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Static Profiling and Optimization of Ethereum Smart Contracts Using Resource Analysis

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ABSTRACT Profiling tools have been widely used for studying the behavior of the programs with the objective of reducing the amount of resources consumed by them. Most profilers collect the information with dynamic techniques, i.e., execute an instrumented version of the program with some specific input arguments to profile the measures of interest. This article presents a novel static profiling technique for Ethereum smart contracts that, using static resource analysis, is able to generate upper-bound expressions that can be used to produce profiling information about the measure of interest. Unlike traditional profiling tools, we get upper-bounds on the measures of interest expressed in terms of the input arguments or the state variables of the smart contracts. The information that can be obtained by the upper-bounds allows us to detect gas-expensive fragments of a Solidity program or to spot resource-related vulnerabilities at specific program points of the program. Moreover, in this article we propose an automatic optimization of Solidity programs which reduces their *gas* consumption replacing the accesses to state variables by gas-efficient accesses to local variables. We have experimentally evaluated our technique and we have detected that 6.81% of the public functions analyzed can be optimized and 1.43% are vulnerable to execute arbitrary code.

INDEX TERMS Blockchain, Ethereum, resource analysis, smart contracts, static analysis.

I. INTRODUCTION

Ethereum [37] is an open-source platform for decentralized applications and nowadays has become the world's leading programmable blockchain. One of the reasons of this success is that Ethereum smart contracts can be programmed using a Turing complete language and it includes a powerful set of tools for its development. An immutable version of the compiled smart contract can be deployed in the Ethereum platform and will be executed using the Ethereum Virtual Machine (EVM). As other blockchains, Ethereum has its native cryptocurrency named *Ether* and the execution fees for running smart contracts on the Ethereum blockchain are metered in units of *gas*. It is a measure of the amount of computational effort spent on executing each single EVM bytecode operation. The gas consumption of each EVM instruction is detailed in [37]. Miners get paid an amount in *Ether* that results of applying a gas price to the total amount of gas that took them to execute a complete transaction. Using this model, Ethereum prevents the emitters from wasting computational power, discourages the programmers to use gas-expensive operations (e.g. as the cost of replicating data in a decentralized environment is high, storage bytecodes are gas-expensive) and prevents from DoS attacks and non-terminating executions.

Solidity [15] is a programming language to write smart contracts and its compiler produces EVM code to be deployed in the Ethereum platform. The Solidity compiler includes several static analyses that produce useful information during the contract development phase. Among this information it can be found the amount of gas that a function will consume for its execution. The Solidity compiler is able to produce precise *constant* gas bounds, however, when the cost expression depends on input parameters (or information stored in the contract state), the compiler simply returns ∞ as gas bound, and we found it occurs in almost one in every ten public functions [3]. Furthermore, minimal modifications on the code make the compiler unable to detect unbounded loops and it does not warn the programmer about this potential risk.

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to storage. It proposed a sound transformation that replaces the accesses to storage by accesses to memory that consume less gas. We have applied them to analyze more than 40,000 real public function of smart contracts getting that a 9.02% are parametric, a 6.81% of them can be optimized, and 4.19% may be potentially vulnerable.

An interesting direction for future work is to improve the precision of our tool optimizing, not only basic type variables, but also complex type variables such as arrays, structs or maps. In addition, we plan to relax the conditions defined to optimize storage accesses in Section V and generalize the optimization to functions which access to the state variables in other functions of the contract different to the one under analysis. Additionally, we would study the applicability of the optimization at EVM level, which is a more complex case as we would modify the structure of the EVM bytecode and it may affect to the size and the addresses of the original bytecode.

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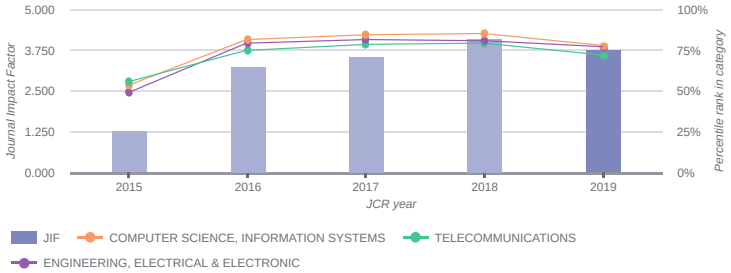

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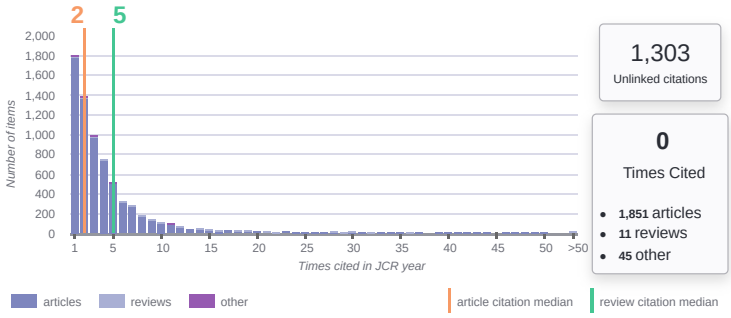

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