

Software protection and dynamic analysis attacks

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Motivation

Dynamic analysis is known to be one of the most powerful tools available to attackers, however its study was somewhat neglected in software security analysis & modeling.

With respect to software engineers using dynamic analysis, **attackers**:

- have a more focused objective;
- can easily accommodate wrong deductions.

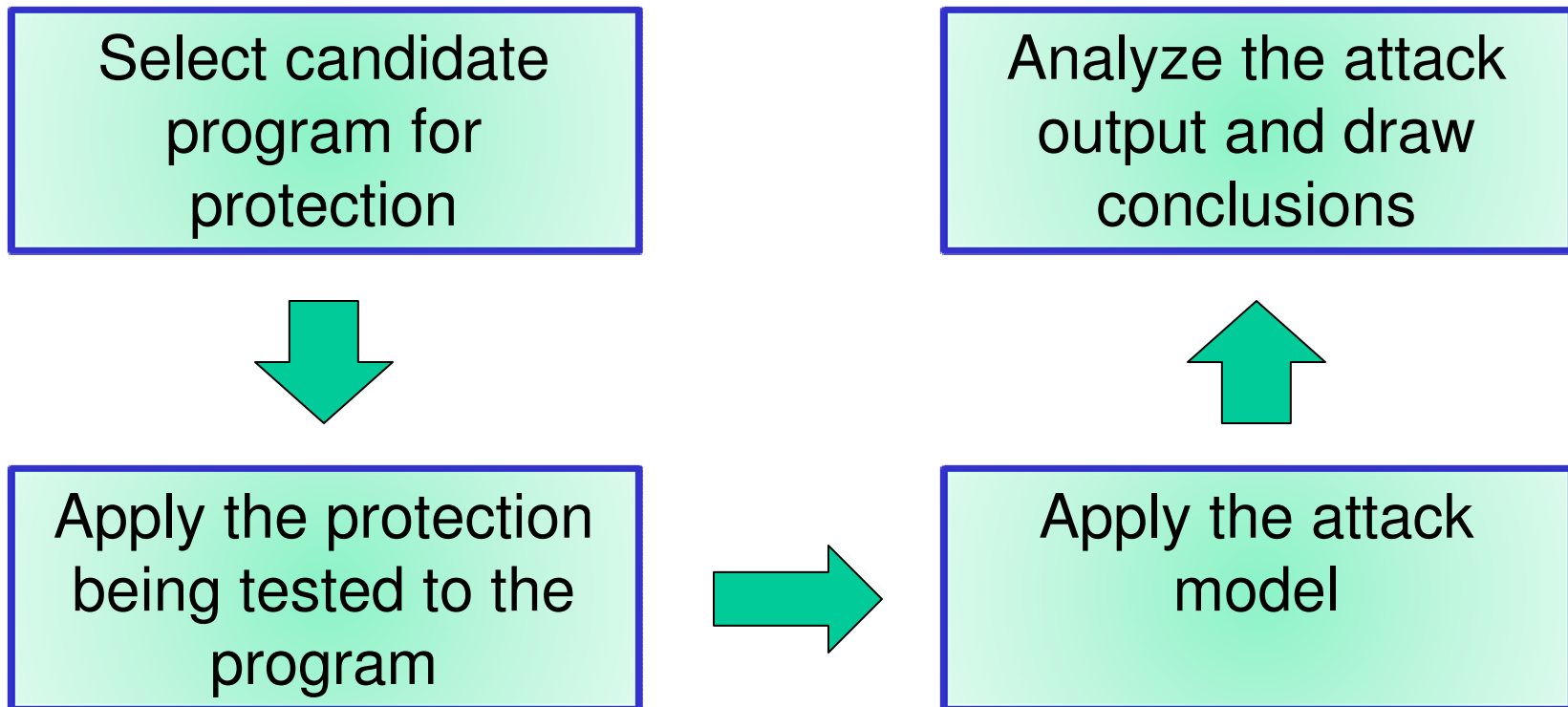
Software protection

- Check-summing, guards.
- Server-side execution (e.g., barrier slicing) and assertion checking.
- Obfuscation (orthogonal replacement).
- Encrypted execution

Reverse engineering attacks:

1. static analysis;
2. dynamic analysis;
3. **program comprehension.**

Testing software protection techniques



This testing framework can be applied at various abstraction levels.

Attack model

Assumptions:

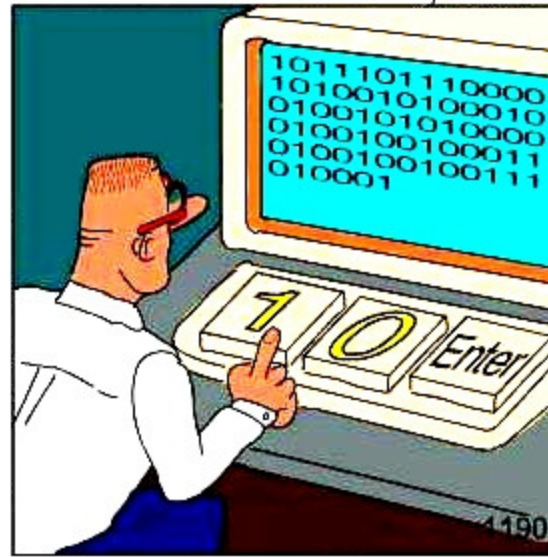
- what the attacker is or is not capable of doing;
- what tools the attacker is supposed to use;
- what information the attacker has access to.

Output:

- secret property of the program, whose integrity is supposed to be protected;
 - accuracy of property localization;
 - capability of tampering (integrity violation).

Dynamic analysis tools

- Debuggers
- Tracers
- Instrumentors
- Sniffers
- Emulators
- Dynamic slicers
- Feature location



... in addition to smart, opportunistic code understanding.

Scenario 1: breaking check sums

Bob, the attacker, can:

1. **Trace** all data read from memory.
2. **Compare** traced data with program's (binary/byte) code.
3. **Locate** check summing operations.
4. **Modify** code or execution to forge correct check sum data.
5. **Tamper** with code integrity without being detected.

Scenario 2:

breaking server-side checks

Bob, the attacker, can:

1. **Sniff** all messages exchanged with server.
2. **Identify** security sensitive messages.
3. **Locate** code producing such messages.
4. **Modify** code or execution to forge legal messages.
5. **Tamper** with code integrity without being detected.

Scenario 3: breaking obfuscation

Bob, the attacker, can:

1. **Trace** I/O operations that cannot be obfuscated.
2. **Associate** obfuscated code portions with I/O related computations.
3. **Locate** code responsible for security sensitive computations.
4. **Modify** code repeatedly, until desired tampering is achieved.

Scenario 4:

breaking (naive) encrypted execution

Bob, the attacker, can:

1. **Trace** program's state.

2. **Follow** data dependencies from obfuscated instructions to memory change.

3. **Locate** code responsible for the execution of each obfuscated opcode.

4. **Inject** malicious opcodes into the program's instructions.

Common attack pattern

1. **Observe:** data (program's state), statements being executed, messages exchanged.
2. **Identify:** security sensitive data.
3. **Locate:** code containing security sensitive computation.
4. **Modify & tamper:** violate code or execution integrity without being detected.

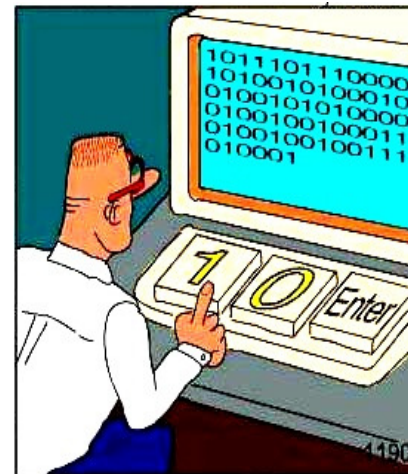
Useful tools & techniques

1. **Observe:** debuggers, tracers, instrumentors, sniffers.
2. **Identify:** string matching, pattern matching, clustering, concept analysis.
3. **Locate:** dynamic slicing, feature location, reconnaissance, code inspection, reverse engineering.
4. **Modify & tamper:** program transformation tools, emulators.

Opportunistic trial and error

Modify code and/or execution.

```
Source Code
0 1 2 3 4 5
#####
P1 = chunksize/2;
P2 = chunksize-1;
mpc_task_query(nbuf, 4, 3);
dontcare = nbuf[0];
printf("Waiting for results from child tasks...\n");
for (i=1; i<= numchild; i++) {
    source = dontcare;
    mpc_hexec((char *) $index, sizeof(int), $source, $indexmsg, $nby
    mpc_hexec((char *) $result[index], chunksize*sizeof(int), $sourc
    $arraymsg, $nbytes);
    printf("-----\n");
    printf("Sample results from child task = %d\n", source);
    printf(" result[%d] = %d\n", index, result[index]);
    printf(" result[%d] = %d\n", index+P1, result[index+P1]);
    printf(" result[%d] = %d\n", index+P2, result[index+P2]);
}
##### end of parent code #####
#####
##### Beginning of child process code #####
#####
if (taskid > PARENT) {
    printf("Child task enrolled on tid= %d\n", taskid);
    /* receive index from parent task */
    source = PARENT;
    mpc_hexec((char *) $index, sizeof(int), $source, $indexmsg, $nbyte
    /* see malloc and then initialize my portion of the array */
    mypart = (int *) malloc (chunksize*sizeof(int));
    if (mypart==NULL) {
        printf("error allocating space for A\n");
        exit(1);
    }
    for(i=0; i<chunksize; i++)
        mypart[i] = index + i;
    /* send results back to parent task */
    mpc_hsend((char *)$index, sizeof(int), PARENT, indexmsg);
    mpc_hsend((char *)mypart, chunksize*sizeof(int), PARENT, $arraymsg);
}
#####
```



Check if tampering is detected.

Building a realistic attack model

- ❖ Change your hat!
- ❖ Apply the common pattern.
- ❖ Be aware of existing tools and techniques.
- ❖ Model opportunistic attempts, based on trial and error.
- ❖ Open your mind: attackers have a lot of fantasy!

Conclusions

In order to build **strong** software integrity protections, we need a deep understanding of dynamic analysis attacks:

- characteristics of available tools and techniques;
- attack model;
- experiments testing the resilience of existing protection techniques;
- empirical studies.