant)
 *   Examples: swapOddEvenBits(0b10110101) -> 0b01111010
 *   Legal ops: & | ^ + << >> ~ !
 *   Max ops: 10
 *   Rating: 3
 */
int swapOddEvenBits(int x) {
  int mask1 = 0x55555555;
  int mask2 = 0xAAAAAAAA;
  int mask3 = ~(1 << 31);
  return ((x & mask1) << 1) | (((x & mask2) >> 1) & mask3);
}
```

Tips:

- *Use 0x7FFFFFFF and &*
- *Unset sign bit*
- *Keep others unchanged*

How to get mask?

- ***Use << and |***
- *0x55555555*
  - *(0x55 << 8) | 0x55*
  - *(0x5555 << 16) | 0x5555*
- ***0xAAAAAAAA = ~0X55555555***

Datalab: Example

correct?	Valid op?	Ops <= 10?
✓	✓	✗

- Third attempt:
  - Ops < 10 ?

```c
/*
 * swapOddEvenBits - Swap odd and even bits
 *   where bits are numbered from 0 (least significant) to 31 (most significant)
 *   Examples: swapOddEvenBits(0b10110101) -> 0b01111010
 *   Legal ops: & | ^ + << >> ~ !
 *   Max ops: 10
 *   Rating: 3
 */
int swapOddEvenBits(int x) {
  int mask = 0x55;
  int mask3 = ~(1 << 31);
  mask |= mask << 8;
  mask |= mask << 16;
  return ((x & mask) << 1) | (((x & (~mask)) >> 1) & mask3);
}
```

Do we really need mask3?

- *Why mask3*
  - *Unset the sign bit*
  - *Keep others unchanged*
- *Why not mask3*
  - *Use >> first*
  - *Mask can help us to unset the sign bit*

Datalab: Example

correct?	Valid op?	Ops <= 10?
✓	✓	✓

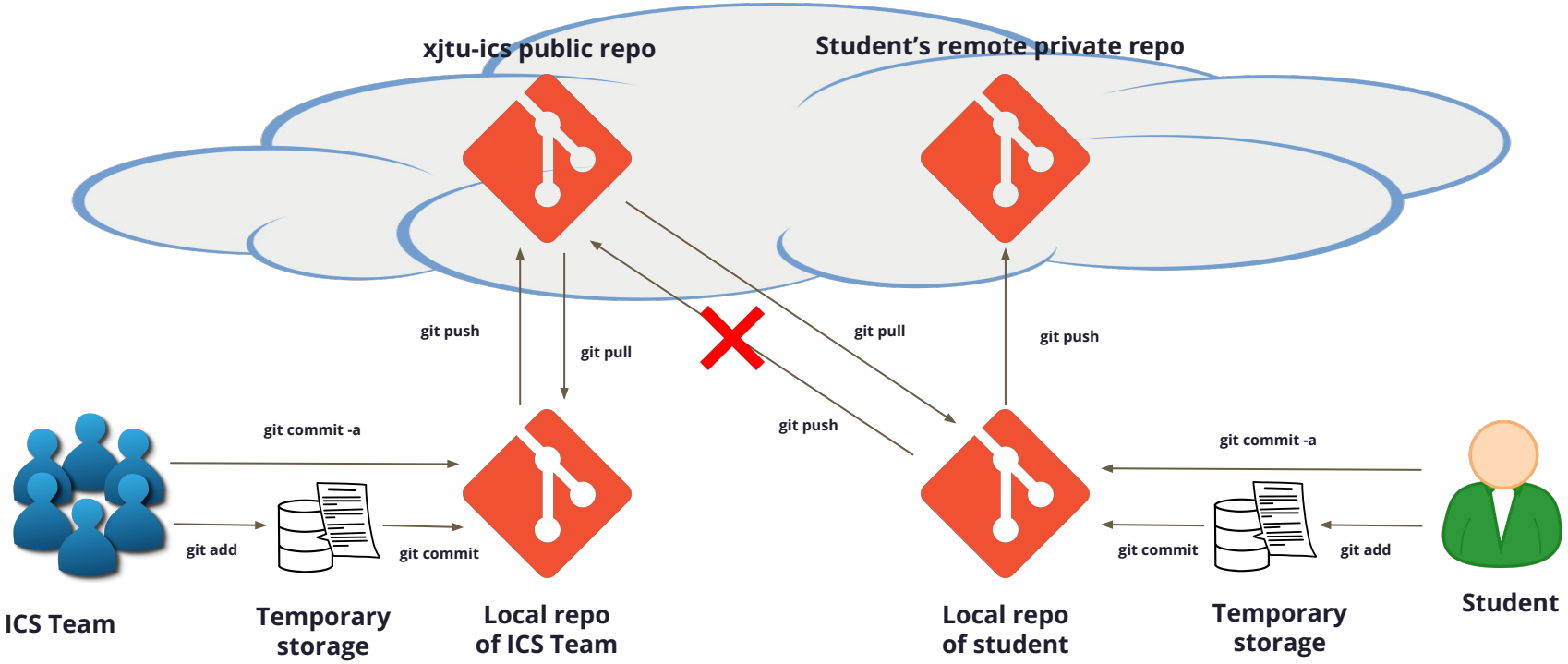
- Final attempt:

10	10	0	2	9	swapOddEvenBits

```c
/*
 * swapOddEvenBits - Swap odd and even bits
 *   where bits are numbered from 0 (least significant) to 31 (most significant)
 *   Examples: swapOddEvenBits(0b10110101) -> 0b01111010
 *   Legal ops: & | ^ + << >> ~ !
 *   Max ops: 10
 *   Rating: 3
 */
int swapOddEvenBits(int x) {
  int mask = 0x55;
  mask |= mask << 8;
  mask |= mask << 16;
  return ((x & mask) << 1) | ((x >> 1) & mask);
}
```

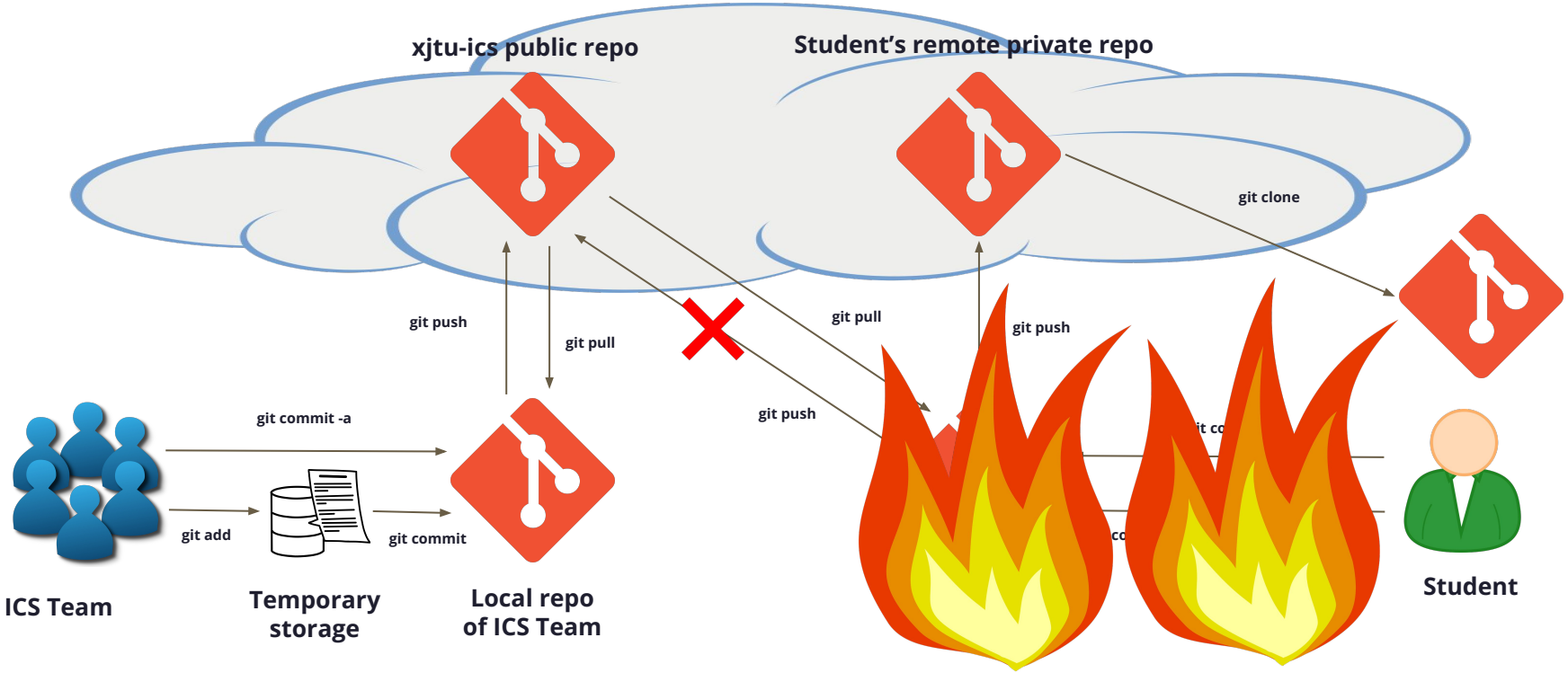
Using Github

- Use your own **private** repo to backup



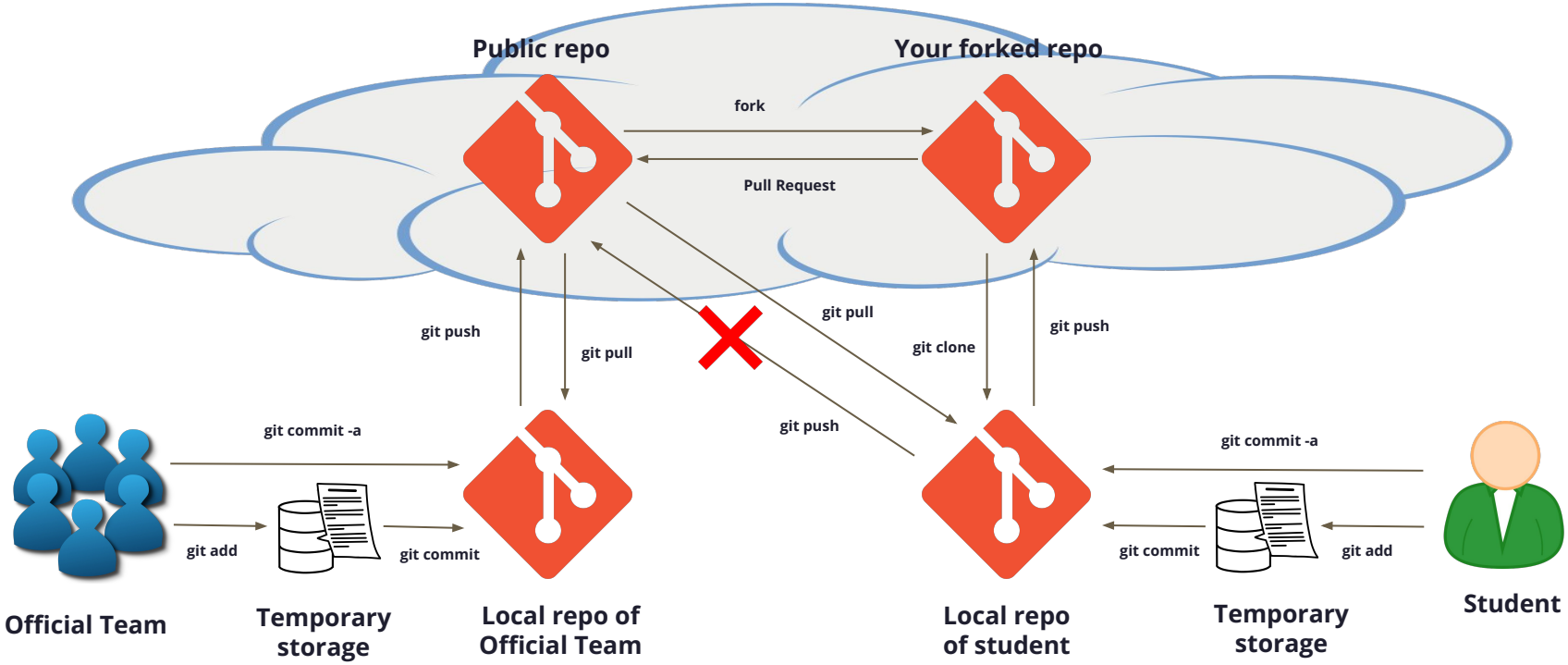
Using Github

- When crashed...



Using Github

- Contributing to open source project



Using Github

- xjtu-ics/textbook is waiting for you