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# LockerGoga quickly reversed

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## Abstract

*Our objective is to illustrate the uses of the software GORILLE that we developed at the High Security Lab<sup>1</sup> and more recently at CYBER-DETECT. The recent attacks of LockerGoga against Altran in France and Norsk Hydro in Norway illustrate the necessity to have advanced anti-malware defences. GORILLE's basis are morphological analysis. As such, the main features of GORILLE are the following. It is robust with respect to heavy code obfuscations. It applies on dynamic data that can be forged within a virtual environment. Its detection engine is based on behaviour recognition. This contribution is an extended version of our Blog's post<sup>2</sup>.*

Before we talk about reverse engineering, let us present the subject of our interest. LockerGoga is a malware that targeted two major companies at the beginning of 2019. The first one is Altran in France [?] while the second one is Norsk Hydro [?]. The "success" of these two attacks show the need of new detection techniques. GORILLE is such a tool. It is now developed by CYBER-DETECT following research in morphological analysis at LORIA [?, ?]. The attack in France happened in January and the one in Norway in March. Actually, those two attacks should have been stopped. Indeed, the GORILLE engine does the job. It detects LockerGoga and its variants as we will show it.

In a nutshell, GORILLE identifies malicious threats embedded in Linux, MacOS and Windows binary files. For this sake, GORILLE keeps a collection of malicious behaviours. Each binary file submitted to GORILLE is then scanned and as soon as a set of malicious inter-link behaviours is detected, GORILLE raises an alert. There is no magic behind, just several years of hard work at Loria's Computer Science Lab. For a full presentation of morphological analysis, we refer the reader to our previous contributions, see for in-

stance [?, ?, ?]. But presently, there is no need to open the engine, looking at morphological analysis as a black box is sufficient.

In this contribution, we do not solve any specific scientific issue. We want to show that our earlier research works—which were attacking some hard scientific points—can/should be reconsidered as a whole. All the ingredients participate to the recipe, dynamic analysis, anti-anti-debugging/virtualization and finally morphological analysis. All these little steps contributed to the tool GORILLE that may serve at many levels within defenses: from detection to retro-engineering. We see this outcome as a strong stimulation to solve some apparently very focused issues. Put all together, they serve greater purposes.

## 1 A first step: the detection

Since GORILLE search process is based on a collection of malicious behaviours, the first question which comes in mind is whether or not GORILLE is able to detect LockerGoga. The database used for the experiments ("malware-static\_24" in the figure below) contains  $N = 32,812,355$  malicious behaviours. Among all of them, GORILLE identifies 60 malicious behaviours in the submitted sample of LockerGoga.

Signature based detection techniques need regular updates of their database. Our slogan is that morphological analysis is quite robust to malware versioning or malware repackaging. For that sake, we actually—but, let's confess it, we did it also for fun—used for the experiments our old malware database dating from 2013. And six years later, it is still up to date!

At first side, it could seem that 60 is not that much compared to the  $m = 3573$  behaviours of `Hmir.tpz` and the  $n = 9879$  behaviours of `LockerGoga`. But, nevertheless, it is significant. We address the question in two parts.

First, finding one behaviour is already meaningful. With the parameters in use, the order of magnitude of the set of

<sup>1</sup><https://lhs.loria.fr/>

<sup>2</sup>See <http://www.cyber-detect.com/fr-blog.html>.

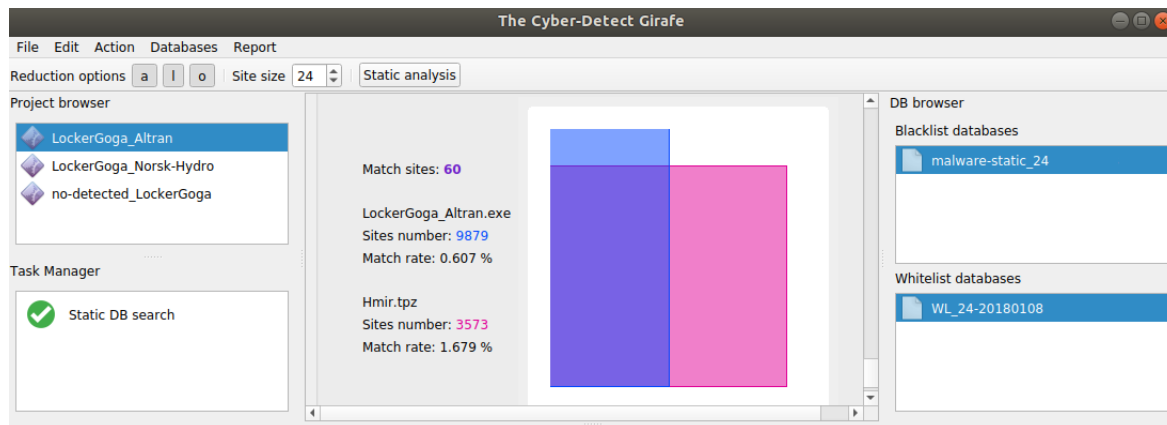


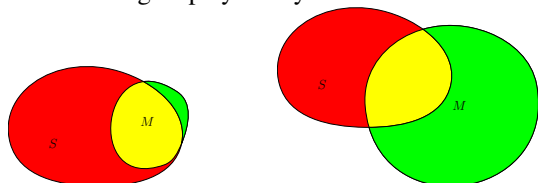
Figure 1. LockerGoga’s proximity to Hmir.tpz

all behaviours (they are stored as labeled graphs of size 24) is

$$|U| \sim 2^{24} \times 24^{48} \sim 2^{244}.$$

Thus, given  $N \sim 2^{25}$ , the probability of a false positive evaluates to  $m \times N/|U| \sim 2^{-244+24+13} = 2^{-207}$ . In other words, there is (almost) no chances we pick up a malware behaviour randomly. Nevertheless, one should be careful: the probability of a behaviour does not follow a uniform random law. For instance, there are quite frequent behaviours that are coming from third party libraries written by companies such as Microsoft or open source libraries. Collectively, third party libraries also denote behaviours. They occur in malware but they are not specific to malware. Thus, our tool stores them in a “white list” database (see “WL\_24-20180108” in the figure below), such behaviours are then removed from malware databases. The observed false positive ratio is compatible with the theoretical one. Conclusion, we can state that the observed sample is definitely a malware. The second question is: can it be related to some particular one?

One may naively think that the number of common behaviours is the right measure. It is not. The issue can be explained as follows. In the following graph, we suppose we have a “green” malware  $M$  and a “red” sample  $S$ , the intersection being displayed in yellow.



Even if the intersection on the left is smaller, we can say that in this case, the sample  $S$  “extends”  $M$  which is not the case for the right drawing. So, it is important to take into account the size of the matched malware. Our proximity measure is based on a probabilistic argument which we

briefly justify.

Let us suppose we have a malware, its behaviours should be in our database. Let us choose randomly  $n$  such behaviours among  $N$ . How many of these are common to the  $m$  behaviours of  $Hmir.tpz$ ? Actually, the value follows an hypergeometric law<sup>3</sup>. Thus, according to it, the expected number of common behaviours is given by the formula:

$$E = \frac{n \times m}{N} \simeq 1.07.$$

Now, 60 takes a different flavor. But we can go further, the standard deviation is given by the formula

$$\sigma = \sqrt{\frac{n \times m \times (N - m) \times (N - n)}{N^2 \times (N - 1)}}$$

which in the present case amounts approximatively to 1.03. As a conclusion, 60 is far beyond the expected value.

Actually, in our experiment, we could see that there is an other related guy to LockerGoga. It is called *Sheldor.db*. It has 47 common behaviours with LockerGoga but all these 47 behaviours are common to  $Hmir.tpz$ . Thus, there are no needs to make enquiries in that way.

To conclude, as we see, GORILLE detects 60 malicious behaviours in the yet undetected sample of LockerGoga. The technological advance of GORILLE allows to stop variants of (some) unknown threats.

The alert being launched, it is time to start to do some retro-engineering.

## 2 LockerGoga wears different dresses

The sample named *LockerGoga\_Altran* [?] corresponds to the malware that attacked Altran in Jan-

<sup>3</sup>As a matter of fact, with  $m \ll N$ , we could use in practice a simple binomial law. But, rigorously, it is hypergeometric.

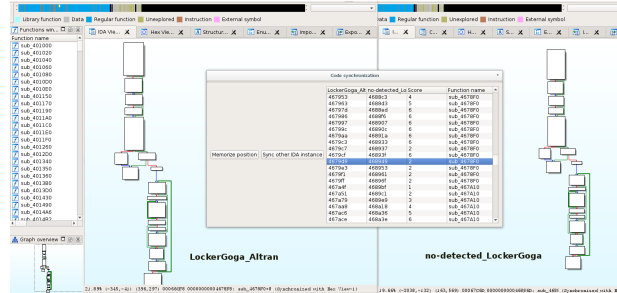
uary 25th, 2019. On March 8th, 2019 that is two months later, **MalwareHunterTeam** discovered in [?] that a variant of LockerGoga, that we name here no-detected\_LockerGoga was left undetected by all anti-virus products in Virus Total [?]. No shame with that, don't forget that malware detection is an heavily complicated problem, actually shown to be undecidable by Cohen [?] or by Adleman [?].



Actually, we can play with GORILLE a little bit more. Indeed, GORILLE is able to learn the specific malicious functionalities of LockerGoga by itself. First, we built the "LockerGoga" specific database which contains the 9879 behaviours (also mentioned as sites) in LockerGoga, not only bad ones. Indeed, LockerGoga incorporates, as usual in any software, see figure ??.

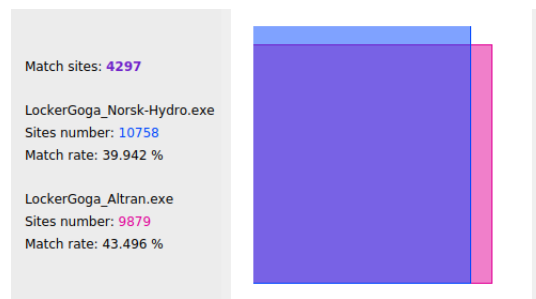
That said, we can compare all behaviours of LockerGoga\_Altran, which were involved in Altran incident and the no-detected\_LockerGoga of MalwareHunter. There are 4270 common behaviours, roughly the half, that are common between bot samples. See figure ??.

Then, using our tool binsim from the GORILLE suite, we can synchronize both codes, that is to find the precise correspondence between functions of LockerGoga\_Altran and no-detected\_LockerGoga. Actually, in that case, the correspondence was "too" easy. Once we know the correspondence, using our synchronization script, we can even see it within the IDA software<sup>4</sup>.



Some other tools may be used for code synchronisation. For instance, let us mention bindiff [?]. Compared to binsim, as their name suggest, bindiff will search for differences where binsim will perform—possibly wrong—connections. For malware, the "signal" being rather "noisy", we think our approach looks to be more productive.

And then came the Norsk Hydro's attack. We wanted to recognize the malware. Again, we find a clue in our main database. After comparison with the LockerGoga database, no doubt that both are very close.



### 3 Some LockerGoga's technicalities

Let us add few words on the retro-engineering of LockerGoga. We learnt from [?] that LockerGoga is using CryptoPP. Let's go. First, we learn CryptoPP and then, we use the function matching engine of GORILLE to simplify the IDA view. Functions within LockerGoga are automatically labeled with CryptoPP library's names.

The other library that is used by LockerGoga is boost. But which version of boost? To determine it, we learned LockerGoga's behaviours and we searched for matching with different versions of boost compiled with different versions of Microsoft Visual C++. The output of GORILLE is:

```
BOOST 1.68 / msvc12
"boost_filesystem-vcl20-mt-x32-1_68.dll": 19 matching sites / 1290 sites
4127 nodes = 425 small nodes + 1390 white nodes + 29 matched nodes + 2283 specific nodes
0.00% 19 / 1290 ou 11148, 1.47% 0.17% : LockerGoga_Norsk-Hydro.exe
-----
BOOST 1.69 / msvc14.0
"boost_filesystem-vcl140-mt-x32-1_69.dll": 19 matching sites / 1406 sites
4821 nodes = 667 small nodes + 1337 white nodes + 29 matched nodes + 2788 specific nodes
0.00% 19 / 1406 ou 11148, 1.35% 0.17% : LockerGoga_Norsk-Hydro.exe
-----
BOOST 1.69 / msvc14.1
"boost_filesystem-vcl141-mt-x32-1_69.dll": 180 matching sites / 1620 sites
3801 nodes = 364 small nodes + 111 white nodes + 647 matched nodes + 2679 specific nodes
```

<sup>4</sup><https://www.hex-rays.com/products/ida/>

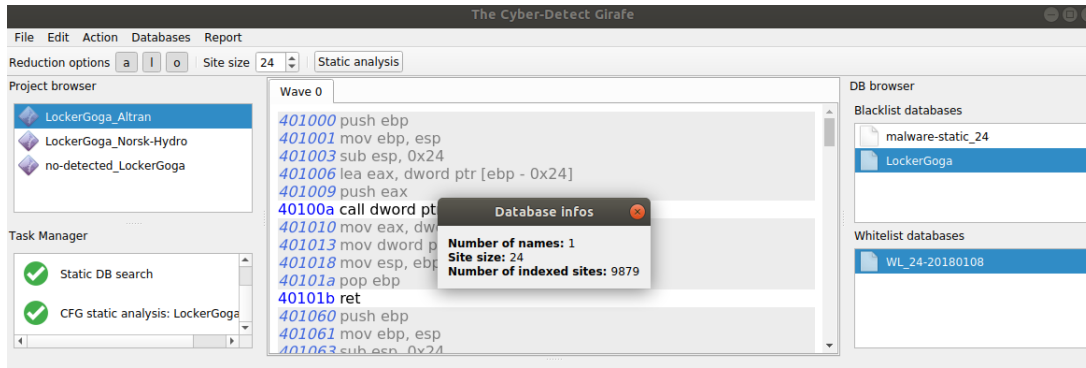


Figure 2. Learning LockerGoga

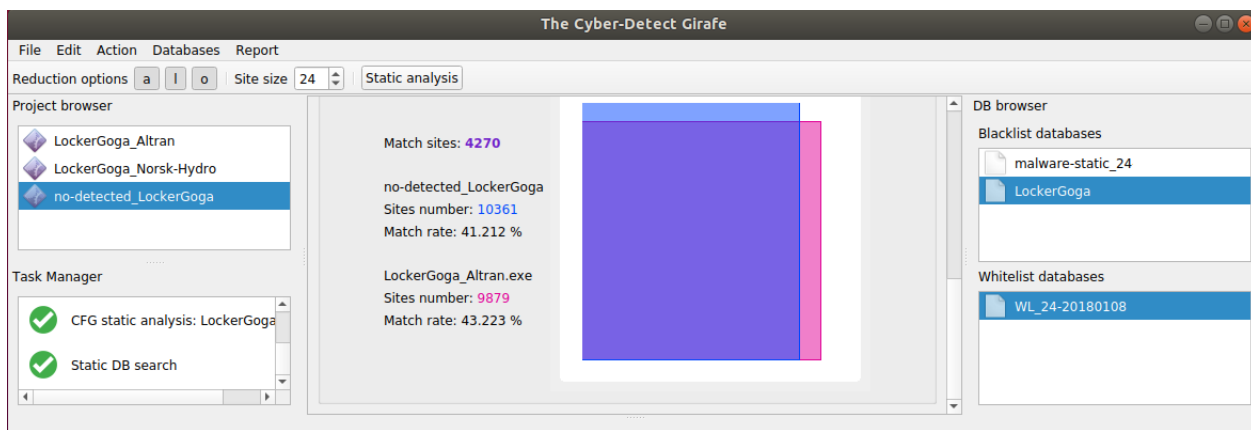


Figure 3. Altran's LockerGoga versus MalwareHunters LockerGoga

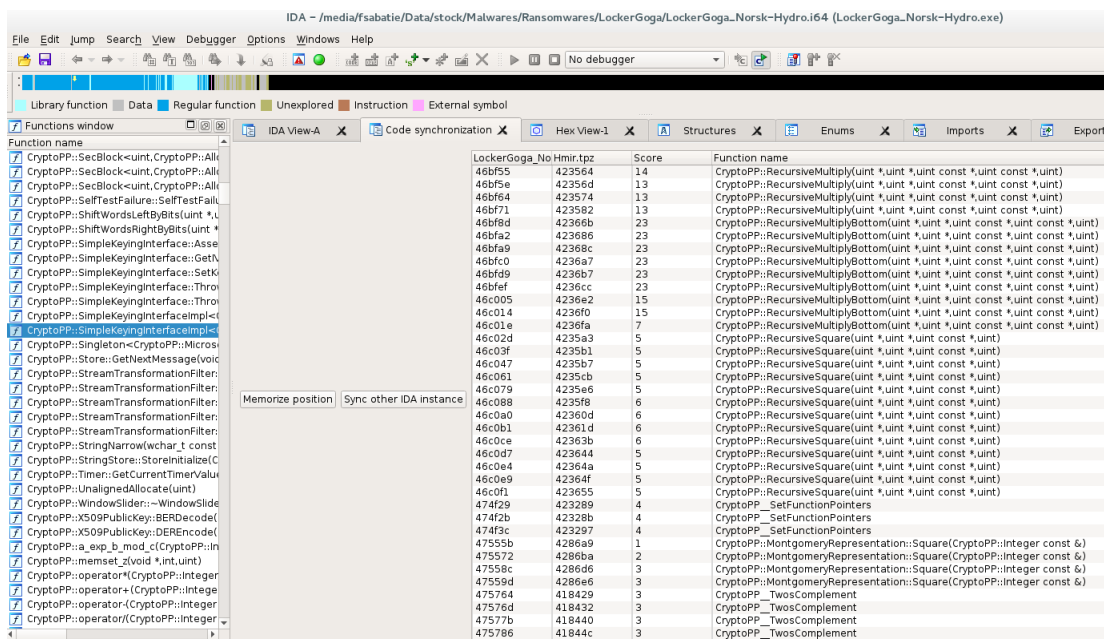


Figure 4. LockerGoga reversed within IDA



```
/c move /y e:\Exec\LockerGoga_Norsk-Hydro.exe \  
C:\Windows\TEMP\tgytutrc720.exe"
```

that is, it launch a copy of itself. We can observe it a little bit afterwards:

```
[0x004d7f18] "C:\Windows\system32\cmd.exe \  
/c move /y e:\Exec\LockerGoga_Norsk-Hydro.exe \  
C:\Windows\TEMP\tgytutrc720.exe"  
[PROCESS_INFORMATION]  
[0x0044e110] 0x000001b4  
...
```

Using the same trick, it runs a new process:

```
[0x004d8ed0] "C:\Windows\TEMP\tgytutrc720.exe -m"  
[PROCESS_INFORMATION]  
...
```

where option m stands for master process. The flag serves to manage encryption.

And just for fun. Was the malware difficult to code? It could be. There is a mysterious call to the debugger.

```
0x0118d5fb call [0x7694b2b7] WINAPI \  
OutputDebugStringA(  
_In_ [0x003bf930] "C:\\Program Files\\ \  
Common Files\\System\\msadc\\msadcor.dll"  
)
```

## 4 Conclusion

All right, GORILLE sees LockerGoga. Does it mean it will discover every malware? No, of course not. But, it clearly sees (some) malware that others don't see. We think that a panel of detecting engine using different technologies is much stronger than a simple anti-virus software and want to contribute to this aim.