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# Smart Contract Templates: foundations, design landscape and research directions

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## Abstract

In this position paper, we consider some foundational topics regarding smart contracts (such as terminology, automation, enforceability, and semantics) and define a smart contract as an automatable and enforceable agreement. We explore a simple semantic framework for smart contracts, covering both operational and non-operational aspects, and describe templates and agreements for legally-enforceable smart contracts, based on legal documents. Building upon the Ricardian Contract, we identify operational parameters in the legal documents and use these to connect legal agreements to standardised code. We also explore the design landscape, including increasing sophistication of parameters, increasing use of common standardised code, and long-term research.

## 1 Introduction

The aim of Smart Contract Templates [2] is to support the management of the complete lifecycle of “smart” legal contracts. This includes the creation of legal document templates by standards bodies and the subsequent use of those templates in the negotiation and agreement of contracts by counterparties. They also facilitate automated performance of the contract and, in the event of dispute, provide a direct link to the relevant legal documentation.

The templates and agreements may (or may not) be nistic to the method by which a contract is automated – that is a design choice for the template issuer, counterparties, network, etc. Smart legal contracts could potentially be implemented as software agents operating on a wide range of technology platforms, including distributed ledger platforms such as AxCore [1], Corda [3], Digital Asset Platform [5], Ethereum [6], and Fabric [11].

Here we aim to make a practical contribution of relevance to financial institutions. We consider how contracts are written, how they are enforced, and how to ensure that the automated performance of a contract is faithful to the meaning of the legal documentation. We discuss these issues using reasonably straightforward language, so that it is accessible not only to financial institutions but also to, for example, lawyers, regulators, standards bodies, and policy makers. We hope that the issues and views raised in this paper will stimulate debate and we look forward to receiving feedback.

**Acknowledgements:** We would like to thank Clive Ansell (ISDA), Ian Grigg (R3) and Darren Jones (Barclays) for their helpful feedback.

## 2 Foundations

To lay the foundation for subsequent discussion, we elaborate four key topics of terminology, automation, enforceability, and semantics.

### 2.1 Terminology — “smart contracts”

In [16], Stark gives an overview of the two different ways that the term “smart contract” is commonly used:

1. The first is operational, involving software agents, typically but not necessarily on a shared ledger. The word “contract” in this sense indicates that these software agents are fulfilling certain obligations and exercising certain rights, and may take control of certain assets within a shared ledger. There is no consensus on the definition of this use of the term “smart contract” — each definition is different in subtle ways [17, 18, 19]. Stark renames these agents as *smart contract code*.
2. The second focuses on how legal contracts can be expressed and implemented in software. This therefore encompasses operational aspects, issues relating to how legal contracts are written and how the legal prose should be interpreted. There are several ideas and projects which focus on these aspects such as CommonAccord [4], Legalese [13], Monax’s dual integration [12], and the Ricardian Contract [7]. Stark renames these as *smart legal contracts*.

Given that there is no clear consensus on the terminology being used, it is important that we should be clear in this paper. We prefer that the term “smart contract” should cover both versions, so we adopt a higher-level definition based on the two topics of automation and enforceability (that are explored in depth in sections 2.2 and 2.3):

***A smart contract is an automatable and enforceable agreement. Automatable by computer, although some parts may require human input and control. Enforceable either by legal enforcement of rights and obligations or via tamper-proof execution of computer code.***

This definition is sufficiently abstract to cover both “smart legal contracts” (where the agreement is a legal agreement, at least some of which is capable of being implemented in software) and “smart contract code” (which is automated software that may not necessarily be linked to a formal legal agreement). It simply states a requirement that the contract must be enforceable without specifying *what* is the aspect being enforced; for smart legal contracts these might be complex rights and obligations, whereas for smart contract code what is being enforced may simply be the actions of the code.

We focus on smart legal contracts, with the expectation that they will be performed using smart contract code. Throughout the rest of this paper we also, for clarity, adopt Stark’s terms *smart contract code* and *smart legal contract*.

## 2.2 Automation

We say that a smart contract is “automatable” rather than that it is “automated” because in practice there may be parts of a legal agreement whose performance requires human input and control. However, to be a “smart contract” we require that some part of the agreement is capable of being automated (otherwise it is not “smart”).

Automation is generally accomplished by the use of one or more computers. The phrase “by electronic means” is a synonym. Our definition of smart contract does not require that this automation occurs on a shared ledger, though that is certainly a possible and even probable method.

As an example of how automation might be achieved using smart legal contracts, Grigg [9] presents the Ricardian Contract triple of “prose, parameters and code”.<sup>1</sup> The legal prose is linked via parameters (name-value pairs) to the smart contract code that provides automation. For example, a software agent might have been developed that will be instantiated on a shared ledger and, once initiated, will proceed to undertake various transfers of value in accordance with the legal prose. The parameters are a succinct way to inform the code of the final operational details.

The code in this case would be suitable for a specific platform but we can imagine in the future that multiple platforms could be targeted from a single contract.<sup>2</sup>

## 2.3 Enforceability

Given a smart contract must be “enforceable” [15], what are the elements that must be enforced? And how? First we consider *what* must be enforced:

### 2.3.1 What to enforce

What needs to be enforced is different for smart contract code and smart legal contracts:

- For ***smart contract code***, the key requirement is that the code should run successfully and accurately within a reasonable time. If the technology platform is in complete control of all of the actions of the smart contract code then these actions should occur faithfully and without undue delay. Things that could go wrong (and therefore require “enforcement”) include technical issues within the platform and issues that take place outside of the platform — an obvious example would be the physical delivery of goods.
- For ***smart legal contracts***, things can be considerably more complex. Typically a legal contract would include rights and obligations that accrue to the different parties and are legally enforceable. These are often expressed in complex, context-sensitive, legal prose and may cover not just individual actions but also time-dependent and sequence-dependent sets of actions. There may also be overriding obligations on one or more of the parties such that a *lack* of action could be deemed to be a wrong-performance or non-performance of the contract.

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<sup>1</sup>[https://en.wikipedia.org/wiki/Ricardian\\_Contract](https://en.wikipedia.org/wiki/Ricardian_Contract)

<sup>2</sup>This could be achieved by, for example, using the list of parameters to connect the legal prose to a *set* of smart software agents, e.g. one agent per platform.

### 2.3.2 How to enforce

Enforcement might be achieved via traditional or non-traditional methods:

- **Traditional** means of enforcement include a variety of dispute resolution methods such as binding (or non-binding) arbitration, or recourse to the courts of law. There is an established body of law, and the methods by which parties can resolve disputes are well known. For illegal acts, courts are for example empowered (to different extents, according to jurisdiction) to impose fines, sequester assets, or deprive the wrong-doer of liberty. For disputes relating to contracts, the courts have extensive experience of adjudicating on issues of contract wrong-performance and non-performance, of awarding damages or other reliefs as appropriate, and in some cases assisting in the enforcement of payment of damages.
- **Non-traditional** methods of enforcement may also be imagined. For example, there is currently debate and experimentation on enforcing the actions of smart contract code at a network level without the need for dispute resolution. This is a fundamentally different notion of enforcement that is often expressed in terms of “tamper-proof” technology, with the assumption that in a perfect implementation of the system wrong-performance or non-performance become impossible.

“Tamper-proof” technology is typically described in terms of distributed networks of computers that are unstoppable and in a technological sense cannot fail regardless of malicious acts, power cuts, network disruption, natural catastrophies or any other conceivable event. For example, a “permissionless” shared ledger might make use of tamper-proof technology. Swanson [18] gives a good overview of many of the complex issues that arise with permissioned and permissionless distributed consensus systems. With such a system, it is assumed that a software agent, once started, could not be stopped. For truly “unstoppable” software agents, code must be defined to take the appropriate action in response to various dynamic states that might occur (such as another party defaulting on a required payment). In a truly unstoppable “tamper-proof” version of the system, all such possibilities would have to be anticipated and appropriate actions determined in advance.

Although some groups are actively pursuing tamper-proof smart contract code, our preference is for smart legal contracts that are enforceable by traditional legal methods for reasons including:

- In a system with enforcement by tamper-proof network consensus, there would be no “executive override” provisions. Agreements, once launched as smart contract code, could not be varied. But it is common for provisions of an agreement to be varied dynamically — for example, to permit a client to defer paying interest, or to permit a payment holiday, or to permit the rolling-up of interest over a period. Unless every possible variation is coded in advance, none of this would be possible in a tamper-proof system.
- Enforcement by network consensus can only apply to the fulfilment of obligations, or the exercising of rights, that are under the control of the network. However, objects and actions in the physical world are unlikely to be under full (if any) control of the network.

- Mainelli and Milne [14] observe that smart contract code “that involved payments would require posting collateral to be completely automated. This locking-up of collateral would lead to a serious reduction in leverage and pull liquidity out of markets. Markets might become more stable, but the significant reduction in leverage and consequent market decline would be strongly resisted by market participants.”

## 2.4 The semantics of contracts

Part of our remit is to consider the semantics of a contract — i.e. what is the “meaning” of a contract? We view a legal contract as having two aspects:

1. The ***operational aspects***: these are the parts of the contract that we wish to automate, which typically derive from consideration of precise actions to be taken by the parties and therefore are concerned with performing the contract.
2. The ***non-operational aspects***: these are the parts of the contract that we do not wish to (or cannot) automate.

We may approach the semantics of these two aspects of the contract in different ways. For example, with the operational aspects we may wish to compare a semantic analysis of the contract with a semantic analysis of the computer code — if it were possible to develop a proof for semantic equivalence<sup>3</sup>, this could be used early in the development lifecycle to increase confidence and reduce testing and debugging effort. By contrast, for the non-operational aspects of the contract we may wish to conduct a range of different semantic analyses — e.g. to analyse different forms of risk associated with a contract.

A contract may comprise several documents, and the process by which these documents are agreed may be complex. The semantics of the non-operational aspects of even quite straightforward contracts can be very large and complex, yet by contrast the semantics of the operational aspects might be simple and easily encoded for automation.

The operational aspects of a contract would typically dictate the successful performance of the contract to completion. If a dispute arises, then the non-operational aspects of the contract would typically dictate what happens next — i.e. in the context of the rights and obligations of the parties, the specification of what remedies shall be applied in the case of contract partial-performance or non-performance by one party.

The greater part of a legal contract may often be devoted to defining the rights and obligations of the parties in the event of a problem. Sometimes, the actions to be taken in case of material breach of contract are expressed precisely; however, this is not always the case and dispute resolution may require a protracted process of negotiated settlement, arbitration, or court proceedings.

Furthermore, it is important to understand the role of law. A lawyer would read and understand the contract *in the context of* the governing law — i.e. each legal document must be interpreted according to the relevant law (corporate law, consumer law, etc.) of its stated or inferred jurisdiction, and therefore the semantics of that law must also be understood. It should be noted that the issue of law relates not only to the non-operational aspects but also to the operational aspects — for example, trading with certain countries may be illegal due to government-imposed sanctions.

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<sup>3</sup>Approaches to formal semantics include, for example, denotational semantics and operational semantics.

Given this semantic framework for the legal contracts that underpin financial instruments, we can derive a different perspective of smart contracts:

- smart contract code focuses exclusively on automation by computer and therefore concerns itself only with performing those *operational aspects* that are expressed in the code, whereas
- smart legal contracts consider both the operational and non-operational aspects of a legal contract, some of whose operational aspects must then be automated (presumably by smart contract code).

This idea was previously expressed in a slightly different way by Grigg [8], displayed as a chart where the y-axis was denoted the “Ricardian axis” of increasing semantic richness (i.e. increasingly capturing the semantics of the legal prose) and the x-axis was the “Smart axis” of increasing performance richness (primarily concerned with the execution of smart contract code): see Figure 1. Both are important, yet they are orthogonal issues and with appropriate interfacing developments can potentially proceed along both axes simultaneously.

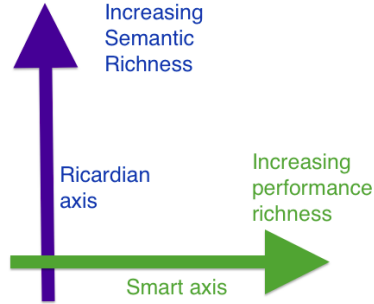


Figure 1: From Grigg [8], the y-axis represents an increasing ability to capture the semantics of a smart legal contract, whereas the x-axis represents the increasing performance of smart contract code.

### 3 Smart Contract Templates

Smart Contract Templates provide a framework to support complex legal agreements for financial instruments, based on standardised templates. Following Grigg’s Ricardian Contract triple [9], they use parameters to connect legal prose to the corresponding computer code, with the aim of providing a legally-enforceable foundation for smart legal contracts.

Complex sets of legal documentation can be augmented with the identification of operational parameters that are key to directing the behaviour of the smart contract code (in this paper we call these “code parameters”) — the smart contract code is assumed to be *standardised* code whose behaviour can be controlled by the input of such parameters.

Here we explore the design landscape for the implementation of Smart Contract Templates. We observe that the landscape is broad and that there are many potentially viable sets of design decisions.

### 3.1 Templates and Parameters

A template is an electronic representation of a legal document as issued by a standards body — for example, by the International Swaps and Derivatives Association (ISDA). As illustrated in Figure 2, a template contains both legal prose and parameters, where each parameter has an identity (a unique name), a type, and may (but need not) have a value.

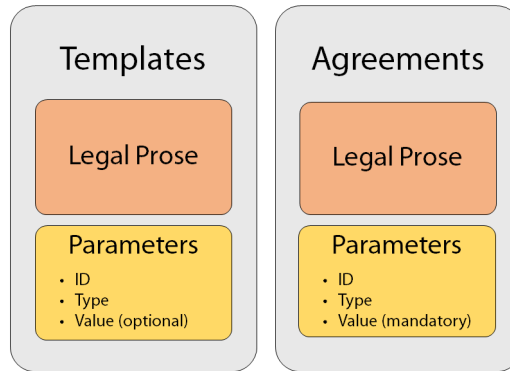


Figure 2: A template may contain both legal prose and parameters. Each parameter has an identifier (a name), a type, and an optional value. Agreements are derived from templates, and both the legal prose and parameters may be customised during negotiation. Values are mandatory for all parameters in a signed agreement.

An agreement is a fully-instantiated template (including any customised legal prose and parameters). The customisation of legal prose and parameters at this stage is commonplace and results from negotiation between the counterparties. The legal prose of an agreement will be derived from that of the template, but need not be identical, and similarly the parameters of the agreement will be derived from the template but need not be identical. It is also common for agreements to comprise multiple documents such as framework agreements (e.g. a Master Agreement) with various annexes (e.g. a Schedule) and credit support documentation (e.g. a Credit Support Annex).

Deriving the set of code parameters may be complicated by three factors:

1. It is common for parameters to be embedded in the legal prose — such parameters would initially be identified visually, aided by a graphical user interface.
2. Some of the values identified as “parameters” in the agreement (or template) may not have an operational impact and therefore would not be passed to the smart contract code.
3. It is possible for a parameter to be defined (given a name) in one document, given a value in a second document, and used (e.g. in business logic) in a third document.

Although parameters need not have values in a template, they must have values in a signed agreement. All of an agreement’s parameter values are a critical part of the contract as they directly reflect the business relationship between parties and those that are code parameters influence the automated operation of the contract.



## 3.2 The design landscape for Smart Contract Templates

In this section, we consider the possible areas for future development of Smart Contract Templates. We do this by considering three areas of development relating to: (i) the sophistication of parameters, (ii) the standardisation of code, and (iii) long-term research.

### 3.2.1 Increasing the sophistication of parameters

Most parameters in existing templates have simple types, such as date, number, etc. These are “base” or “primitive” types<sup>4</sup> and, as an example, Figure 3 illustrates the identification of a date in a master agreement; once highlighted and annotated, the name (“Agreement Date”), type (“Date”) and value (“16-Mar-2016”) of this parameter will be passed to the code.

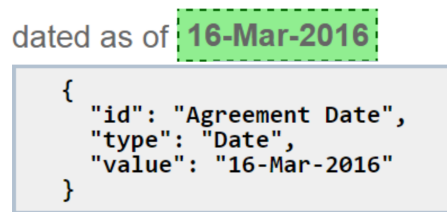


Figure 3: From a Barclays demonstration of Smart Contract Templates: an editor permits a date in the legal prose to be highlighted, and then annotated to denote a simple parameter. The parameter has a name “Agreement Date”, type “Date” and value “16-Mar-2016”.

It is not necessary for parameters to be restricted to base types. It is very likely that values of more complex types, such as lists, will also need to be transferred to the code.

The passing of parameters to the code is necessary because of the desire to use *standardised* code. The number of parameters, and the complexity of the types of those parameters, will typically increase as the code becomes more generic.

Beyond parameters with base types and more complex types such as lists, parameters can also be expressions containing references to other parameter names. Unless those other parameter names are defined within the expression, the expression is effectively a function. Where a function is passed as a parameter, this is known as a “higher-order” parameter and the receiving code is known as a “higher-order” function.<sup>5</sup>

An example of a higher-order parameter is illustrated in Figure 4 where some business logic in the legal prose has been highlighted and annotated to be a parameter with name “DailyInterestAmount” of type “Expression”<sup>6</sup> and with a value that is an encoding of the business logic in a format that is easily understandable by a computer. This business logic refers to three things whose values are unknown. The first two are simple: “the amount of cash in such currency on that day” (in the expression this is called CashAmount), and “the relevant Interest Rate in effect for that day” (in the expression this is called InterestRate). The third occurs in the phrase “in the case of pounds sterling”, which requires some analysis to determine that it is referring to the prevailing currency (hence the name Currency used

<sup>4</sup>[https://en.wikipedia.org/wiki/Data\\_type](https://en.wikipedia.org/wiki/Data_type)

<sup>5</sup>[https://en.wikipedia.org/wiki/Higher-order\\_function](https://en.wikipedia.org/wiki/Higher-order_function)

<sup>6</sup>In a conventional type system this expression would have an associated function type such as: (Decimal, Decimal, Currency) -> Decimal

in the expression) and that the normal abbreviation for pounds sterling is “GBP”. Since this expression contains three parameter names whose values are unknown, it will be stored in the set of code parameters as a function taking three arguments (CashAmount, InterestRate, and Currency) and returning a numeric value that is the result of the expression.

(x) the amount of cash in such currency on that day; multiplied by  
 (y) the relevant Interest Rate in effect for that day; divided by  
 (z) 360 (or, in the case of pounds sterling, 365)

```
{
  "id": "DailyInterestAmount",
  "type": "Expression",
  "value": "(CashAmount * InterestRate) / (if Currency == 'GBP' then 365 else 360)"
}
```

Figure 4: From a Barclays demonstration of Smart Contract Templates: an editor permits business logic from the legal prose to be highlighted, and then annotated to denote a higher-order parameter. The parameter has a name “DailyInterestAmount”, type “Expression”, and value corresponding to an arithmetical expression.

When business logic is converted into an expression this may involve the creation of new parameter names (e.g. a new name for the expression itself, and for unknown quantities). Sometimes the business logic may refer to a name that is already defined as a parameter, and sometimes it may refer to a value provided by an “oracle” — i.e. a value, such as an interest rate, that is provided from a trusted source of data and is available to the code while it is running.

The use of parameters may not only support greater standardisation of code. In the far future, we may see an increasing use of a formally structured style of expression embedded in legal prose; if all business logic in legal prose could be replaced with arithmetical or logical expressions, such as the higher-order parameters discussed in the previous paragraph, this should lead to reduced ambiguity in legal prose and fewer errors. The adoption of formal logic into legal prose would require such formal constructs to gain acceptance in the courts and to be admissible as evidence of the intentions of the parties.

Figure 5 illustrates how the sophistication of parameters and their role in Smart Contract Templates may evolve in the future.

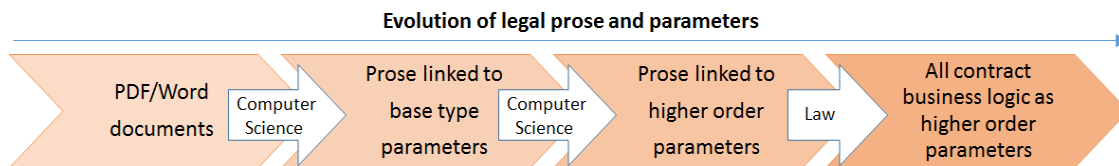


Figure 5: Parameters may become more sophisticated in the future, evolving from just simple base type parameters to also include more complex higher-order parameters. In the far future, if the encoding of business logic used in the parameters becomes acceptable to lawyers and admissible in court, then it could potentially replace the corresponding legal prose.

### 3.2.2 Increasing the use of common standardised code

In the previous subsection, we observed that the passing of parameters to smart contract code is necessary because of the desire to use *standardised* code. This is important for efficiency reasons as different smart contract code would otherwise have to be built, tested, certified and deployed for *every* different trade. The effort is reduced if such code can be standardised with parameters being passed to each invocation of that code.

This drives a desire for greater genericity of code, which can be enabled by passing more parameters, and/or more sophisticated parameters (with more complex types). Yet there remains the problem that each bank currently manages its own distinct codebases. If smart contract code could be *common* (i.e. *shared*) then it could be built, tested and certified once — and then utilised by every counterparty.

We envisage that the potential economic benefits of using common (shared) code will drive greater adoption in the future. One possible evolutionary route could build upon the use of common utility functions — programs that are already very nearly identical in all counterparties. As the potential economic benefits become clearer and the supporting technologies mature, the size and importance of such common code could increase until, eventually, common business logic may become standardised smart contract code. Figure 6 illustrates how the sharing of code may evolve in the future.

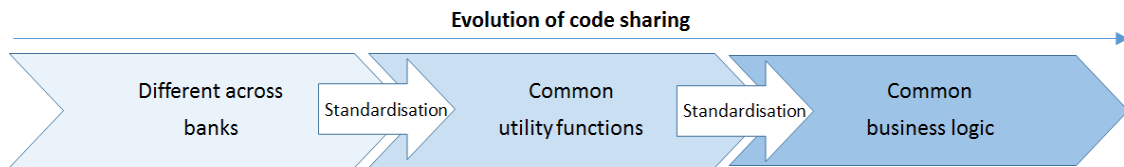


Figure 6: Code may become more standardised in the future through increased sharing, evolving from different codebases across banks to greater adoption of common utility functions to common business logic.

### 3.2.3 Long-term research challenges

Several research challenges concerning smart contracts, shared ledgers, and blockchains are currently being explored in academia. Financial institutions are providing input and inspiration by highlighting relevant business challenges in technology and operations. A good example is the potential to increase straight-through processing. Currently, lawyers draft legal contracts, which are then negotiated and changed by possibly other teams of lawyers, and then operations staff inspect the contract documents and/or other materials<sup>7</sup> to identify the parameters that are then passed to code that may have been written some time ago.

This raises several issues:

- Can we be absolutely certain of the meaning of the contract? Are all parties truly agreed on the meaning of the contract, or do they instead each have a subtly different understanding of what the contract means?

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<sup>7</sup>Other supporting materials may include confirmations, emails, facsimiles, telephone recordings etc.

- Can we be certain that *all* code parameters have been identified, and that each is operationally relevant? And can we be certain that their names, types and values have been faithfully transcribed?
- After the parameters have been passed to the code, and the code runs, can we be certain that the code will be faithful to the semantics of the operational aspects of the contract? And will it do so under all conditions?

A possible solution would be to develop a formal language in which to write legal documents — i.e. contract documents — such that the semantics would be clear and the code parameters could automatically be identified and passed to standardised code (alternatively, new code could be generated). This formal language would:

1. derive a number of important qualities from well-designed computer programming languages, such as a lack of ambiguity, and a compositional approach where the meaning of any clause can be clearly deduced without reading the rest of the document; and
2. be simple and natural to use, to such an extent that a lawyer could draft contracts using this formalism instead of using traditional legal language.

The former aspect has already received considerable attention in academia (see survey in [10]) and beyond (e.g. the open-source Legalese project). In contrast, the latter aspect is likely to be by far the greater challenge.

Another challenge is whether such a contract, written in a computer-like language, would be admissible in court as a true and faithful representation of the intentions of the parties. Issues of signature and tamper-evident documents are easily solved, yet whether a court would accept the definitions of the meanings of phrases in such a contract is not immediately clear.

As illustrated in Figure 7, this problem could be solved in two ways:

1. Initially, the language could generate a document version of the contract in a more “natural” legal style, with the expectation that this document would be admissible in court.
2. Eventually, further research in domain-specific languages and law could result in a new formalism itself being admissible in court.

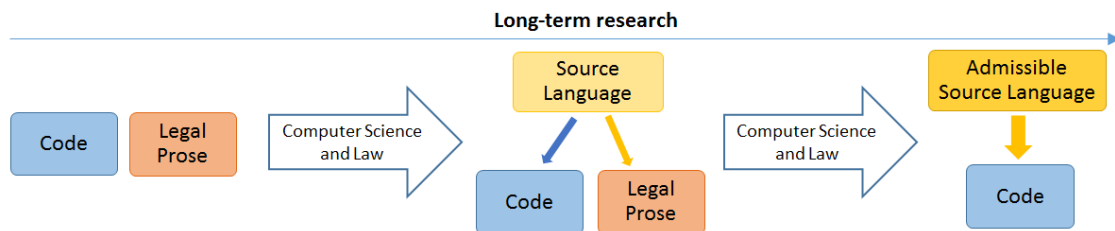


Figure 7: Long-term research may lead from existing separate code and legal prose to source languages which can be automatically translated into both code and legal prose, with the prose being admissible in court. Even longer term research could result in formal languages which themselves are admissible in court. Note, this figure omits parameters for clarity.

### 3.2.4 Future developments and initial requirements

The areas of future development described in the preceding sections are brought together in Figure 8, illustrating the potential evolution of aspects of legally-enforceable smart contracts.

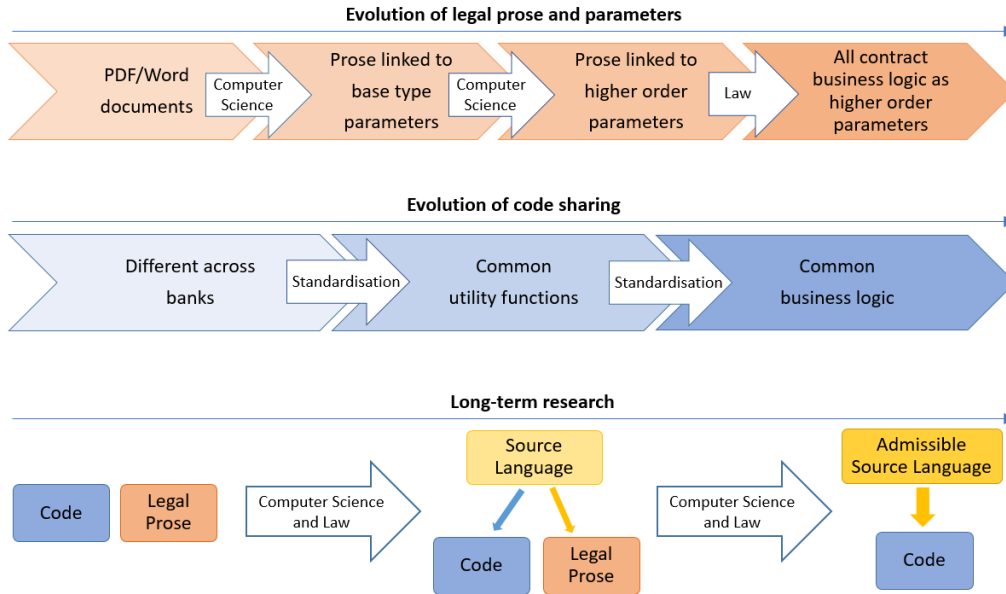


Figure 8: Potential evolution of aspects of legally-enforceable smart contracts in three streams: legal prose and parameters, code sharing and long-term research.

This complexity motivated us to sketch the following initial set of requirements for the design landscape of storage, processing and transmission of smart legal contracts:

- support both legal prose and parameters;
- support structured data formats such as XML, FpML, etc.;
- support the instantiation of multiple agreements from a single template;
- permit parameters to be defined in one document, given a value in a second document, and used in a third document;
- support contracts that comprise multiple documents;
- support a wide range of parameter types, including higher-order parameters in future;
- support the extraction of code parameters for transmission to the smart contract code;
- support increasing standardisation and sharing of common code;
- support increasing automation of, and interaction between, legal prose and code;
- support multiple execution platforms;
- support Ricardian Contracts (and therefore, for example, support digital signing of contracts and the construction of a cryptographic hash of the contract).

We aim to report on progress in a subsequent paper, including essential requirements and design options of potential formats for the storage and transmission of smart legal contracts.

## 4 Summary and Further Work

### 4.1 Summary

This paper has considered four foundational topics regarding smart contracts: terminology, automation, enforceability, and semantics. We defined a smart contract as an automatable and enforceable agreement. We viewed legal contracts within a simple semantic framework based on two key aspects: one being the operational aspects concerning automation of the contract and another being the non-operational aspects. We then described templates for legally-enforceable smart contracts as electronic representations of legal documents containing prose and parameters (with each parameter comprising an identifier, a type and an optional value). Agreements are then fully-instantiated templates, including customised legal prose and parameters. By selecting the appropriate smart contract code, this approach results in the creation of Ricardian Contract triples.

We then explored the design landscape: increasing the sophistication of parameters to complex higher-order types and business logic that could be admissible in court and potentially replace the corresponding legal prose. We also explored increasing the use of common standardised code through greater sharing, evolving from different codebases across banks to broader adoption of common utility functions to common business logic. Additionally, long-term research was outlined which could lead to source languages which can be automatically translated into both code and legal prose; even longer term research could result in formal languages which themselves are admissible in court.

### 4.2 Further Work

A benefit of looking to the future is that it helps to identify a potential roadmap for applying research within industry. Smart Contract Templates have already demonstrated a way to link *standardised agreements* to *standardised code* and so, in the near term, it may be possible to utilise them with existing infrastructure. In the longer term, they could be utilised on shared ledgers.

We are continuing to collaborate broadly, including via trade associations such as ISDA and FIA, on exploring formats for the storage and transmission of smart legal agreements comprising legal prose and parameters. Of particular interest are the corresponding essential requirements and design options, including the possibility of extending the scope of existing data standards such as FpML (Financial products Markup Language) for derivatives.

There are many open questions for the future. We have explored some of these questions in this paper, but we will end with one more: is it possible to provide straight-through-processing of financial contracts, with full confidence in the fidelity of the automated computer code to the entire semantics of the contract? This, of course, will require substantial work and collaboration by the financial services industry, standards bodies, academia<sup>8</sup>, and lawyers.

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<sup>8</sup> For example, further investigation of contract semantics and the specification language CLACK is being pursued at University College London.

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