Hacking (in) Games

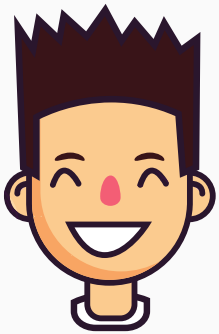
Protecting your Games and your Gamers

Michael Schwarz, Daniel Gruss

September 1, 2018

IAIK – Graz University of Technology

Who am I?



Michael Schwarz

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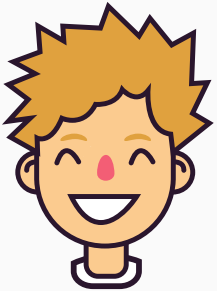

Daniel Gruss

PostDoc @ Graz University of Technology

@lavados

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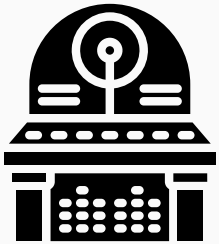
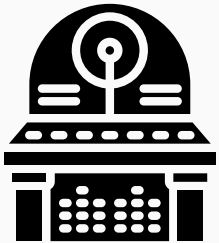


- Hacking (in) the game industrie is as old as the game industry

Hacking



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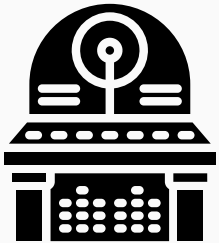
- Trainers ("cheat programs") appeared in 1981

Hacking



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→ Exploit insecure implementations of games

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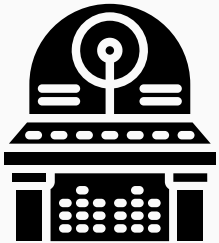

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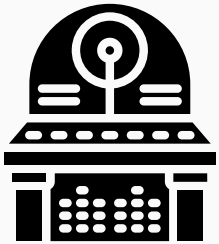

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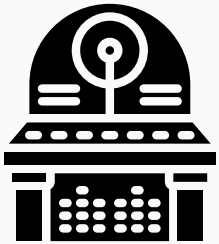

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- Trainers ("cheat programs") appeared in 1981

→ Exploit insecure implementations of games

- Not only cheating → piracy
- Bugs in games allowed subverting gaming console security

Piracy

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Piracy. /ˈpʌɪrəsi/ noun.

the unauthorized use or reproduction of another's work.

"software piracy"

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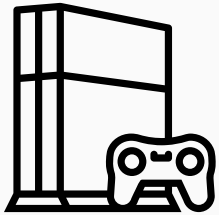
"software piracy"

synonyms: illegal reproduction, plagiarism, illegal copying, copyright infringement, bootlegging, stealing, theft

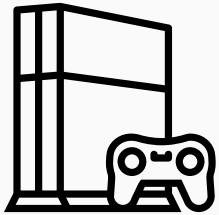
Source: Google

Gaming Consoles



- Gaming console are usually closed systems

Gaming Consoles



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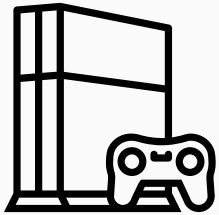

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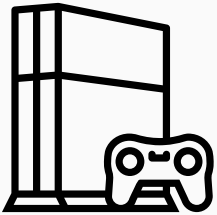

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→ Only certified, original games can run

- Prevents illegal copies of games

- Goal of many console hackers: run own programs

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- Often a small step from homebrew to pirated games
- Arbitrary programs can be executed

→ Patched games as well


PIRACY? LET'S CALL IT
"HOMEBREW"
imgflip.com

- Running homebrew is a cat-and-mouse game

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- Side effect: platform and games become more secure

Jailbreaks (e.g., getting root) on various devices:

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- Xbox (buffer overflow in savegames)
- PSP (buffer overflow in image library and savegame)

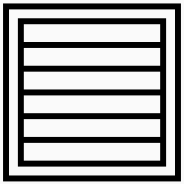
1. ⬆ 13,166% Sales Rank in Video Games: 6 (was 796)

Lumines
by Ubisoft
Platform: PSP Sony PSP
Average Customer Review:
Available from these sellers

18 used & new from $18.82

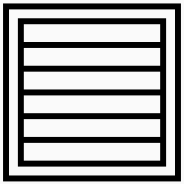

CRAFTSMAN

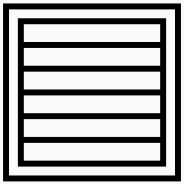
- A buffer is a chunk of memory...



Buffer

- A buffer is a chunk of memory...
  - with boundaries





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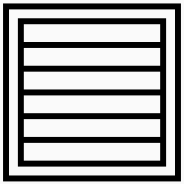

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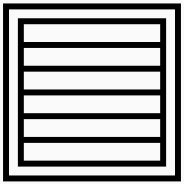
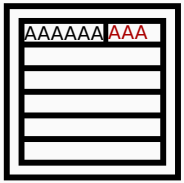
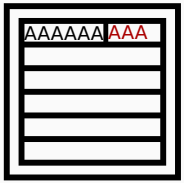


- A buffer is a chunk of memory...
  - with boundaries
  - defined by a start address and size
  - storing elements of a certain type
- Example: Arrays in C/C++

```
char buffer[12];
strcpy(buffer, "Hello");
```

- Not all buffers check their bounds





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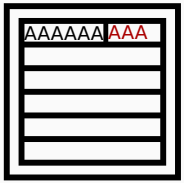

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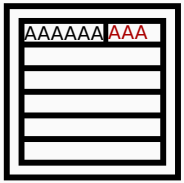
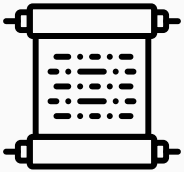


- Not all buffers check their bounds
- Out-of-bounds reads/writes access *something*
- Most commonly: array index out of bounds
- Example: Buffer overflow in C/C++

```
char buffer[4];
strcpy(buffer, "Hello");
```

1972 First documentation of buffer overflows



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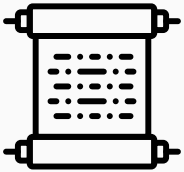

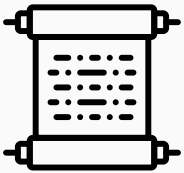

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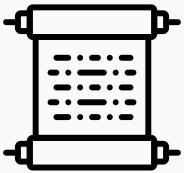

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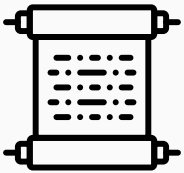
Buffer Overflow - Short History



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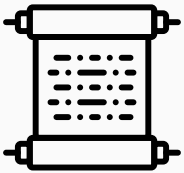

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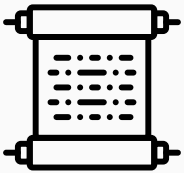

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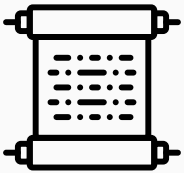

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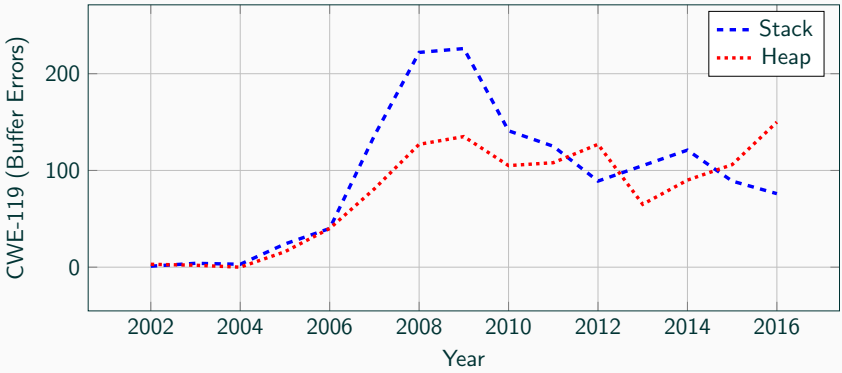
2003 Buffer overflows in Xbox games used to run unlicensed software

Buffer overflows are very common



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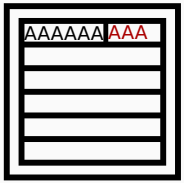
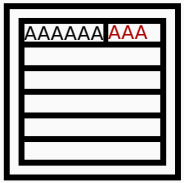
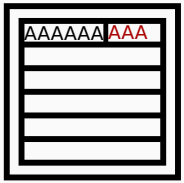




- Local buffers are on the stack
- What is next to the buffer?



- Local buffers are on the stack
- What is next to the buffer?
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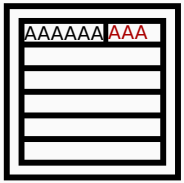
  - Function parameters
  - Saved return addresses



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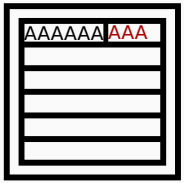

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- What is next to the buffer?
  - Other variables
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  - Saved return addresses
- Attacker controls the buffer input, overwrites this data
- Changes control flow or manipulates data

Practical Example: Stack Overflow

Buffer Overflow (Stack)

```c
#include <stdio.h>
#include <string.h>

void printName(char* buffer) {
  char name[16];
  strcpy(name, buffer);
  printf("Hello %s\n", name);
}

int main(int argc, char* argv[]) {
  if(argc > 1) printName(argv[1]);
  return 0;
}
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Buffer Overflow (Stack)

```
% gdb --args ./hello Students
(gdb) r
Starting program: /home/hello Students
Hello Students
[Inferior 1 (process 21312) exited normally]
```

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Starting program: /home/hello Students
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```
% gdb --args ./hello AAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
(gdb) r
Starting program: /home/hello AAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
Hello AAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

Program received signal SIGSEGV, Segmentation fault.
0x41414141 in ?? ()
```

Practical Example Analysis: Stack Overflow

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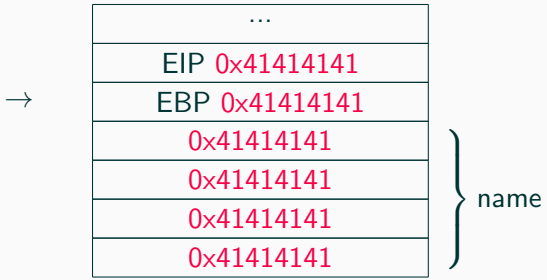

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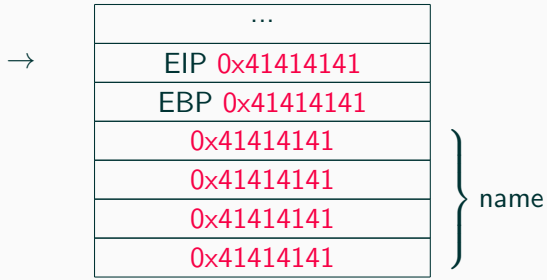
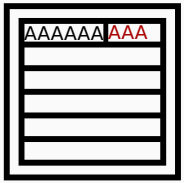
  if(argc > 1) printName(argv[1]);
  return 0;
}
```

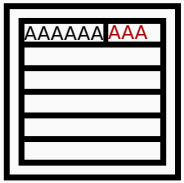


Practical Example Impact: Stack Overflow

Buffer Overflow (Stack)



- Attacker can jump to arbitrary location in memory



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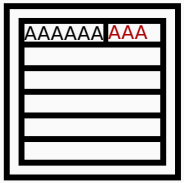
- Every function that is mapped in the address space can be executed



- Attacker can jump to arbitrary location in memory
- Every function that is mapped in the address space can be executed
- Attacker has effectively full control over the program

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Pokémon Red

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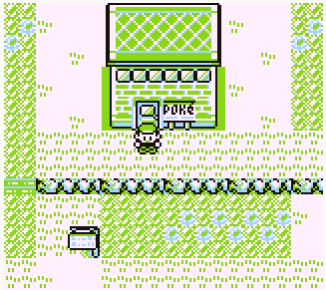
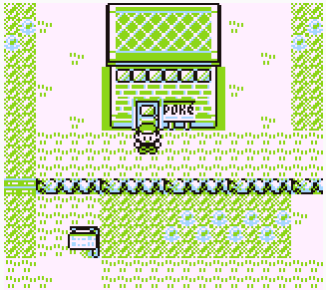
- Among the best games of all time (according to IGN)
- Sad that they never produced any sequel (or similar)
- Completely reverse engineered:
  `https://github.com/pret/pokered`
- Source code analysis reveals many bugs...

- Pokémon Centers have a so-called Cable Club





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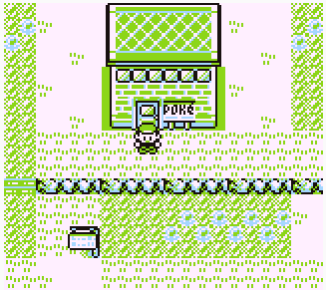

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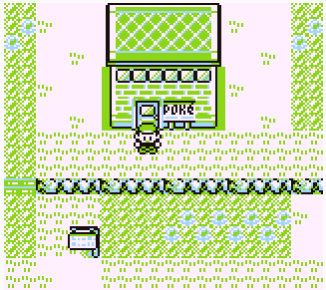

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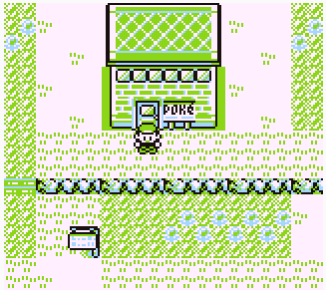

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- Maybe there is something more interesting?

- Pokémon list is terminated with special character

Pokémon List

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```
void TradeCenter_PrintPartyListNames(char*
    start_ids, char* dest) {
  char* current_id = start_ids;
  while (*current_id != 0xFF) {
    char* name_str = GetMonName(*current_id);
    PlaceString(name_str, dest);
    dest += 20;
  }
}
```

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```
- Buffer overflow with Pokémon names into stack

Live Demo

Running Self-Compiled Code in Pokémon Red

Result

- We can run any code $\leq$ 192 bytes

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- For larger programs: use Link cable to request more data
- Also works on real Game Boy hardware (©vaguilar)

Consequence

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- Could be used to run pirated games
- (Non-existing) Security completely subverted

Countermeasures

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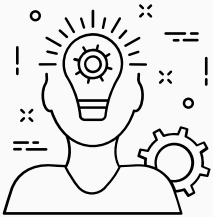
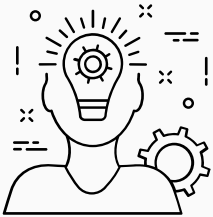
- Test (a lot) $\rightarrow$ automated tests



Things to keep in mind

- User input is evil



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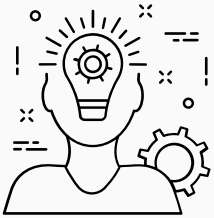
- Whitelisting is more secure than blacklisting



Things to keep in mind

- User input is evil
- Whitelisting is more secure than blacklisting
- Input can be indirect → network packets, files


I DON'T ALWAYS TRUST
BUT WHEN I TRUST, I VERIFY
memegenerator.net

Cheating

Cheating

cheat. /tʃi:t/ verb.

gerund or present participle: cheating.

act dishonestly or unfairly in order to gain an advantage.

Source: Google

Cheating

- Cheating was always part of video games

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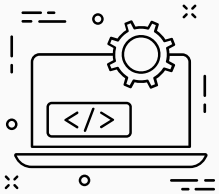
- Developers implemented cheat codes for testing
- 1981 cheat programs (aka trainers) appeared
- Modified game before launching



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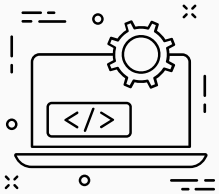

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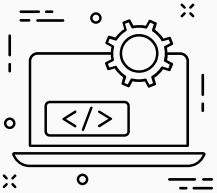

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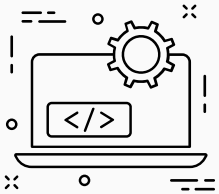

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- Gives player (unfair) advantages

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- Two's complement for signed integers, positive and negative
- Sign bit + Magnitude for floating point numbers

- An n-bit integer x is represented as

$$x = (x_{n-1}, x_{n-2}, \cdots, x_1, x_0) = \sum_{i=0}^{n-1} 2^i \cdot x_i$$

- The range of representable values is

$$0 \leq x < 2^n$$

- On overflow, the value is reduced modulo 2^n

$$x = \begin{cases} x & x < 2^n \\ x \mod 2^n & x \geq 2^n \end{cases}$$

- An n-bit integer x is represented as

$$x = (x_{n-1}, x_{n-2}, \cdots, x_1, x_0) = -2^{n-1}x_{n-1} + \sum_{i=0}^{n-2} 2^i \cdot x_i$$

- The range of representable values is

$$-2^{n-1} \leq x < 2^{n-1}$$

- A single-precision (IEEE 754-2008) float x is represented as

$$\begin{aligned} x &= (x_{31}, x_{30}, \cdots, x_1, x_0) \\ &= (-1)^{x_{31}} \cdot \left(1 + \sum_{i=1}^{23} x_{23-i} 2^{-i}\right) \cdot 2^{([x_{30}:x_{23}]-127)} \end{aligned}$$

- A single-precision float can encode numbers up to $\approx 3.4 \times 10^{38}$
- All integers with ≤ 6 decimal digits can be encoded
- All values 2^n with $-126 \leq n \leq 127$ can be encoded

- Example: $x = 3.3125$

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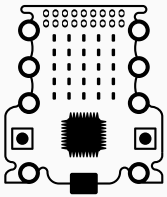
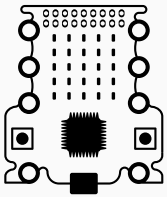
```
int i = 0b01000000101010000000000000000000;
float f = *(float*)&i;
printf("%.4f\n", f); // prints 3.3125
```



- Patterns can be searched in memory



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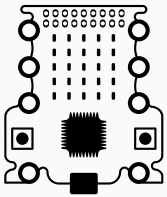

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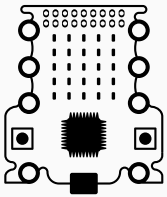

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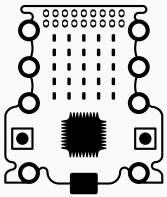
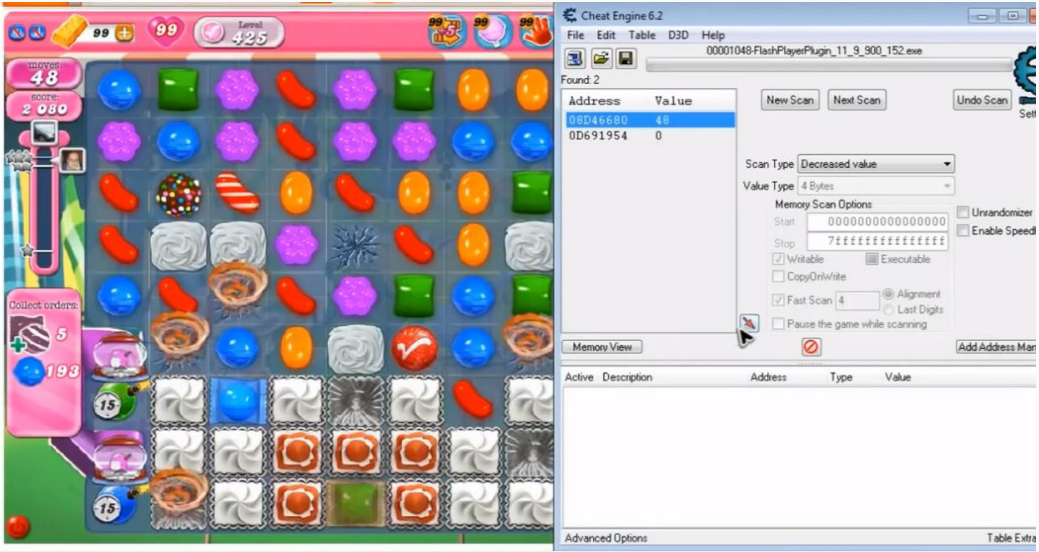
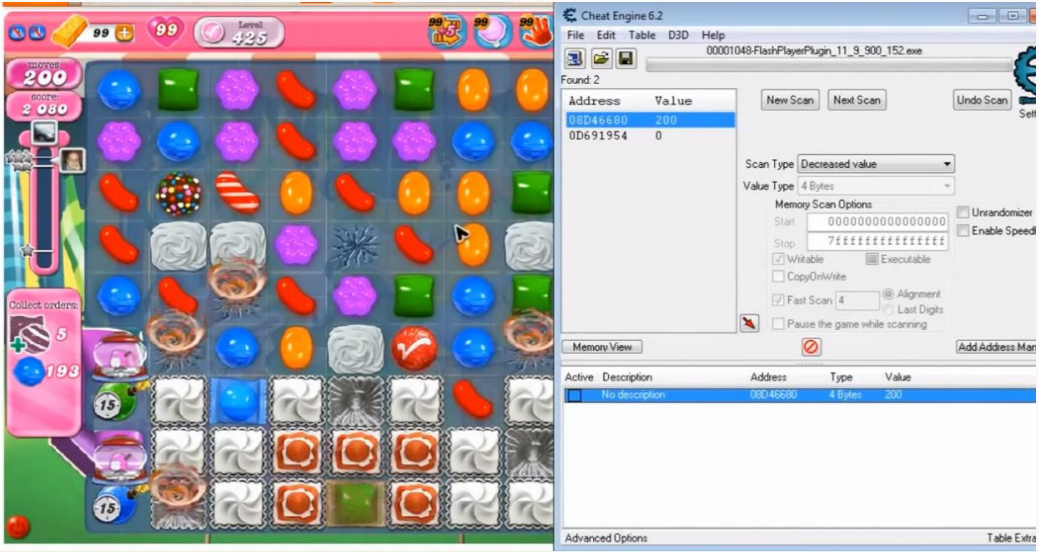


- Patterns can be searched in memory
- Dedicated tools (e.g., ArtMoney, Cheat Engine)
- Works for many games
- Easy to use for users
- Found values can be changed or frozen


Cheat Engine 6.2
File Edit Table D3D Help
00001048-FlashPlayerPlugin_11_9_900_152.exe
Found: 2
Address Value
08D46680 48
0D691954 0
New Scan
Next Scan
Undo Scan
Scan Type Decreased value
Value Type 4 Bytes
Memory Scan Options
Start 0000000000000000
Stop 7fffffffffffffff
Writable
Executable
CopyOnWrite
Fast Scan 4
Alignment
Last Digits
Pause the game while scanning
Unrandomizer
Enable Speedh
Memory View
Add Address Man
Active Description Address Type Value
Advanced Options
Table Extra
moves: 48
score: 2 080
Collect orders:
5
193
15
15
Level 425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Fast Scan 4
Alignment
Last Digits
Pause the game while scanning
Unrandomizer
Enable Speedh
Memory View
Add Address Man
Active Description Address Type Value
No description 08D46680 4 Bytes 200
Advanced Options
Table Extra
moves 200
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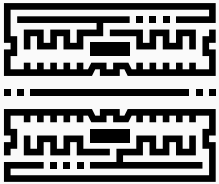
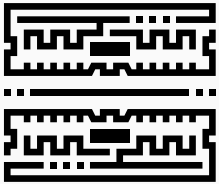
193
15
15
Level 425


WHAT YEAR IS IT?
MOVIECLIPS.COM
imgflip.com

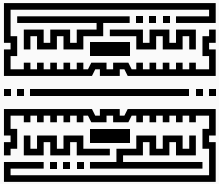
Do not trust user data!





Do not trust user data!

- Store important values (e.g., money) on server



Do not trust user data!

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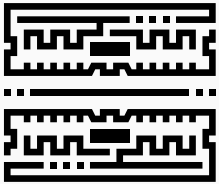

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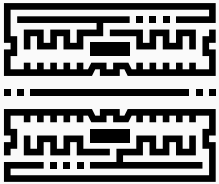

Do not trust user data!

- Store important values (e.g., money) on server
- Calculate values on server based on user action
- Use checksums for data
- Encrypt values in memory (simple XOR is already a lot harder to hack)

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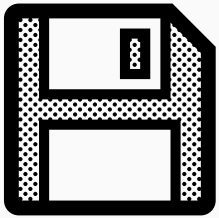
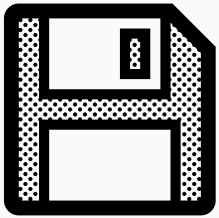
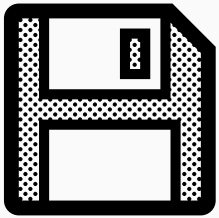
- Values can only be changed through certain functions
- These functions also require keys/secrets



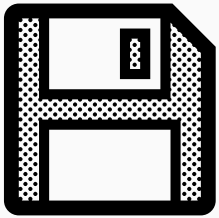
- Values are not only in memory



- Values are not only in memory
- Savegames store important values



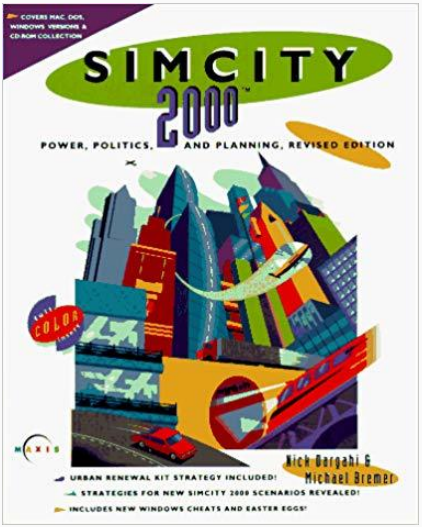
- Values are not only in memory
- Savegames store important values
- Similar method as memory hacking



- Values are not only in memory
- Savegames store important values
- Similar method as memory hacking
- Modifying savegames is often even easier

SimCity 2000 (1993)

SimCity 2000 (1993)



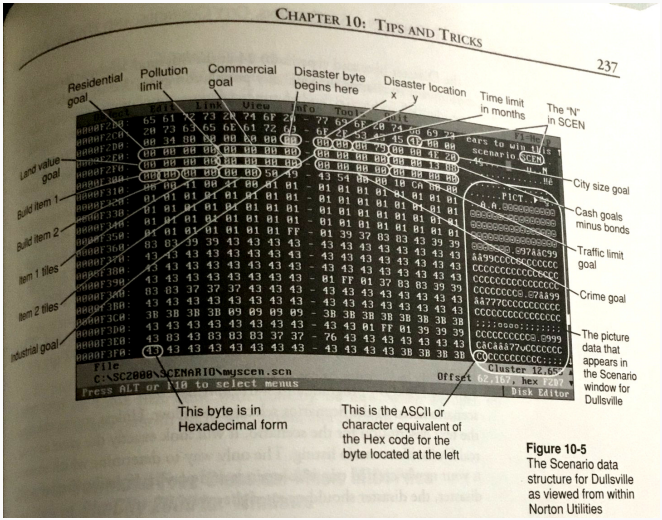
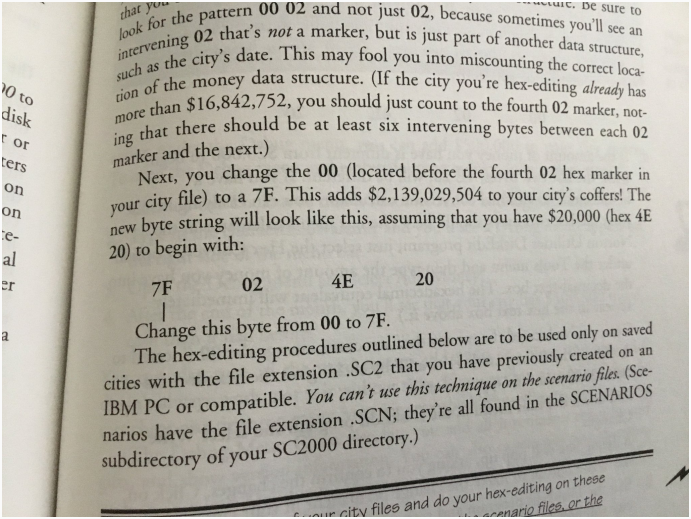


Figure 10-5
The Scenario data structure for Dullsville as viewed from within Norton Utilities

Photos: https://twitter.com/0xabad1dea/status/1021813237032132608



look for the pattern **00 02** and not just **02**, because sometimes you'll see an intervening **02** that's *not* a marker, but is just part of another data structure, such as the city's date. This may fool you into miscounting the correct location of the money data structure. (If the city you're hex-editing *already* has more than $16,842,752, you should just count to the fourth **02** marker, noting that there should be at least six intervening bytes between each **02** marker and the next.)

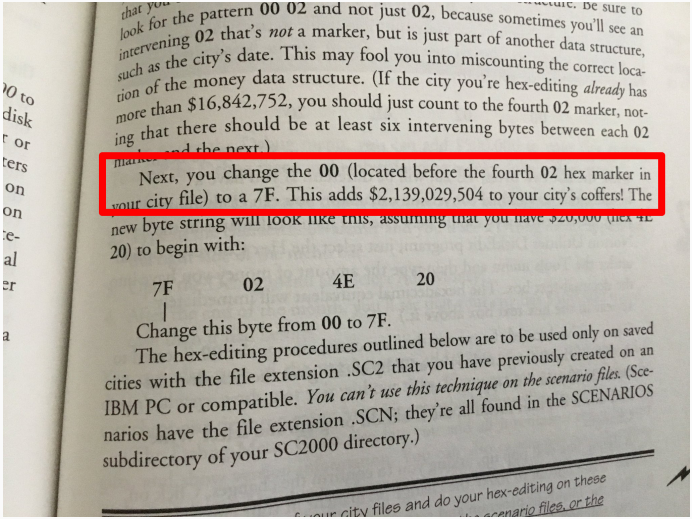
Next, you change the **00** (located before the fourth **02** hex marker in your city file) to a **7F**. This adds $2,139,029,504 to your city's coffers! The new byte string will look like this, assuming that you have $20,000 (hex 4E 20) to begin with:

7F 02 4E 20

Change this byte from **00** to **7F**.

The hex-editing procedures outlined below are to be used only on saved cities with the file extension .SC2 that you have previously created on an IBM PC or compatible. *You can't use this technique on the scenario files.* (Scenarios have the file extension .SCN; they're all found in the SCENARIOS subdirectory of your SC2000 directory.)

Photos: `https://twitter.com/0xabad1dea/status/1021813237032132608`



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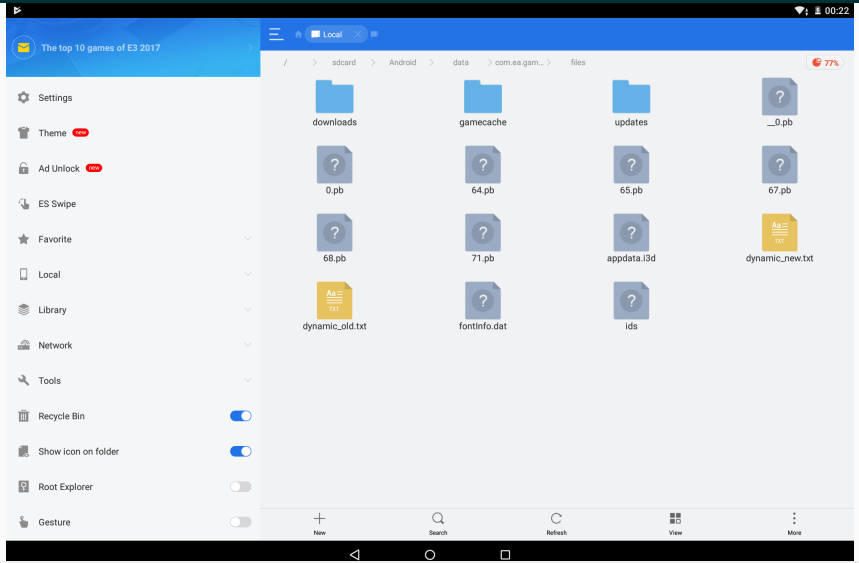
Photos: https://twitter.com/0xabad1dea/status/1021813237032132608

SimCity Build It (2014)

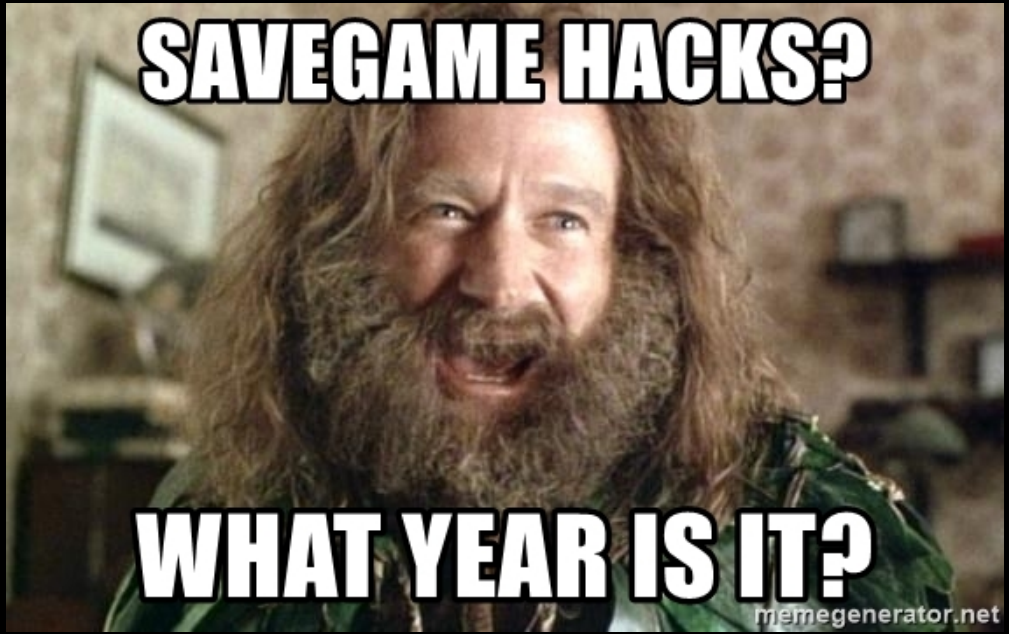
Do you think this still works 21 years later?

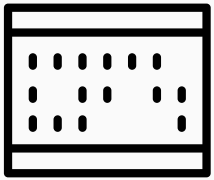
SimCity Build It (2014)

SimCity Build It (2014)

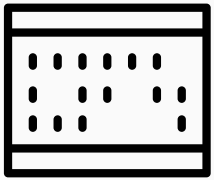


SimCity Build It (2014)


SAVEGAME HACKS?
WHAT YEAR IS IT?
memegenerator.net

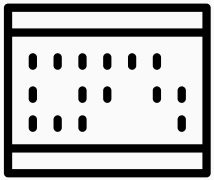


- Savegame hacking is similar to memory hacking



- Savegame hacking is similar to memory hacking

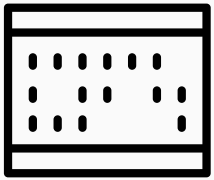
→ Similar countermeasures



- Savegame hacking is similar to memory hacking

→ Similar countermeasures

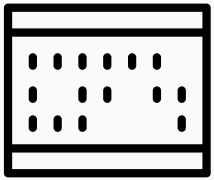
- Store important values on server



- Savegame hacking is similar to memory hacking

→ Similar countermeasures

- Store important values on server
- Add checksums

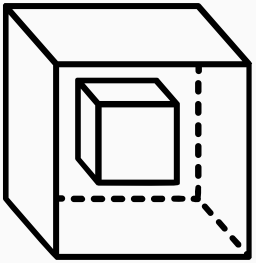


- Savegame hacking is similar to memory hacking

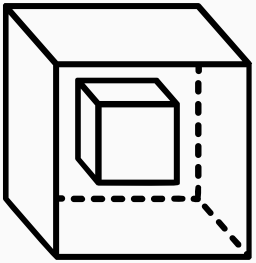
→ Similar countermeasures

- Store important values on server
- Add checksums
- Encrypt savegame

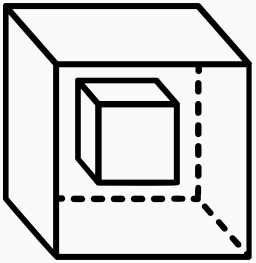
The User Controls the Environment



- User can modify binary...

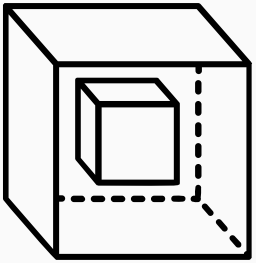


- User can modify binary...
- ...but also the environment



- User can modify binary...
- ...but also the environment

$\rightarrow$ Files, network packets



- User can modify binary...
- ...but also the environment

→ Files, network packets

- And also functions → hooking/preloading

- Microsoft provides Detours framework
  `https://github.com/Microsoft/Detours`

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- Replace any Windows function with custom function

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→ Filter functions or function arguments

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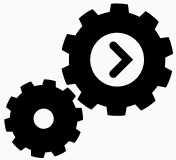
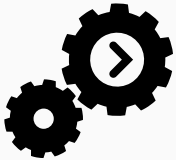
  `https://github.com/Microsoft/Detours`
- Replace any Windows function with custom function

→ Filter functions or function arguments

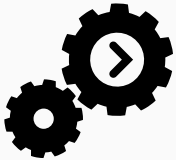
- Example: redirect internet connection to own local server



- LD_PRELOAD is used by the dynamic linker/loader



- LD_PRELOAD is used by the dynamic linker/loader
- Contains one or more ELF shared object files



- LD_PRELOAD is used by the dynamic linker/loader
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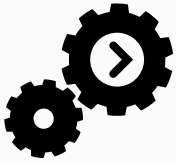


- LD_PRELOAD is used by the dynamic linker/loader
- Contains one or more ELF shared object files
- Object files are loaded before anything else
- Overwrites functions in other shared libraries

Fun Example: LD_PRELOAD

```c
#include <stdio.h>
#include <string.h>
#include <unistd.h>
#include <sys/types.h>

int main(int argc, char* argv[]) {
    char buffer[32];
    strcpy(buffer, "ultra secret password");
    if(getuid() == 0) {
        printf("Password: %s\n", buffer);
    } else {
        printf("Only root can get the password\n");
    }
}
```

```
% ./secret
Only root can get the password
```

```
% ./secret
Only root can get the password
```

```
#include <stdio.h>
char *strcpy(char *dest, const char *src) {
    printf("Copy: %s\n", src);
    while((*dest++ = *src++));
}
```

```
% gcc -shared -fPIC strcpy.c -o strcpy.so
```

```
% ./secret
Only root can get the password
```

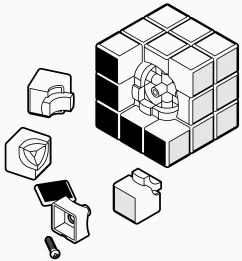
```c
#include <stdio.h>
char *strcpy(char *dest, const char *src) {
    printf("Copy: %s\n", src);
    while((*dest++ = *src++));
}
```

```
% gcc -shared -fPIC strcpy.c -o strcpy.so
% LD_PRELOAD=$PWD/strcpy.so ./secret
Copy: ultra secret password
Only root can get the password
```

Live Demo

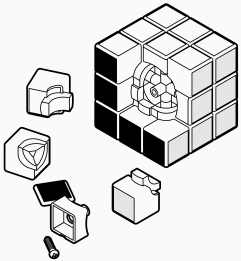
Cheating in Tetris with LD_PRELOAD

Cheating

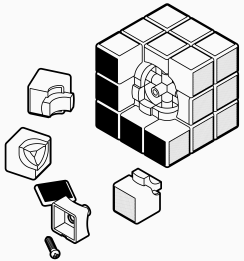


- Cheating might be okay in single-player games

Cheating



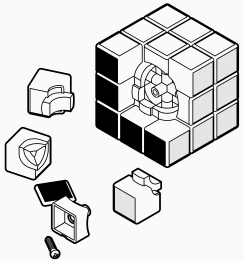
- Cheating might be okay in single-player games
- Problematic for multi-player games



- Cheating might be okay in single-player games
- Problematic for multi-player games

→ Gamers get frustrated

Cheating

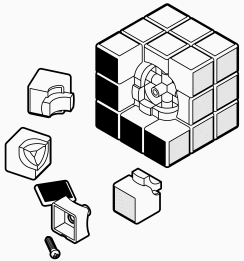


- Cheating might be okay in single-player games
- Problematic for multi-player games

→ Gamers get frustrated

- Problematic if in-game purchases are cheated

Cheating

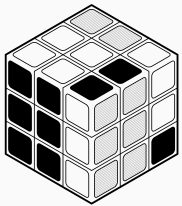


- Cheating might be okay in single-player games
- Problematic for multi-player games

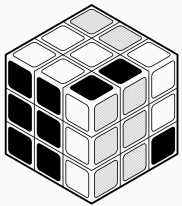
→ Gamers get frustrated

- Problematic if in-game purchases are cheated

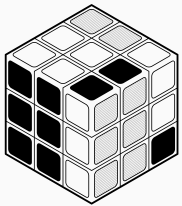
→ Potential monetary loss



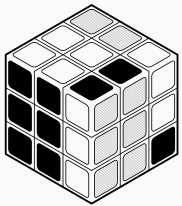
- Preventing cheating is nearly impossible



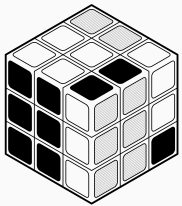
- Preventing cheating is nearly impossible
- Some ways to make it harder



- Preventing cheating is nearly impossible
- Some ways to make it harder
  - Store important info on server



- Preventing cheating is nearly impossible
- Some ways to make it harder
  - Store important info on server
  - Add plausibility checks



- Preventing cheating is nearly impossible
- Some ways to make it harder
  - Store important info on server
  - Add plausibility checks
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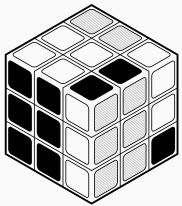

- Preventing cheating is nearly impossible
- Some ways to make it harder
  - Store important info on server
  - Add plausibility checks
  - Use cryptography
- Detecting and banning users sometimes easier

What else?

- Some hackers do all this for fun

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- Many also want to profit

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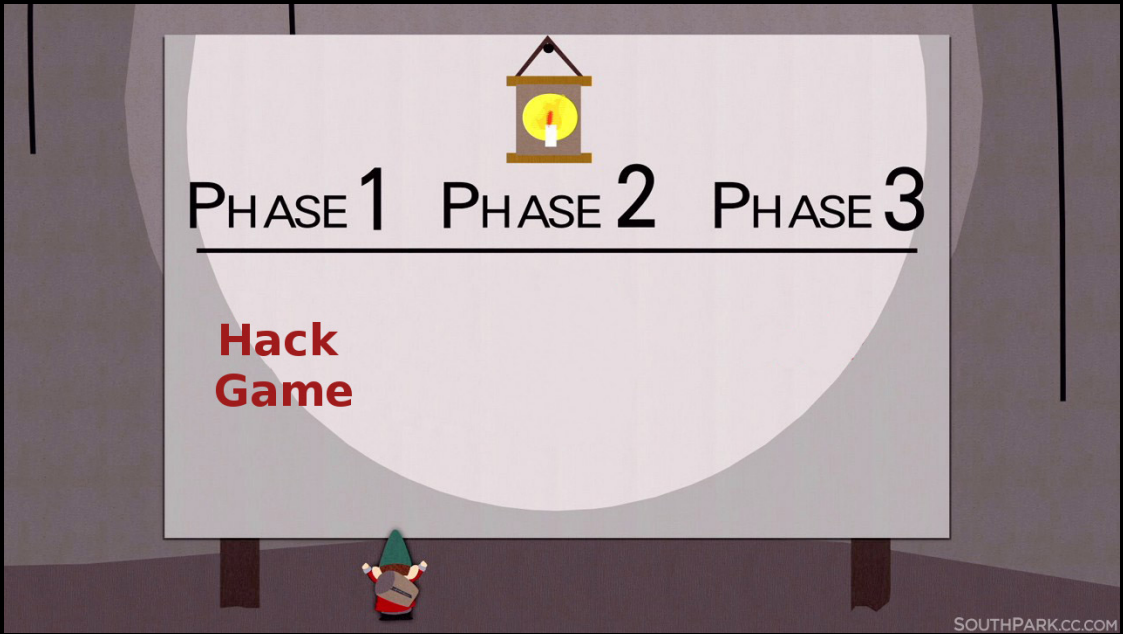
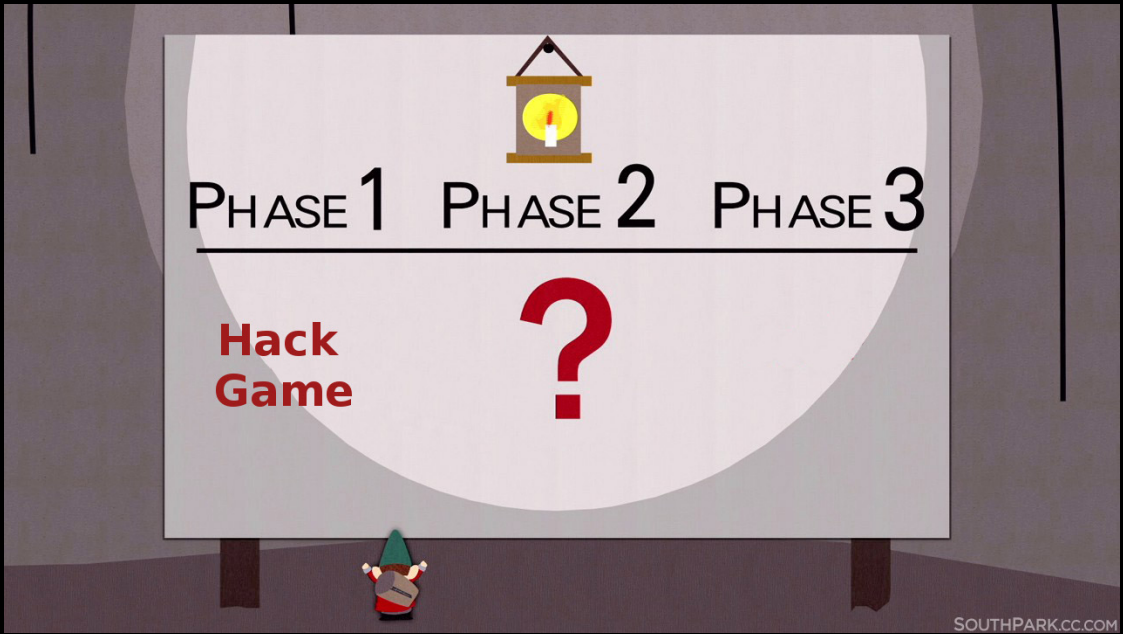
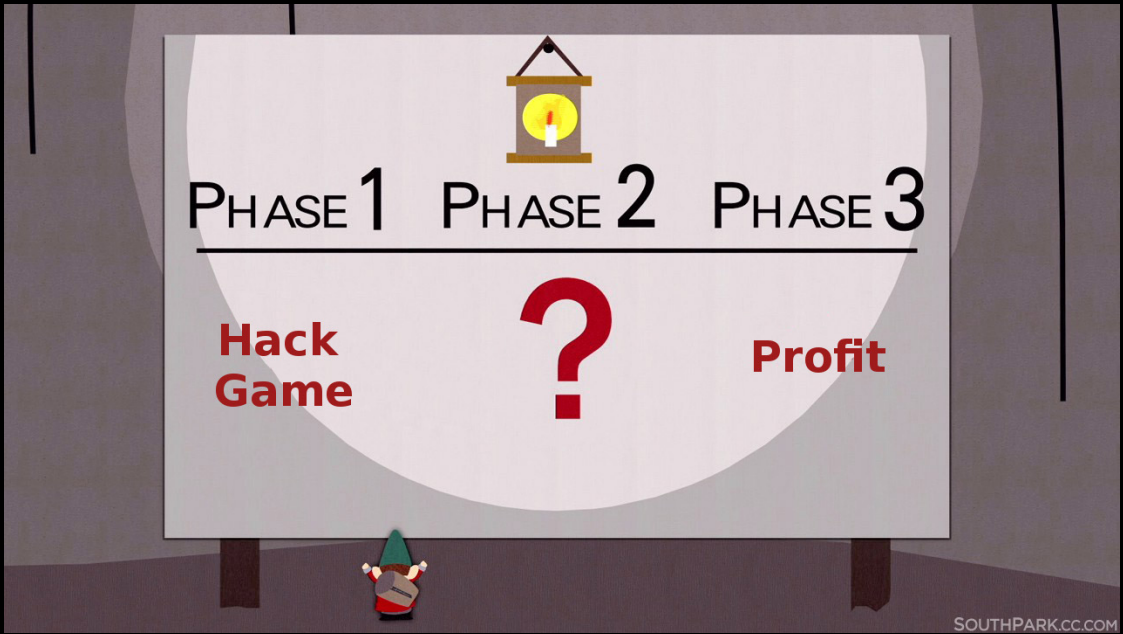
- Cheating can be profitable

PHASE 1 PHASE 2 PHASE 3


PHASE 1
PHASE 2
PHASE 3
Hack
Game
SOUTHPARK.CC.COM


PHASE 1
PHASE 2
PHASE 3
Hack Game
?
SOUTHPARK.CC.COM


PHASE 1
PHASE 2
PHASE 3
Hack Game
?
Profit
SOUTHPARK.CC.COM

Fraud

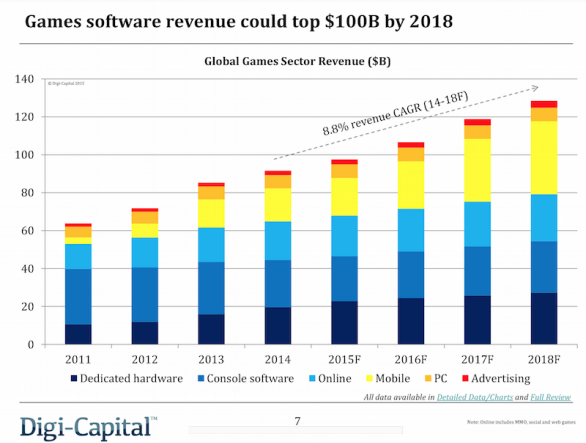
Fraud

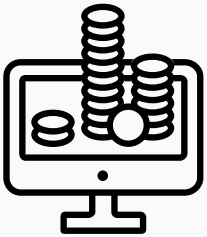
Fraud. /frɔ:d/ noun.

wrongful or criminal deception intended to result in financial or personal gain.

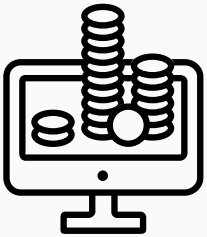
Source: Google

- There is a lot of money in the game industry

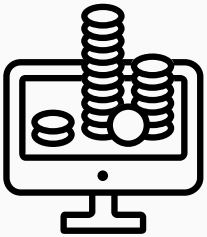




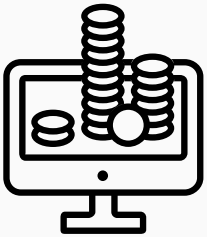
- Gamers pay for/in online games



- Gamers pay for/in online games
- User information stored on servers



- Gamers pay for/in online games
- User information stored on servers
- Personal information



- Gamers pay for/in online games
- User information stored on servers
- Personal information
- Even credit card data

- PlayStation Network data breach (2011)

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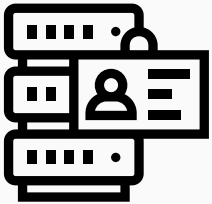
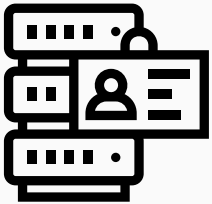
- 77 million accounts exposed
- 12.3 million credit cards
- No evidence that credit card data was stolen
- Still some reports of fraud



- Credit card info not the only target



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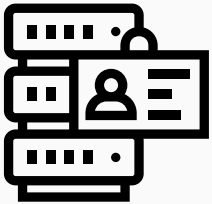
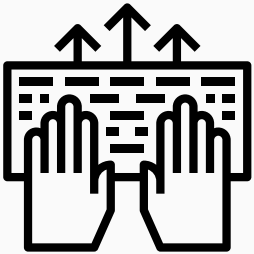


- Credit card info not the only target
- Personal info can be sold on black market
- Depending on data quite valuable

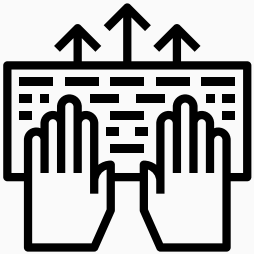
BRAZILIAN UNDERGROUND

Set of business application account credentials	**US$155–193**
Set of credit card credentials	**US$35–135**
Set of online service account credentials	**US$19**
List of mobile phone numbers	**US$290–1,236**
List of landline phone numbers	**US$317–1,931**

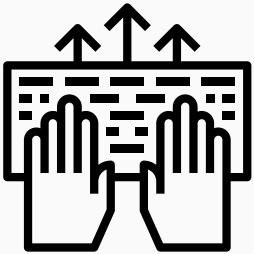
https://www.trendmicro.com/vinfo/us/security/special-report/cybercriminal-underground-economy-series/global-black-market-for-stolen-data/



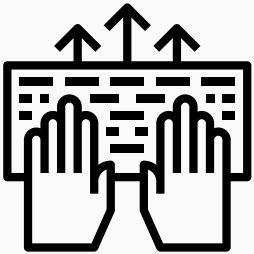
- Server backend requires security as well



- Server backend requires security as well
- Also receives user input

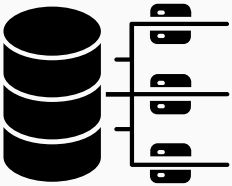


- Server backend requires security as well
- Also receives user input
- Sometimes not obvious

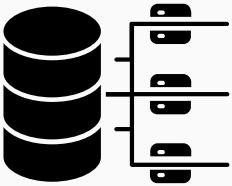


- Server backend requires security as well
- Also receives user input
- Sometimes not obvious

→ chats, highscore name, inventory, ...

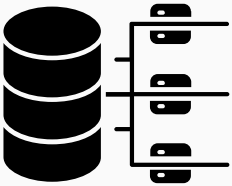


- Online tutorials often without security



- Online tutorials often without security

→ Name used for database query



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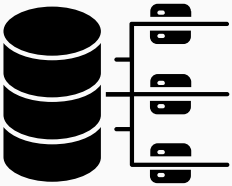
→ Name used for database query

- Enables SQL injections



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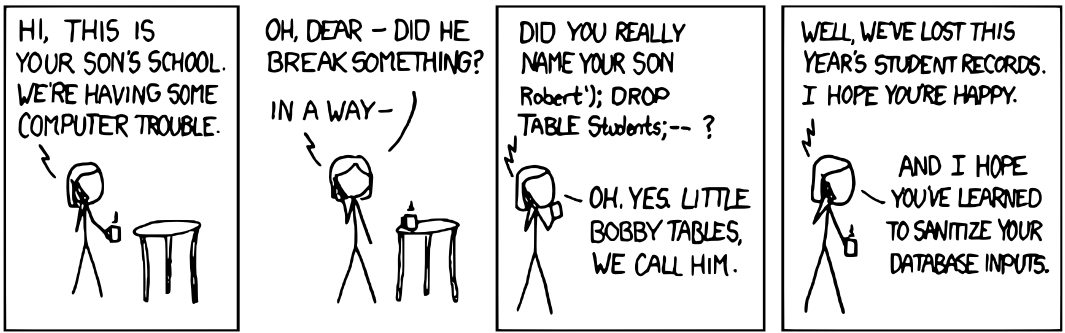
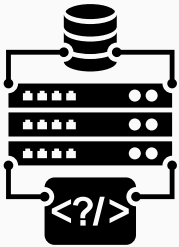
→ Name used for database query

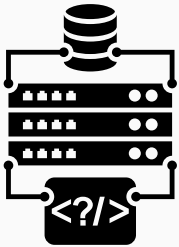
- Enables SQL injections

→ Gamer controls part of query, can exfiltrate data


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR - DID HE BREAK SOMETHING?
IN A WAY-
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.



- Securing backend is important



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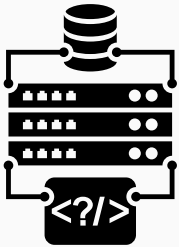
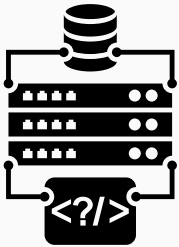


- Securing backend is important
- Does not only protect infrastructure...
- ...but also the gamers



- Securing backend is important
- Does not only protect infrastructure...
- ...but also the gamers
- Private data is valuable and needs good protection

Try the Dark Side

- Hacking games sounds like fun?

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- It is fun!

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- Side effect: learn about security

- Hacking games sounds like fun?
- It is fun!
- Side effect: learn about security
- Where to start?


Pwn
ADVENTURE 3
Pwnie Island

- 3D, first-person, open-world MMORPG

- 3D, first-person, open-world MMORPG
- Intentionally vulnerable game

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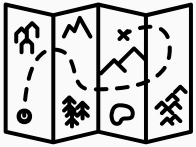
- Learning "platform" for game developers

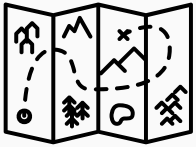
- 3D, first-person, open-world MMORPG
- Intentionally vulnerable game
- Learning "platform" for game developers
- Understand how design and programming flaws create vulnerabilites

Challenges



- Multiple quests in the game

Challenges



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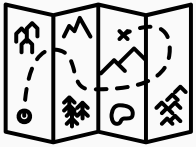

- Multiple quests in the game
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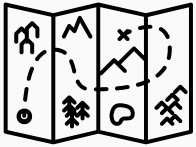

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- Can only be solved by cheating/hacking
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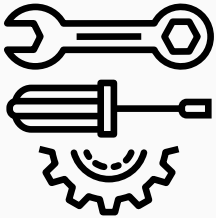
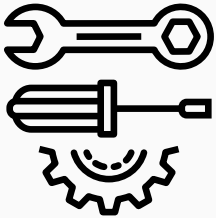
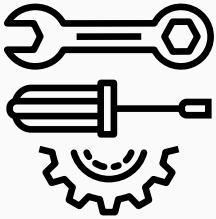
→ Some covered in this talk, e.g., hooking/preloading



- Intercepting network → teleport



- Intercepting network → teleport
- Reverse engineering → hidden elements



- Intercepting network → teleport
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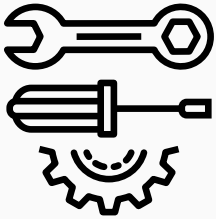
- Hooking → speed/gravity hack



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More Resources

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- Many techniques, tricks, and tools

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- Many techniques, tricks, and tools
- Good start:

The Ultimate Game Hacking Resource

`https://github.com/dsasmblr/game-hacking/`

PLAYING
A GAME

PROGRAMMING A GAME

HACKING A GAME

PROGRAMMING A SECURE GAME WITH TECHNIQUES LEARNED FROM HACKING A GAME

Conclusion

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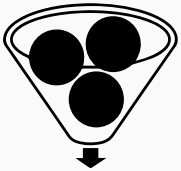
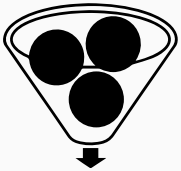
- Security in game design is often neglected
- Old hacking techniques still applicable
- Vulnerabilites can cost money
- Hard to retrofit security mechanisms



- Never trust the user (input)



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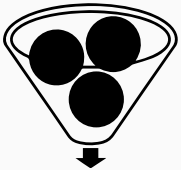

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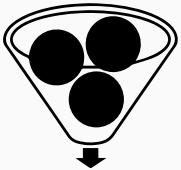
- Security should be part of the design process



- Never trust the user (input)
- Hacking games is often easy
- Security should be part of the design process
- Small implementation details make hacking already harder

Thank you!

Hacking (in) Games

Protecting your Games and your Gamers

Michael Schwarz, Daniel Gruss

September 1, 2018

IAIK – Graz University of Technology