

# Is Your Legal Contract Ambiguous? Convert to a Smart Legal Contract

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**Abstract**—A legal contract is something that is in spoken or in written form, which binds a party or multiple parties into given terms and conditions. On the other hand, a smart contract is also a contract which is a computer program that binds parties into given terms and conditions but unlike a legal contract, it is self-executable, efficient, and unambiguous. Almost all legal contracts are complex while reading because of its ambiguous nature. In this paper, we take a real-world ambiguous legal contract as a test contract, and generate various interpretations from it, convert all those interpretations into the smart legal contracts and identify the most ambiguous and accurate smart legal contract by performing various measurements such as transaction fees and ambiguity index for each interpretation. We came to the conclusion that the most ambiguous legal contract would be the contract with general interpretation as it was more complex when written in the smart contract and had many possible interpretations due to ambiguity than the rest of the interpretations.

**Index Terms**—Smart contract, smart legal contract, ambiguity, complexity, crowdfunding legal contract, blockchain, ethereum, clauses, interpretations, ambiguity index

## I. INTRODUCTION

A contract is an agreement that is in written or spoken form. It settles an agreement or a dispute between one or more parties since it is intended to be enforceable by law [1]. It can be classified into different types [2]. However, in this paper, we will only be focusing on the traditional legal contracts, which are usually in paper form, or in some cases, in electronic form. Fundamentally, this type of contract contains do's and don'ts under different clauses. As we now all know that a contract involves one or more parties, so, consequently, a team of lawyers is also involved since a contract is involved in legal cases. These lawyers can be considered as "middlemen" since they are the ones who try to arrange and decide the best possible situation for all the parties who are involved in the legal contract. Nevertheless, the most infamous feature of a legal contract is that it is very unclear, vague, and ambiguous. Hence, this almost always results in multiple interpretations of multiple parties. An ambiguous contract means that a specific term, word, phrase, or definition is vague and has multiple meanings depending on a person's knowledge, experience, or perception [3]. On the other hand, a Smart Contract (SC) is a computer program that

is self-executable and self-enforced managed by a blockchain [4]. The computer program comprises of the unambiguous and precise set of rules under which the parties of that smart contract agree to interact with each other. If and when the predefined rules written in the smart contract are met, the agreement is self-executed and enforced. In this paper, we have referred to a smart contract as a "smart legal contract" as we are working with a legal contract.

Thus, the main problem definition of this paper is how we can convert or translate a "dumb" legal contract that is full of ambiguities into an accurate "smart" legal contract that can be applied and used in Ethereum based Blockchain. To perform the experiment and to measure the accuracy of a derived smart legal contract from a traditional legal contract, we have specifically taken a general crowdfunding legal contract [5] because of its application in blockchain and long set of ambiguous terms and conditions. In this paper, we discuss the steps that were taken in order to translate a legal contract to a smart legal contract considering all the ambiguities and vague terms present in a legal contract. This paper also discusses the different interpretations of a legal contract that people can have based on their knowledge and experience and how those multiple interpretations can have an effect on the accuracy of the translated smart contract.

Although there has been profound research going on for smart contracts in a substantial manner in recent years, the study on 'smart legal contracts' has not been so thorough. Despite the fact there has been extensive research in ambiguities, legal contracts, and smart contracts separately, there has not been any study on the relationship between the legal contracts and smart contracts. Smart contract and the ambiguity has been studied in [6], but the author does not have any methodology to classify the interpretations of legal contracts and smart legal contract based on the ambiguity level. There is an only superficial classification of ambiguities from a linguist's perspective made in [2] by the author, which was not enough as our study covered more aspects than just a linguistic point of view. In [7], the author explains how a contract can be computed and how it can be converted into code but lacks the research and discussion of ambiguities and concepts of a smart legal contract. In [8], the author talks about the rules

by which various sequences of the events trigger particular sequences of state transitions in the relationship between the entities in which ambiguities have not been discussed. In [9], the author talks about blockchain being used for drafting and probating wills and making the contract transparent and secure, yet we cannot find the explanation of the relationship between a legal contract and smart legal contract based on the ambiguity. In [10], the author takes ambiguity into account by encoding contract metadata, but the consideration of actual clauses is completely ruled out.

### A. Contributions

The main contributions of this paper are as follows:

- We investigate the legal contract’s ambiguity by generating all possible interpretations a contract has and convert into separate control flow graphs.
- We translate the generated control flow graphs of all interpretations into the separate smart contracts for each interpretation for ethereum based blockchain.
- We find the ambiguity of each translated smart contract based on their performance.
- We use McCabe’s cyclomatic complexity [11] to generate the ambiguity index based on the complexity of the control flow graph of each interpretation.
- Finally, we identify the most ambiguous as well as accurate translated smart contract based on its performance and ambiguity index.

### B. Outline

The rest of the paper is organized as follows: Section II presents the kind of relationship between a legal contract and a smart legal contract when ambiguities are considered. Section III talks about the experimental setup and the tools used for this project. The methodology of the project is discussed in Section IV. Section V explains the ambiguity level of each interpretation based on their measurement of performance. Section VI compares the transaction fees of each interpretation and total time taken to deploy in Ropsten Testnet [12]. In Section VII, ambiguity index and complexity is measured for smart contracts with each interpretation. Section VIII explains the total translation rate of a legal contract to a smart contract. Section IX discusses the challenges we faced in this project and also about the future work. We conclude the paper in Section X by summarizing the key concepts and ideas of this paper.

## II. RELATIONSHIP BETWEEN A TRADITIONAL LEGAL CONTRACT AND A SMART LEGAL CONTRACT WHEN AMBIGUITIES ARE CONSIDERED

Since a legal contract consists of a plethora of ambiguous and legal words, it results in various different interpretations. For instance, a person who is reading a legal contract might perceive it in a different way than the other person who is reading the same legal contract. The main reason for the multiple interpretations of the people reading the same legal

contract comes from the ambiguity of the words used in it and how the meanings of those words can be perceived [2]. Fig. 1 shows that several versions of smart contracts can be mapped or converted from a legal contract as legal (natural) language can result in different interpretations and understandings for different people. It also explains the relationship between a legal contract and the generated smart legal contracts from the same legal contract can have one too many relationships.

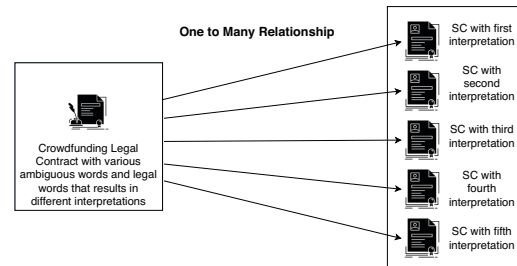


Fig. 1. One to many relationship between a legal contract and smart legal contract

## III. EXPERIMENTAL SETUP

The tools and materials that we have used for this project are listed below:

- Ropsten Test Network [12],
- Solidity Programming Language 0.5.3 [13],
- Remix Web IDE [14],
- Metamask [15],
- Node.js [16],
- Truffle [17],
- Ganache-CLI [18],
- Web3 [19],
- HD Wallet [20],
- Google Chrome in Incognito Mode [21],
- A crowdfunding legal contract [5]
- An employment agreement legal contract [22].

*Source of the different interpretations were collected from the random people who were asked to read the contract.*

## IV. METHODOLOGY

Fig. 2 shows there are four different fundamental phases in this paper. The first phase is the selection of a legal contract. For this project, we have selected a regular crowdfunding legal contract as a test contract. The second phase talks about having different interpretations of the same legal contract. In the third phase of the project, we translate all possible interpretations derived from the ambiguous crowdfunding legal contract into a respective smart legal contract. In the fourth and final phase, we find out which interpretation of the smart legal contract is the most ambiguous and accurate.

Oftentimes, we have heard people and companies suing each other because of the lack of understanding of the terms and conditions in the contract. The only reason a legal contract is making everyone’s life difficult is because of the way it is written, i.e., with many ambiguous terms and jargon words [23]. As a result, it is obvious for different people to perceive the same contract in different ways. Hence, people who are reading a legal contract might have different interpretations of each other, as shown in the Fig.

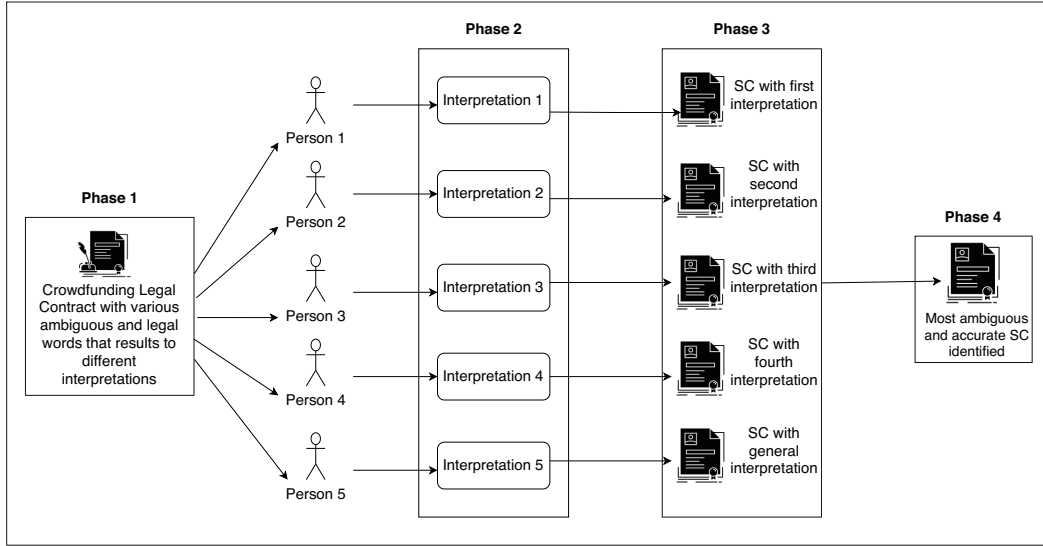


Fig. 2. Selection of a legal contract in the first phase, generation of all possible interpretations of the selected legal contract in the second phase, translation of all possible interpretations derived from the ambiguous legal contract into their respective smart legal contract, and identification of the most ambiguous as well as accurate smart legal contract in the fourth phase.

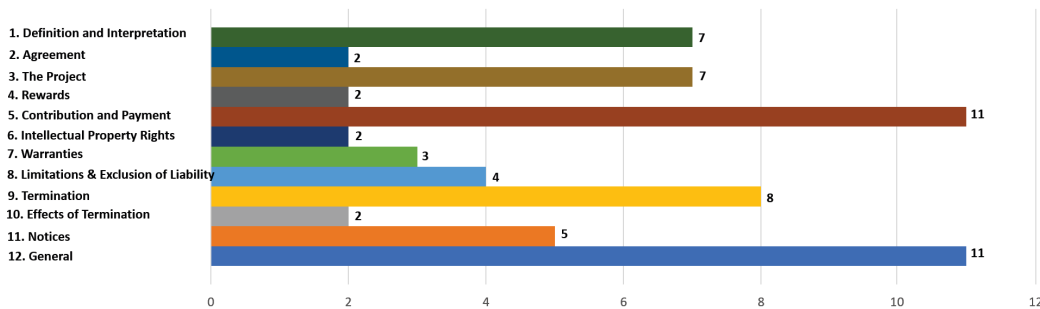


Fig. 3. Number of times ambiguous words and phrases were found in each clause with 'Contribution and Payment' and 'General' being the highest.

2. Another objective of this study was to create all possible interpretations people might have when reading a legal contract and convert all those interpretations into the smart contract and finally find out the most ambiguous as well as the most accurate smart legal contract among them. This crowdfunding legal contract was taken as a test sample from Cloudset Solutions from Coherence Design [5]. However, since the crowdfunding legal contract is several pages long and had 12 clauses in total, we have only taken one particular clause, i.e., "Contribution and Payment" (Clause number 5) into consideration for testing. The reason behind selecting only this particular clause out of all 12 clauses is that the number of ambiguous words and phrases in this clause were more in numbers compared to other clauses, as we can see in Fig. 3 and this clause also constantly revolved around the idea and mechanism of how crowdfunding works and involved more transactions. The other reason to select this particular clause among other clauses because of the more number of permissive and ambiguous words and phrases

used in that clause such as "may", "otherwise", "time to time", "is not intended" and "might". From Fig. 3, we can also see that out of 64 ambiguous words and phrases found in the legal contract, this clause has 11 of them, i.e., 17.18%.

The control flow graph shown in Fig. 4 was generated from the fifth clause called "Contribution and Payment". This clause says that in a crowdfunding platform, a 'developer' who is seeking for monetary aid receives money from 'sponsors' once the sponsors like his/her idea. However, this clause also states the rules of payment to the developer. It uses statements as "All contribution amount are stated exclusive of VAT, unless the context requires otherwise" and "If the Sponsor does not pay any amount properly due to the Developer under or in connection with the Agreement, the Developer may charge the Sponsor interest on the overdue amount." However, the words like "otherwise", "properly" and "may" does not give clear and specific instructions hence, result in multiple interpretations. The word "may" itself could

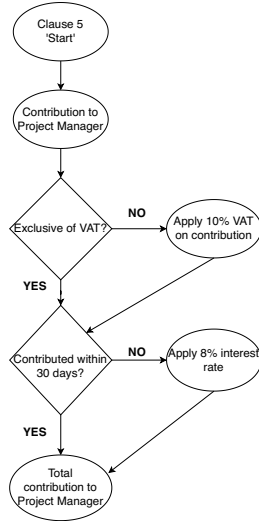


Fig. 4. Control Flow graph of the events from a clause “Contribution and Payment” from Crowdfunding Contract (General Interpretation).

mean “yes” or “no”. Fig.4 explains the steps of Clause 5 with additional possible steps that arise from these ambiguous words. Hence, from the control flow graph from Fig. 4 and these two ambiguous statements, we have created and categorized four further possible interpretations and shown them in their respective control flow graphs in Fig. 5.

As shown in the Fig. 5, we can see that Fig. 4’s control flow graph can be further categorized into 4 different interpretations from where we can create 4 different control flow graphs. This is only possible due to the words such as

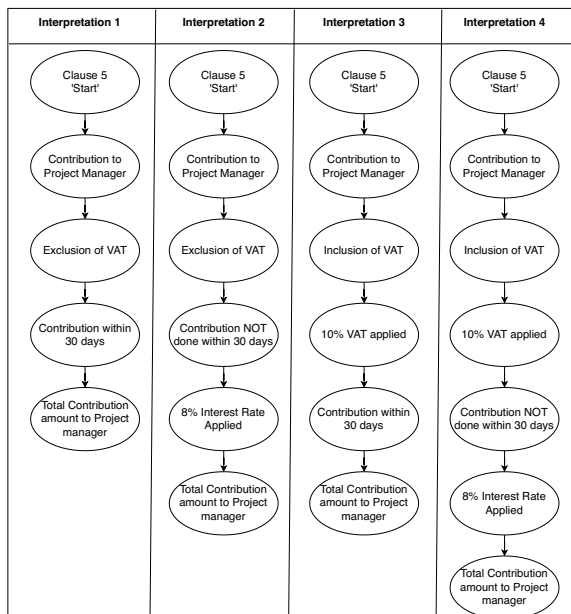


Fig. 5. The variation in control flow graphs showing multiple interpretations from Fig.4’s control flow graph.

“may” and “otherwise” present in Clause 5 of crowdfunding legal contract which have ambiguous and multiple meanings. If mandatory words such as “must” or “will” were present instead of “may” and “otherwise”, then we would only have one control flow graph and no other variations because of its preciseness.

## V. METRICS FOR EACH SMART LEGAL CONTRACT WITH THEIR RESPECTIVE INTERPRETATIONS

As we have generated a maximum of five different interpretations in total, including General Interpretation, we also have studied and measured the metrics for each interpretation.

### A. SMART LEGAL CONTRACT WITH INTERPRETATION 1

- *Transaction Fee of 100 transactions of Interpretation 1:* 25 deployments of the same smart contract with Interpretation 1 were performed, in addition to 75 transactions in Ropsten Testnet. The deployment cost is constant. It is approximately 0.0007 ethers and is constant until the end. The deployment cost was much higher than the transaction cost. Although there were few discrepancies in the transactions cost, the ethers that it consumed to run in Ropsten Testnet are very similar. Apart from the deploy function, there is only one function that took more than 0.0001 ethers, i.e., withdraw() function. This function is used when the sponsors contribute a payment to the developer and when the developer is ready to withdraw the payment.

- *Total time taken for each transaction of Smart Legal Contract with Interpretation 1:*

The lowest time taken by one of the transactions was 9 seconds. On the other hand, a transaction took 1463 seconds, which is approximately 25 minutes. However, the average time taken by all these 100 transactions was 155 seconds, which is approximately 3 minutes. The time these transactions take depends on various factors. If the function is too complex and has a greater number of parameters, then it takes more time. Also, if the test net gets busy at its peak time, then it takes more time to be registered.

### B. SMART LEGAL CONTRACT WITH INTERPRETATION 2

- *Transaction Fee of 100 transactions of Interpretation 2:* The transaction fees and deployment cost of 100 transactions for Interpretation 2. The highest transaction fee is 0.0006 ethers. Out of 100 transactions, 25 transactions have the same amount of fees, i.e., 0.0006 ethers. Since these 25 transactions were deployment costs, therefore the fees were much higher compared to other transactions cost.

- *Total time taken for each transaction of Smart Legal Contract with Interpretation 2:*

The lowest time for a transaction to register taken was 9 seconds. The highest time for a transaction to register was 1549 seconds. And the average time for all 100 transactions was 96 seconds.

### C. SMART LEGAL CONTRACT WITH INTERPRETATION 3

- *Transaction Fee of 100 transactions of Interpretation 3:*  
This data of Transaction Fees for the smart legal contract with Interpretation 3 was exactly as same as for Smart Contract Interpretation 2. The highest transaction fee is 0.0006 ethers. Out of 100 transactions, 25 transactions that are the deployment costs have the same amount of fees, i.e., 0.0006 ethers, which is the same as the previous case from Interpretation 2. The only reason behind the costs to be the same is that the smart legal contract complexity for both of the interpretations 2 and 3 is also similar.
- *Total time taken for each transaction of Smart Legal Contract with Interpretation 3:*  
The time taken to register keeps on varying as the peak rate of Rospsten Testnet varies. Whenever the network is too busy, it usually takes more time to register the transactions. The lowest time taken for a transaction to register taken was 5 seconds. The highest time for a transaction to register was 1703 seconds. And the average time for all 100 transactions was 89 seconds.

### D. SMART LEGAL CONTRACT WITH INTERPRETATION 4

- *Transaction Fee of 100 transactions of Interpretation 4:*  
Although this data for transaction fees for the smart legal contract with Interpretation 4 is very much similar to previous interpretations except Interpretation 1, the highest transaction fees, in this case, is a bit more than previous interpretations 2 and 3.
- *Total time taken for each transaction of Smart Legal Contract with Interpretation 4:*  
The lowest time for a transaction to register taken was 1 second. The highest time for a transaction to register was 390 seconds. And the average time for all 100 transactions was 55 seconds, which is much lesser than Interpretation 3. The reason for the variance in time taken to deploy was the fluctuations in the peak rate of the Ropsten Testnet.

### E. SMART LEGAL CONTRACT WITH GENERAL INTERPRETATION (USUAL CASE)

- *Transaction Fee of 100 transactions of General Interpretation:*  
This smart legal contract with General Interpretation is the kind of smart contract where most of the people perceive the legal contract in a more practical way in the real world. This is the case of how a clause looks like in General Interpretations where there are lots of branches of "yes" and "no". 25 transaction fees that

are the deployment costs were the highest compared to all interpretations, the highest transaction fees. The highest transaction fee here is more than 0.0007 ethers. This is the first sign of a smart legal contract with this interpretation type being ambiguous compared to the other interpretations. The more ambiguous an interpretation is, the more complex it becomes. As a result, the more complex an interpretation is, the more costly it is in terms of fees. This means that ambiguity, complexity, and cost has a direct relationship.

- *Total time taken for each transaction of Smart Legal Contract with General Interpretation:*  
The lowest time for a transaction to register taken was 1 second. The highest time for a transaction to register was 671 seconds. And the average time for all 100 transactions was 80 seconds. The reason for this variance in time taken to deploy is the same as previous cases, i.e., the fluctuations in the peak rate of the Ropsten testnet.

## VI. COMPARISON OF AVERAGE TRANSACTION FEES BETWEEN DIFFERENT INTERPRETATIONS OF SMART LEGAL CONTRACT

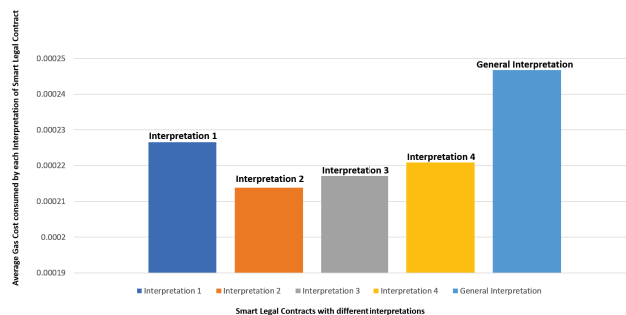


Fig. 6. Comparison of average transaction cost by 5 different interpretations of Smart Legal Contract to find out the complexity of each Smart Legal Contract.

In Fig. 6, a comparison of all smart contracts with their respective interpretations has been made. 500 transactions were performed, 100 for each interpretation. As we can see in Fig. 6, Interpretation 1 consumed approximately 0.00023 ethers. Interpretation 2 has consumed the least, i.e., slightly more than 0.00021 ethers. Interpretation 3 has always been very similar to Interpretation 2 in all aspects. Even the average transaction cost is similar, i.e., slightly more than what Interpretation 2 cost. Interpretation 4 has consumed approximately 0.00022 ethers. However, smart legal contract with General Interpretation has consumed the most among all, consuming slightly more than 0.000245 ethers. As demonstrated in Fig. 6, since the General Interpretation is more ambiguous and complex, the consumption rate is higher compared to other interpretations.

The reason smart legal contract with General Interpretation consumed more gas for transaction fee than the rest of smart legal contracts is because it is more complex and has more

lines of codes. And the only reason it is more complex is because it is more ambiguous. We also discuss about finding out the most ambiguous interpretation in Section VII where we calculate the ambiguity index based on the complexity level of each smart legal contract to strengthen our observations and conclusion. From this transaction fee consumption pattern, we can say that smart legal contract with General Interpretation is much more ambiguous and complex contract than smart legal contracts with other four interpretations.

## VII. MEASUREMENT OF COMPLEXITY AND AMBIGUITY INDEX OF EACH SMART LEGAL CONTRACT

We have also calculated and measured the complexity of all five different interpretations. We have used McCabe's cyclomatic complexity in order to find the complexity of each interpretation. The relationship between complexity and ambiguity is directly proportional, whereas ambiguity and accuracy are inversely related. The more complex an interpretation is, the more ambiguous it becomes. We have used the control flow graphs from Fig. 4 and Fig. 5 to calculate the complexity. To evaluate the complexity, we used McCabe's cyclomatic complexity. The cyclomatic complexity is defined in [11], which measures the complexities and the total number of linearly independent paths of a program.

$$C = N_e - N_n + 2 * N_{cc} \quad (1)$$

Where,  $C$  is the complexity,  $N_e$  is the number of edges of the control flow graph,  $N_n$  is the number of nodes of the control flow graph, and  $N_{cc}$  is the number of connected components.

TABLE I

COMPLEXITY MEASURE OF CROWDFUNDING SMART LEGAL CONTRACTS

Type of Smart Legal Contract	Complexity Measure (Ambiguity Index)
Interpretation 1	1
Interpretation 2	1
Interpretation 3	1
Interpretation 4	1
General Interpretation	3

As we can see in Table I, smart legal contracts with Interpretations 1, 2, 3, and 4 have the same complexity measure, i.e., 1. This means that when measuring the ambiguity index of smart legal contracts with Interpretations 1, 2, 3, and 4, we found that they are equally ambiguous at the same level. However, the complexity measure for the smart legal contract with General Interpretation is 3. Hence, the ambiguity index for General Interpretation is three times more than that of the other four smart legal contracts. Therefore, from Fig. 4, Fig. 5, Fig. 6 and Table I, we have measured the complexity level of each smart legal contract with five different interpretations and found out that the most ambiguous one is the smart legal contract with General Interpretation which makes it less accurate. In other

words, smart legal contracts with Interpretations 1, 2, and 3 are more accurate compared to the smart legal contract with General Interpretation.

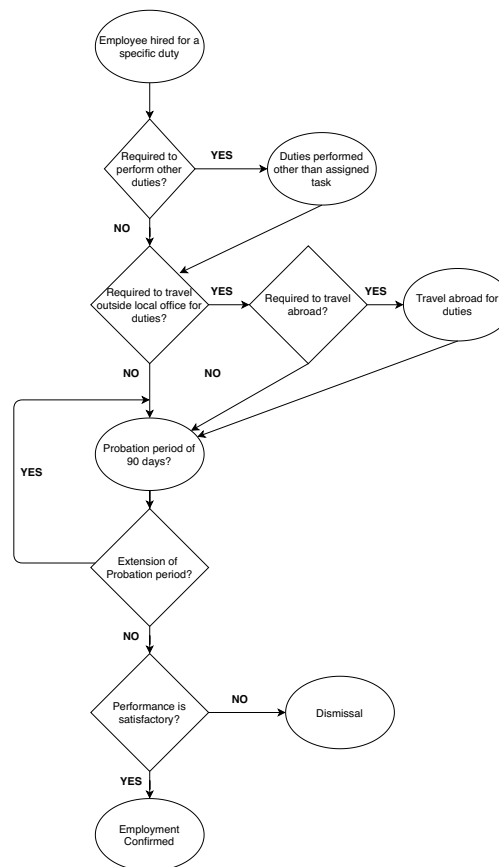


Fig. 7. Control Flow graph of the events from Employment Agreement Contract (General Interpretation).

TABLE II

COMPLEXITY MEASURE OF EMPLOYMENT AGREEMENT SMART LEGAL CONTRACTS

Type of Smart Legal Contract	Complexity Measure (Ambiguity Index)
Interpretation 1	1
Interpretation 2	1
Interpretation 3	1
Interpretation 4	1
Interpretation 5	1
Interpretation 6	1
Interpretation 7	1
Interpretation 8	1
Interpretation 9	1
Interpretation 10	1
General Interpretation	5

Not only we calculated McCabe's cyclomatic complexity for Crowdfunding Legal Contract, but we also took an **Employment Agreement Contract** [22] and we performed our test on it to find the complexity measure and ambiguity

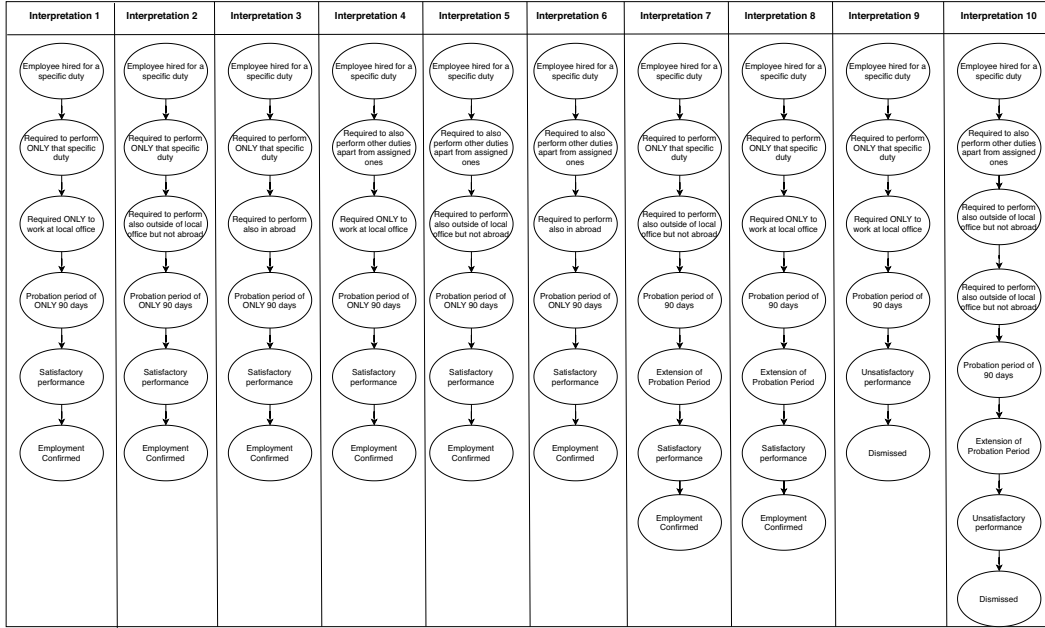


Fig. 8. The variation in control flow graphs showing multiple interpretations from Fig.7's control flow graph.

index to see if the level of ambiguity is also greater in General Interpretation for Employment Agreement Contract. From the Employment Agreement Contract, we generated a general interpretation along with 10 more different interpretations for test purpose, although even more interpretations could be generated. The more ambiguity is in the legal contract, the more interpretations can be generated from it.

From Table II, we can see that the smart legal contract with the general interpretation has the ambiguity index of 5. On the contrary, the smart legal contract with the rest of the interpretations have the same level of ambiguity index, hence have equal ambiguity index. Therefore, we can conclude the smart legal contract with the General Interpretation always has higher ambiguity index compared to other interpretations

because it comprises of words and phrases with multiple meanings and is full of ambiguity or least accurate.

In both contracts, the contract with general interpretation scored highest, meaning the contract with general interpretation is more ambiguous than any other interpretations in any given contract. Our observations and the comparison between ambiguity index from Table I, Table II, Fig. 7 and Fig. 8, shows that the Employment Agreement smart legal contract is more ambiguous than the Crowdfunding smart legal contract because of the higher ambiguity index.

### VIII. TOTAL TRANSLATION PERCENTAGE OF A LEGAL CONTRACT

There are altogether of 12 clauses in our test crowdfunding legal contract. 4 out of 12 clauses have been successfully converted into the smart contract. In other words, we can say that we were able to convert 33.33% of the total contract into the smart legal contract as shown in Fig. 9. The clauses that have been converted are 'Agreement', 'The Project', 'Rewards', and 'Contribution and Payment' that revolves around the idea and mechanism of the crowdfunding process. The clauses that were not converted were not related to the mechanism and functioning of a crowdfunding process and hence did not contribute much when it came to writing the smart contract. The whole contract cannot always be converted into a smart legal contract as the activities, events, and other major aspects in a legal contract also include physical and non-transactional activities. In that case, we only take the subset of the legal contract and convert the convertible subset into the code, i.e., smart legal contract.

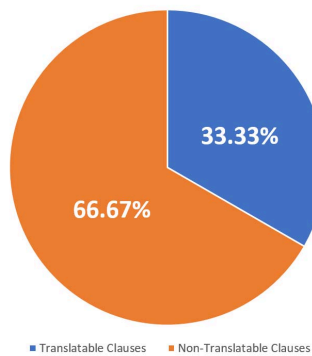


Fig. 9. Total translation percentage of a whole Crowdfunding Legal Contract into Smart Legal Contract.



## IX. CHALLENGES, LIMITATIONS AND FUTURE WORK

Understanding the semantic legal terms, which makes a contract ambiguous, will always be a challenge as these legal words are understood clearly only by certain people whose profession lies in the legal sector. The idea of a Smart Legal Contract is itself a novel idea. Conversion of the legal terms into a smart contract correctly without being ambiguous is quite difficult. Also, the whole contract might not be converted into a smart legal contract since the activities and events in a legal contract might include physical and non-transactional activities, as shown in Fig. ?? . In that case, we only take the subset of the legal contract and convert the convertible subset into the code, i.e., smart legal contract. In the real world, all the parties/entities who digitally sign the smart legal contract will have to believe and approve its functionality and accuracy after the natural (legal) language is converted into the code.

Future work would be to compare the ground truth of the smart legal contracts with the lawyers and contrast the integrity of our ambiguity index with the lawyers' measurement standard. Future work would also be to use and develop Natural Language Processing systems and Artificial Intelligence for legal contract analysis where we plan to extract the texts of a given contract automatically and generate all possible interpretations to find ambiguity.

## X. CONCLUSION

In this paper, we introduced a novel study on the relationship between an ambiguous legal contract and a smart legal contract. We also created all possible interpretations from an ambiguous legal contract and then evaluated and compared different metrics that helped us to ultimately find the most ambiguous as well as accurate interpretation. By assessing the transaction fees and ambiguity index of all the possible interpretations of the smart legal contract, we were able to strengthen our final conclusion and point out whether a given interpretation of a smart legal contract was accurate or ambiguous. We also compared two legal contracts and found which contract is more ambiguous than the other. We also studied the total translation rate of a traditional legal contract into a smart legal contract and what type of clauses are more likely to be converted to computer code easily. The concept of the smart legal contract is still in the embryonic stage. A smart legal contract has countless advantages that will someday disrupt several legal bodies and organizations despite the challenges it might have in its area. The main purpose of this paper is to study how a legal contract in the real world has been affecting people's lives in different ways by being ambiguous and vague and how we can convert a given legal contract into a smart legal contract and leverage the blockchain technology to make the work efficient and effective.

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