Analysis of the Solidity Compiler for Smart Contract Redundancy Detection

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Outline

1. Motivation and Background Information
2. Problem Statement
3. Research Questions
   3.1. What are the internal workings of the bytecode-optimizers in the Solidity compiler?
   3.2. How does enabling the optimization in the compiler-instruction modify the bytecode in general?
   3.3. How many bytecodes and therefore smart-contracts are redundant regarding their functionality due to different or missing optimization?
4. Conclusion and Future Work

Motivation and Background Information

Solidity Code
(sourceFile.sol)

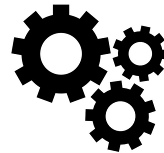
```
pragma solidity 0.5.8;

contract ExampleContract {
    uint256 number = 1;
}
```

```
0x6080604052600160005534801560145760
0080fd5b5060358060226000396000f3fe6080604052600080fdfea16562
7a7a723058204e048d6cab20eb0d9f95671510277b55a61a582250e04db7f658
7a1bebc134d20029
```

EVM (Deployment)
Bytecode

solc - Solidity Compiler



```
$ solc --optimize --bin sourceFile.sol
```

Motivation and Background Information

Contract creation transaction

```
> src =  web3.eth.accounts[0];
> ourContractDeploymentBytecode = "0x6080604052600160005534801560014…"
```

```
> web3.eth.sendTransaction ({
      from: src,
      data: ourContractDeploymentBytecode,
      gas: 113558,
      gasPrice: 200000000000
})
```

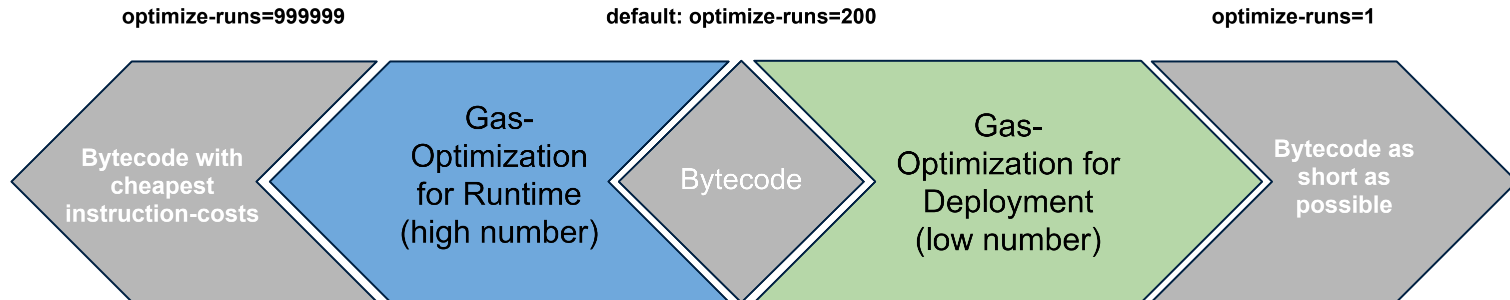
Deployment workflow of a smart contract

Motivation and Background Information

```
pragma solidity 0.5.8;

contract ExampleContract {
    uint256 number = 1;
}
```

```
0x6080604052600160005534801560145760
57600080fd5b506035806022600039 60
```



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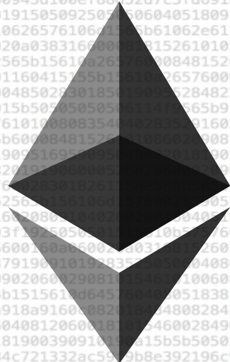
Problem Statement

Many studies in bytecode-analysis work with sets of unique smart contracts

Missing inclusion of the optimization process of the compiler



How many EVM bytecodes are redundant due to different or missing optimization?

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Research Questions

R1: What are the internal workings of the bytecode-optimizers in the Solidity compiler?

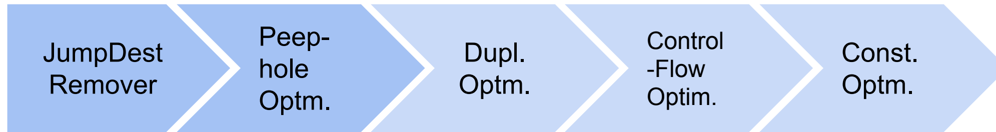
R2: How does enabling the optimization in the compiler-instruction modify the bytecode in general?

R3: How many bytecodes and therefore smart-contracts are redundant regarding their functionality due to different or missing optimization?

What are the internal workings of the bytecode-optimizers in the Solidity compiler?

Research question 1

RQ1.1 Of which sub-optimizers does the bytecode-optimizer of the Solidity compiler consist and what are their functionalities?



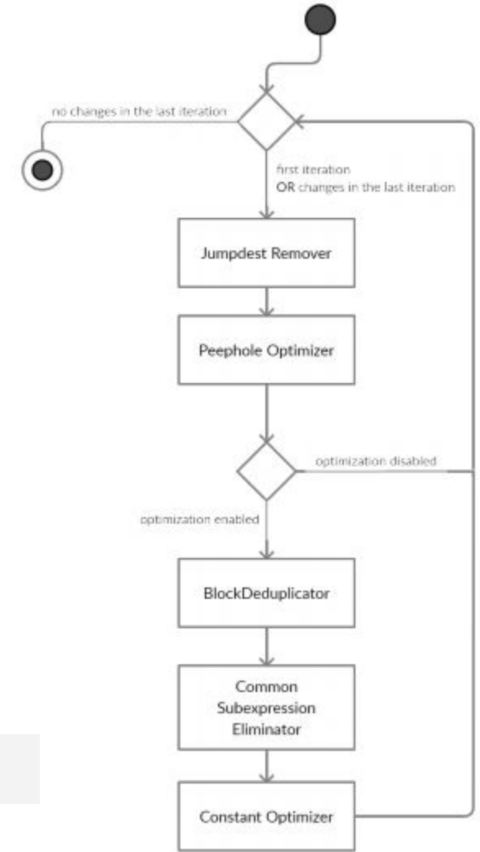
RQ1.2 How do the compilation-parameters affect the optimization-process of the compiler and the resulting bytecode?

```
pragma solidity 0.5.8;

contract ExampleContract {
    uint256 number = 1;
}
```

```
0x6080604052600160005534801560145
7600080fd5b50603580602260003960
00f3fe6080604052600080fdfea16562
7a7a723058204e048d6cab20eb0d9f95
671510277b55a61a582250e04db7f658
7a1bebc134d20029
```

```
$ solc --optimize-runs=200  --bin sourceFile.solv
```



How does enabling the optimization in the compiler-instruction modify the bytecode in general?

Research question 2

RQ2.1 Which bytecode-sections get optimized in what way of the compilation-process?

Deployment-Bytecode

```
608060405234801561001057600080fd5b506040516020806102178339810160409081529051 60
00818155338152600160205291909120556101d1806100466000396000f300
```

Runtime-Bytecode

```
6080604052600436106100565763ffffffff7c0100000000000000000000000000000000000000
00000000000000000060003504166318160ddd811461005b57806370a0823114610082578063a9
059cbb146100b0575b600080fd5b34801561006757600080fd5b506100706100f5565b60408051
918252519081900360200190f35b34801561008e57600080fd5b5061007073ffffffffffffffff
ffffffffffffffffffffffff600435166100fb565b3480156100bc57600080fd5b506100e173ff
ffffffffffffffffffffffffffffffffffffff6004351660243561012356 5b604080519115158 2
52519081900360200190f35b60005490565b73ffffffffffffffffffffffffffffffffffffffff
166000908152600160205260409020549056 5b600073ffffffffffffffffffffffffffffffffff
ffffff83161515610147 57600080fd5b33600090815260016020526040902054821115610163 57
600080fd5b503360009081526001602081905260408083208054859003905573ffffffffffffff
ffffffffffffffffffffffffff85168352909120805483019055929150505600a1
```

Meta-data Hash

```
65627a7a72305820a5d999f4459642872a29be93a490575d345e40fc91a7cccb2cf29c88bcdaf3
be0029
```

How does enabling the optimization in the compiler-instruction modify the bytecode in general?

Research question 2

RQ2.2 Which opcode-patterns and bytecode-methods can be simplified through setting optimization in the compiler-instruction?

```
CALLER
PUSH20
0xffffffffffffffffffffffffffffffffffffffff
AND
```

```
CALLER
PUSH1 0x01
PUSH1 0xA0
PUSH1 0x02
EXP
SUB
AND
```

Dynamic Calculations on the stack instead of hardcoding constants

```
608060405234801561001057600080fd5b506040516020806102178339810160409081529051 60
00818155338152600160205291909120556101d18061004660003960 00f300
```

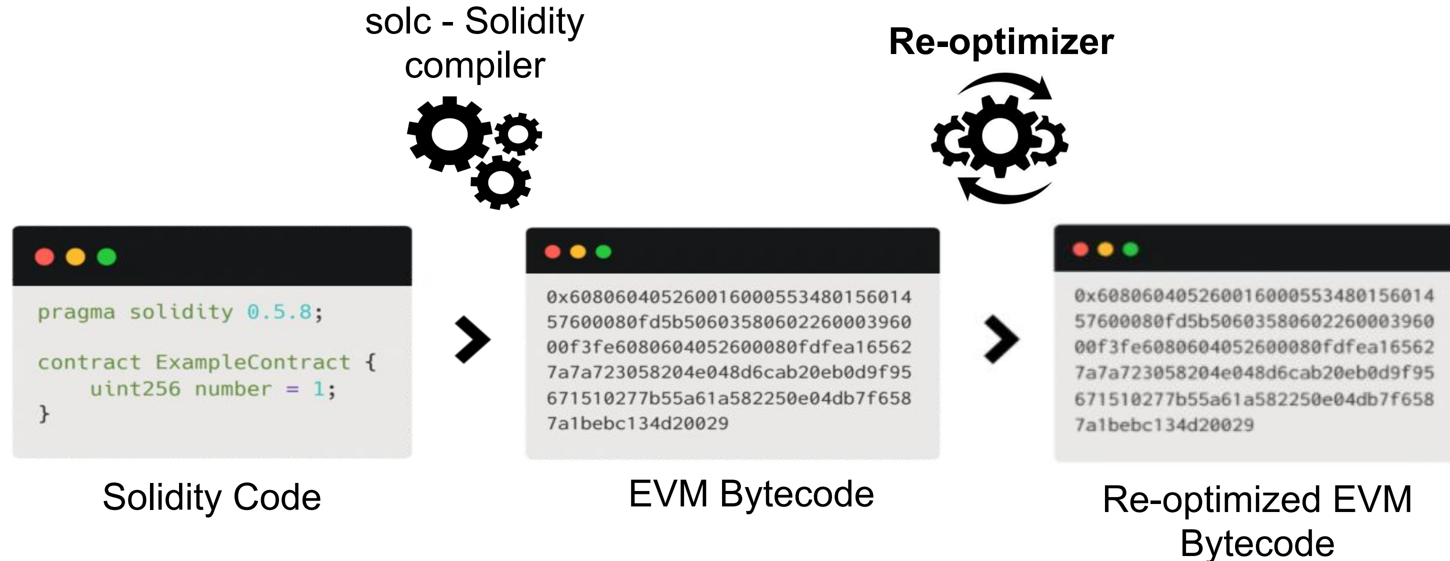
```
608060405260043610610056576 3ffffffff7c0100000000000000000000000000000000000000
000000000000000000006000350416631816 0ddd811461005b57806370a0823114610082578063a9
059cbb146100b0575b600080fd5b348015610067576 00080fd5b506100706100f5565b60408051
918252519081900360200190f35b3480156100 8e57600080fd5b5061007073ffffffffffffffff
ffffffffffffffffffffffff600435166100fb565b3480156100bc57600080fd5b506100e173ff
ffffffffffffffffffffffffffffffffffffff6004351660243561012356 5b6040805191151582
5251908190036020 0190f35b60005490565b73ffffffffffffffffffffffffffffffffffffffff
1660009081526001602052604090205490 565b600073ffffffffffffffffffffffffffffffffff
ffffff831615156101475760 0080fd5b33600090815260016020526040902054821115610163 57
600080fd5b503360009081526001602081905260408083208054859003905573ffffffffffffff
ffffffffffffffffffffffffff85168352909120805483019055929150505600a1
```

```
65627a7a7230582 0a5d999f4459642872a29be93a490575d345e40fc91a7cccb2cf29c88bcdaf3
be0029
```

How many bytecodes and therefore smart-contracts are redundant regarding their functionality due to different or missing optimization?

Research question 3

RQ3.1 What design could a re-optimizer have and what restrictions on the re-optimization are there?



How many bytecodes and therefore smart-contracts are redundant regarding their functionality due to different or missing optimization?

Research question 3

RQ3.1 What is a possible design of such a re-optimizer?

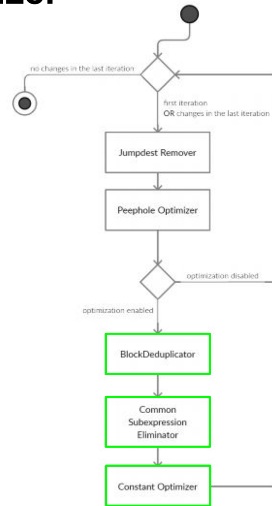
Re-optimizer

```
0x6080604052600160005534801560145
7600080fd5b50603580602260003960
00f3fe6080604052600080fdfea16562
7a7a723058204e048d6cab20eb0d9f95
671510277b55a61a582250e04db7f658
7a1bebc134d20029
```

EVM Bytecode

```
{
  "m_items": [
    0: {solidity::evmasm::AssemblyItem},
    1: {solidity::evmasm::AssemblyItem},
    2: {solidity::evmasm::AssemblyItem},
    3: {solidity::evmasm::AssemblyItem},
    4: {solidity::evmasm::AssemblyItem},
    5: {solidity::evmasm::AssemblyItem},
    ...
  ]
}
```

```
{
  "0": {
    m_modifierDepth = 0,
    m_type = solidity::evmasm::Push,
    m_instruction = -3,
    m_data = { m_data },
    m_location = { m_location },
    m_jumpType = solidity::evmasm::AssemblyItem::JumpType::Ordinary,
    ...
  }
}
```



```
0x6080604052600160005534801560145
7600080fd5b50603580602260003960
00f3fe6080604052600080fdfea16562
7a7a723058204e048d6cab20eb0d9f95
671510277b55a61a582250e04db7f658
7a1bebc134d20029
```

Re-optimized EVM Bytecode

How many bytecodes and therefore smart-contracts are redundant regarding their functionality due to different or missing optimization?

Research question 3

RQ3.2 Which restrictions does such an re-optimization have?

Technical restrictions

```
0x6080604052600160005534801560145
7600080fd5b5060358060226000396
00f3fe6080604052600080fdfea16562
7a7a723058204e048d6cab20eb0d9f95
671510277b55a61a582250e04db7f658
7a1bebc134d20029
```

EVM Bytecode

```
{
  "m_items": [
    0: {solidity::evmasm::AssemblyItem},
    1: {solidity::evmasm::AssemblyItem},
    2: {solidity::evmasm::AssemblyItem},
    3: {solidity::evmasm::AssemblyItem},
    4: {solidity::evmasm::AssemblyItem},
    5: {solidity::evmasm::AssemblyItem},
    ...
  ]
}
```

```
{
  "0": {
    m_modifierDepth = 0,
    m_type = solidity::evmasm::Push,
    m_instruction = -3,
    m_data = { m_data },
    m_location = { m_location },
    m_jumpType = solidity::evmasm::AssemblyItem::JumpType::Ordinary,
    ...
  }
}
```

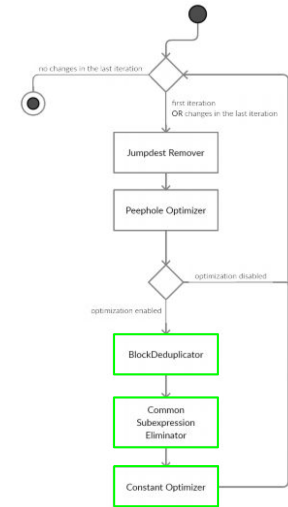
Conceptual restrictions

Yul Optimizer

Bugfixes and modifications in the Solidity compiler

Runtime bytecodes

Standard optimization



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Conclusion and Future Work

Conclusion

First comprehensive description of the inner workings of the Solidity optimizer

Insights are already outdated with the introduction of the Yul-optimizer

- ➢ Analysis of deployed smart-contracts in the past

Compilation-parameters affect the optimization and the resulting bytecode

Possible design of an bytecode re-optimizer

Conclusion and Future Work

Future Work

Actual implementation of such an re-optimizer

- ➢ use the re-optimization in combination with statistical methods to determine the redundancy of smart-contracts deployed on Ethereum

Integration of the Yul-optimizer

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