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Don't run on fumes—Parametric gas bounds for smart contracts☆

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ABSTRACT

Gas is a measurement unit of the computational effort that it will take to execute every single replicated operation that takes part in the Ethereum blockchain platform. If a transaction exceeds the amount of gas allotted by the user (known as gas limit), an *out-of-gas* exception is raised and its execution is interrupted. One of the main open problems in the analysis of Ethereum smart contracts is the inference of *sound* bounds on their gas consumption.

We present, to the best of our knowledge, the first static analysis that is able to infer sound *parametric* (i.e., non-constant) gas bounds for smart contracts. The inferred bounds can be parametric on the sizes of the input parameters for the functions, but also they can be parametric on the contract state, or blockchain data. Our gas analysis is developed at EVM bytecode level, in which Ethereum gas model is defined.

Our analysis is implemented in a tool named GASTAP, Gas-Aware Smart contracT Analysis Platform, which takes as input a smart contract and automatically infers *sound* gas upper-bounds for its public functions. GASTAP has been applied over 318,093 functions fetched from the Ethereum blockchain, and succeeded to obtain gas bounds for 90.24% of them.

1. Introduction

In the Ethereum consensus protocol, every operation on a replicated blockchain state, which can be performed in a transactional manner by executing a *smart contract* code, costs a certain amount of *gas* (Wood, 2014). Gas has a monetary value in *Ether*, Ethereum's currency, and it is paid by a transaction-proposing party. Computations (initiated by a protocol client invoking a smart contract) that require *more computational or storage resources*, cost more gas than those that require fewer resources. As regards storage, the Ethereum Virtual Machine (EVM) has three areas where it can store items: (a) the *storage* is where all *contract state* variables reside, every contract has its own storage and it is persistent between external function calls (transactions) and quite expensive to use; (b) the *memory* is used to hold temporary values, and it is erased between transactions and thus is cheaper to use; (c) the *stack* is used to carry out operations and it is free to use, but can only hold a limited amount of values.

The rationale behind the resource-aware smart contract semantics, instrumented with gas consumption, is three-fold. First, paying for gas at the moment of proposing the transaction does not allow the emitter to waste other parties' (aka *miners*) computational power by requiring them to perform a lot of worthless intensive work. Second, gas fees disincentivize users to consume too much of replicated *storage*, which is a valuable resource in a blockchain-based consensus system. Finally, such a semantics puts a cap on the number of computations that a transaction can execute, hence prevents attacks based on non-terminating executions (which could otherwise, *e.g.*, make all miners loop forever).

The gas-instrumented operational semantics of EVM has introduced novel challenges *wrt*. sound static reasoning about resource consumption, correctness, and security of replicated computations: *(i)* While the EVM specification (Wood, 2014) provides the precise gas consumption of the low-level operations, most of the smart contracts are written in high-level languages, such as Solidity (Ethereum, 2018b) or Vyper (Ethereum, 2018c).

The translation of the high-level language constructs to the low-level ones makes static estimation of runtime gas bounds challenging (as we will see throughout this paper), and is implemented in an *ad-hoc* way by state-of-the art compilers, which are only able to give constant gas bounds, or return ∞ otherwise. *(ii)* As noted in the recent study by Grech et al. (2018) and Foundation (2018), in general it is dangerous for a smart contract to make its gas consumption dependent on the size of the data it stores (*i.e.*,

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directions. First, we are studying a more precise abstraction for the memory-allocated data (*i.e.*, for the abstraction explained in Section 3). Also, we aim at handling bit-wise operations by including in our tool an abstraction for them.

CRediT authorship contribution statement

Elvira Albert: Conceptualization, Methodology, Software, Validation, Investigation, Formal analysis, Writing - original draft, Writing - review & editing. **Jesús Correas:** Conceptualization, Methodology, Software, Validation, Investigation, Formal analysis, Writing - original draft, Writing - review & editing. **Pablo Gordillo:** Conceptualization, Methodology, Software, Validation, Investigation, Formal analysis, Writing - original draft, Writing - review & editing. **Guillermo Román-Díez:** Conceptualization, Methodology, Software, Validation, Investigation, Formal analysis, Writing - original draft, Writing - review & editing. **Albert Rubio:** Conceptualization, Methodology, Software, Validation, Investigation, Formal analysis, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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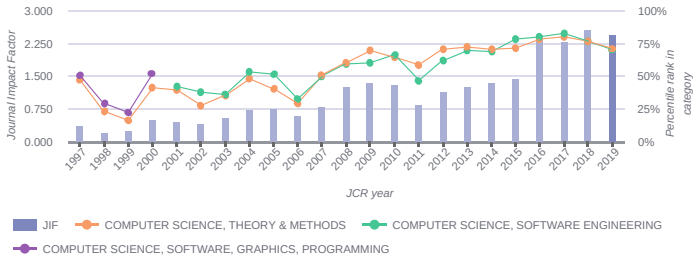

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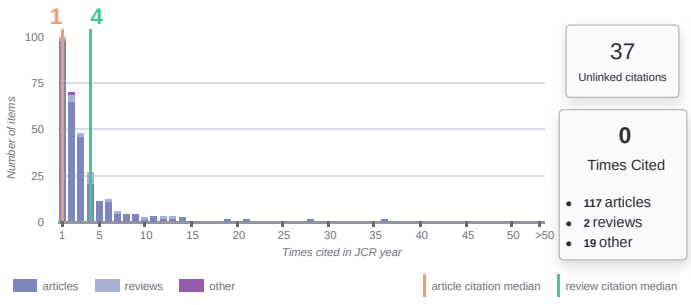

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JCR Year	COMPUTER SCIENCE, SOFTWARE ENGINEERING			COMPUTER SCIENCE, THEORY & METHODS			COM
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2018	26/107	Q1	76.168	25/105	Q1	76.667	
2017	19/104	Q1	82.212	21/103	Q1	80.097	
2016	22/106	Q1	79.717	23/104	Q1	78.365	
2015	24/106	Q1	77.830	31/105	Q2	70.952	
2014	33/104	Q2	68.750	31/102	Q2	70.098	
2013	33/105	Q2	69.048	29/102	Q2	72.059	
2012	41/105	Q2	61.429	30/100	Q2	70.500	
2011	57/104	Q3	45.673	42/99	Q2	58.081	
2010	34/99	Q2	66.162	35/97	Q2	64.433	
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2002	49/77	Q3	37.013	51/69	Q3	26.812	
2001	44/75	Q3	42.000	44/71	Q3	38.732	
2000	n/a	n/a	n/a	40/67	Q3	41.045	
1999	n/a	n/a	n/a	52/61	Q4	15.574	
1998	n/a	n/a	n/a	50/64	Q4	22.656	
1997	n/a	n/a	n/a	32/59	Q3	46.610	