SYNDICATE WARS™ PORT

How to port a DOS game to modern systems

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What did we do

- Port Syndicate Wars
- DOS → modern x86 systems
  - GNU/Linux, Windows, Mac OS X
  - others with SDL/OpenAL support
- no source code

About Syndicate Wars

- DOS 3D tactical squad action game by Bullfrog
- sequel to Syndicate

Syndicate Wars

About Syndicate Wars

- Demo

Why?

- For fun and profit
- Did not work on DOSBox
- Inspired by the John Jordan's Frontier: First Encounters (JJFFE) project

How we did it

- Using recompilation techniques:
  1. Disassemble → recompilable form
  2. Find & replace DOS-specific parts with portable C code, using free software portable libraries
  3. Compile → native executable

Disassembling

- Executable type: 32-bit Linear Executable (LE) with a DOS extender (dos4gw)
- Compiled with the WATCOM C/C++ compiler
  - `$ strings main.exe | grep WATCOM`
    `vWATCOM C/C++32 Run-Time system. (c) Copyright by WATCOM International Corp. 1988-1995. All rights reserved.`
- No applicable disassembler
- We created our own: swdisasm

Disassembling - LE

- 16-bit loader (that called dos4gw.exe)
- 32-bit application code (loaded by dos4gw.exe)
- Sections (called objects)
- Relocations

LEDISASM → SWDISASM

- Goal:
  - all static addressing → labels
  - code and data separation
  - compilable output
- Three attempts:
  - ledisasm v1 (C)
  - tracing ledisasm (Python)
  - swdisasm (C++)

LEDISASM → SWDISASM

ledisasm v1:

- ndisasm engine
- multiple linear passes
  - detecting functions
  - detecting padding
  - detecting “vtables” (?)
- output: nasm

LEDISASM → SWDISASM

ledisasm v1 problems:

- mixed consts/valid addresses
- alignment problems
- didn't detect all “labels”
- reasons:
  - linear passes
  - insufficient use of relocs

LEDISASM → SWDISASM

swdisasm:

- tracing disassembler
- prototype in Python (slow)
- using binutils instead of ndisasm
- region map
  - 1 region per section at start, subdivided into smaller regions with assigned types (code/data/vtable)
- label list

LEDISASM → SWDISASM

swdisasm:

- how does it work:
  - has a trace address queue
  - add OEP to the queue
  - trace through the queue until empty
    - adds new addresses to the queue while tracing
    - subdivides regions
  - trace through the reloc targets
  - add labels for data relocs

LEDISASM → SWDISASM

swdisasm problems:

- padding is ignored → data arrays in code sections are lost
- a few unusual cases in the source executable
- workaround: assign 14 regions manually

LEDISASM → SWDISASM

swdisasm summary:

- ~2 seconds to disassemble a 1.7MB exec

```
$ time ./swdisasm main.exe > swars.S
Tracing code directly accessible from the
entry point...
Tracing text relocs for vtables...
Warning: Reloc pointing to unmapped memory
at 0x140096.
Tracing remaining relocs for functions and
data...
0 guess(es) to investigate.
Region count: 3954

real  0m1.755s
user  0m1.716s
sys   0m0.024s
```

What's left to recompile?

- add underscores on OSX/W32

```
#ifdef NEED_UNDERSCORE
# define TRANSFORM_SYMBOLS
# define EXPORT_SYMBOL(sym) _ ## sym
#endif
```

- call swars main from C

```
// Call game main
asm volatile ("call asm_main\n"
   : "=a" (retval) : "a" (argc), "d" (argv));
```

What's left to recompile?

- it works!!!
  - (well, actually it just compiles/links)

What next?

- Now the game would execute and immediately crash
- Next goal:
  - finding/replacing asm code with C code/calls to libc
- Things to look for:
  - interrupts (int $0xNN, int386(), setvect()), port accesses (in, out instructions)
  - DPMI / dos4gw “API”
  - statically-linked libc functions

C LIB

- Manually look for functions:
  - Find a function using interrupts
  - Easy picks: file operations
  - Compare to Open WATCOM source
  - Look at nearby code for other likely libc functions
  - Time consuming!
  - Did not finish (got 40% of used functions)
- Received a .map of libc in main.exe from an IDA user (thank you :)

Replacing code: asm → C

- Incompatible calling conventions
- x86 cdecl: arguments pushed on stack
- “watcall”: passing in registers:
  - eax, edx, ebx, ecx, rest pushed on stack
  - but cdecl for vararg functions
- Different registers preserved

mkwrappers

- mkwrappers: asm → C ABI wrapper generation in python
- input: configuration file, parameters
  - e.g. wrappers_libc.conf

```
# name      type  args
rename      w     ss
rmdir       w     s
setbuf      w     pp
sprintf     v     psv
srand       w     x
sscanf      v     ssv
```

mkwrappers

- configuration file syntax

```
# type is one of:
# w - watcom: args passed in
#             eax, edx, ebx, ecx
# c - cdecl
# v - vararg
#
# args is a sequence of zero or more of:
# i - int
# x - int (displayed in hex)
# p - void * (general pointer)
# s - char *
# c - char
# v - ...
# l - va_list
```

MKWRAPPERS

- Output: wrappers in asm:

```
.global ac_rename
ac_rename: /* w ss */
push %ecx
push %edx

push %edx
push %eax

call _rename
add  $0x8,%esp

pop  %edx
pop  %ecx
ret
```

MKWRAPPERS

- Output: wrappers in asm (debug):

```
.global ac_rename
ac_rename: /* w ss */
        push   %ecx
        push   %edx
        push   %edx
        push   %eax
        push   %edx
        push   %eax
        push   $0f
        call   _printf
        add $0xc, %esp
        call   _rename
        add $0x8,%esp
        pop %edx
        pop %ecx
        ret
.data
    0:  .string "rename (\"%s\", \"%s\")\n"
.text
```

MKWRAPPERS

```
strcmp ("OBJ3016.DAT", "OBJ2846.DAT")
read (4, 0027FC08, 20)
strcmp ("OBJ3016.DAT", "OBJ3002.DAT")
read (4, 0027FC08, 20)
strcmp ("OBJ3016.DAT", "OBJ3016.DAT")
close (4)
sprintf (0027FBC8, "%s.WAD", ...)
strncmp ("qdata/posdefs.WAD", "data", 4)
strncmp ("qdata/posdefs.WAD", "qdata", 5)
dos_sopen ("qdata/posdefs.WAD", 0x200, 0x40, ...)
lseek (4, 2163, 0)
read (4, 005820D3, 1)
read (4, 0058200B, 80)
close (4)
strrchr ("textdata/netscan.txt", '/')
toupper ('n')
toupper ('e')
toupper ('t')
toupper ('s')
toupper ('c')
toupper ('a')
toupper ('n')
toupper ('.')
toupper ('t')
toupper ('x')
toupper ('t')
sprintf (0027FBDC, "%s.IDX", ...)
strncmp ("qdata/alltext.IDX", "data", 4)
strncmp ("qdata/alltext.IDX", "qdata", 5)
dos_sopen ("qdata/alltext.IDX", 0x200, 0x40, ...)
```

MKWRAPPERS

- Output: wrappers in asm (vararg):

```
.global ac_printf
ac_printf: /* v sv */
        push   %ebp
        mov    %esp,%ebp

        push   %ecx
        push   %edx

        lea    0xc(%ebp),%eax
        push   %eax
        push   0x8(%ebp)

        call   _vprintf            <------------
        add     $0x8,%esp

        pop  %edx
        pop  %ecx
        leave
        ret
```

MKWRAPPERS

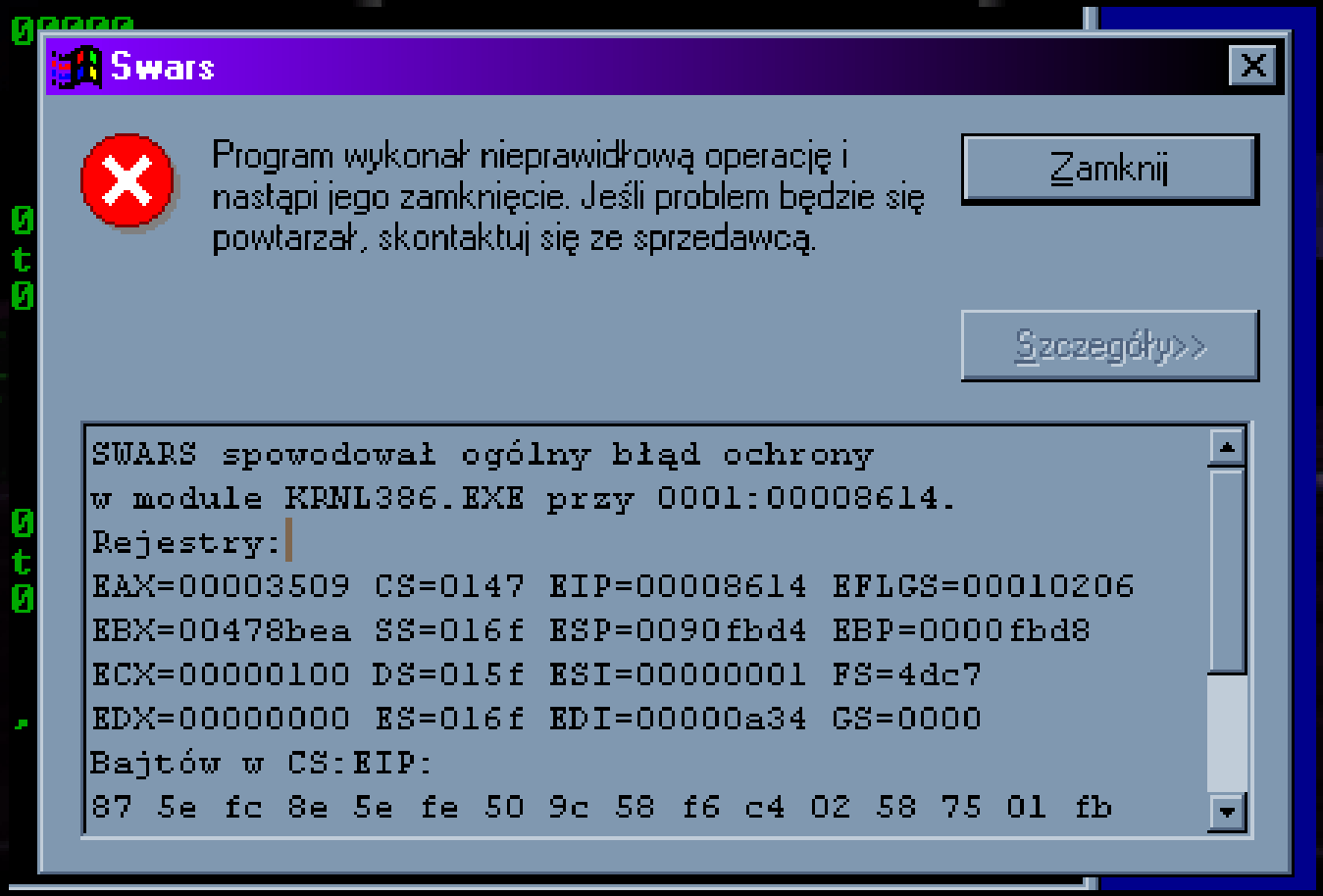
- Function renames (strcasecmp vs stricmp)
- Additional parameters:
  - Underscores in symbols
  - Call stack alignment

Replacing libc calls

- We now had mkwrappers and the libc symbol map
- We made substitutions: s/_printf/ac_printf/g

Replacing libc calls

- Game started working!



(as in: displaying debug output before crashing hard)

Approach to Replacing Game Code

- Having found DOS-specific functions, we:
  - Identified purpose using DPMI spec/Ralf Brown's interrupt list
  - Noted what data they touch
  - Looked for other functions touching it
- After finding interesting functions:
  - Manually translated functions into C
  - Got an understanding of how a subsystem works
  - Wrote replacements

Replacing unportable code

- The aim of replaced functions:
  - Communication with game by reading/writing variables according to some protocol
  - In a portable manner
  - Call free software portable libraries for video, audio, keyboard and mouse input

Things replaced

- Low level DOS/hardware functions
- Video code
- Audio
- Mouse and keyboard input
- Event loops

Low Level DOS/Hardware

- Path handling
  - Case-insensitive file names on case-sensitive file systems
  - Support for per-user profiles
  - Date and time (gettime/getdate), file handling (sopen, setmode)
- Timing
  - 8254 Programmable Interrupt Timer (PIT) used in intro playback

VIDEO

- Game uses 3D software rendering
- Originally implemented using VESA
- 8-bit palette mode
- Needed to set video mode and provide a framebuffer
- Reimplemented with SDL


VIDEO
swars
SDL_app
flip_buffers()0050137F read(3,
Swars
Program wykonał nieprawidłową operację i nastąpi jego zamknięcie. Jeśli problem będzie się powtarzał, skontaktuj się ze sprzedawcą.
Zamknij
Debugowanie
Szczegóły>>
994 720 k
.graphics.c
.swars.asm
Makefile

VIDEO

```
<silent@silent:src>$ vim swars.asm
<silent@silent:src>$ make clean
rm -f swars swars.o main.o clib.o graphics.o timer.o debug.o clib.inc core
<silent@silent:src>$ make
../util/wrappers.py -g ../util/wrappers.conf > clib.inc
nasm -f elf -o swars.o swars.asm
gcc -c -g -Wall -I/usr/include/SDL -D_REENTRANT -o main.o main.c
```

```
phics.o graphics.c
er.o timer.c
ug.o debug.o
 debug.o -L/usr/lib -Wl,-r

 not be used.
```

```
0xb788df2
0xb788df2
0xb788df2
0xb788df3
0xb788df3
0xb788df3
0xb788df3
0xb788df4
0xb788df4
0xb788df4
0xb788df4
0xb788df5
0xb788df5
0xb788df5
0xb788df5
0xb788df6
0xb788df6
0xb788df6
0xb788df6
0xb788df7
```

Terminal

```
<silent@silent:silent>$ python
Python 2.3.5 (#1, Apr 28 2005, 02:32:18)
[GCC 3.3.5-20050130 (Gentoo Linux 3.3.5.20050130-r1, ss
on linux2
Type "help", "copyright", "credits" or "license" for mo
```

Terminal

```
    }

jump_19576:                    ; 000ff0
    esi = &local_4;
    push esi
    local_8 = eax;
    push eax
    push ds
```

Input

- Also SDL-based replacements
- Keyboard
  - Keyboard controller interrupt handler
  - Needed to fill key-event ring buffer and set key state table
  - Talking with 8041/8042
- Mouse
  - Mouse interrupt handler (with “Mickeys”)
  - Set location, motion and button state variables according to a locking protocol

AUDIO

- Originally statically-linked Miles Sound System library
- Pluggable drivers
- Analysed top-down, not bottom-up
  - Found getenv("AIL_DEBUG") which controlled debug output
  - Found newer headers for this library
  - Used the two to identify functions and data structures

AUDIO

- Originally samples polled by sound card interrupts
- Reimplemented using OpenAL
- CDDA music → Ogg/Vorbis with libvorbis, needs to be ripped and encoded

Event Loops

- riginally sound/input updates triggered asynchronously – no longer an option
- Needed to periodically call game_update() to flip frames / poll input / push audio
- 4 “main loops” in the game, depending on mode:
  - intro, menu gui, mission display, paused mission gui
- Easy to find: game would freeze!

OS X issues

- 16-byte call stack alignment
- Ancient version of GNU as in XCode
  - No support for .global, .string, .fill, C-style escapes and instruction syntax differences
  - Bug which miscalculated loop* instruction target relative addresses
- Workaround:
  - Add stack alignment to mkwrappers
  - asfilter script in python implementing missing features and replacing loops with sub/jmp

Success


CRYOVAT
CRYO
1 KRAUSE
2 NELSON
3 DICKS
4 YASUHARA
5 BOURNE
6 WOLFF
7 MANN
8 YOUNG
CHAMPAGNE
CHANOINE
A REIMS

Release

- Wrote installers:
  - bash script with cdparanoia for the UNIX-like
  - Nullsoft with AKRIP for Windows (by j00ru)
  - bash script for making Mac OS bundles
- Port released 5 years since inception
- Available at http://swars.vexillium.org/

Post-Release

- Bug reports:
  - Missing bounds checking on paths, overflow after 100 bytes
- Things left to do:
  - Network multiplayer support
  - Joystick/game controller support

Conclusion

- Final code size:
  - asm: 380 kLOC
  - portable C: 2.5 kLOC
- Time to completion: 5 years
  - (of which a few months of real work)
- Countless nights spent debugging
- A cool working game!

Questions ? Contact

- http://swars.vexillium.org
- http://unavowed.vexillium.org
- http://gynvael.coldwind.pl
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