



PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE
ESCUELA DE INGENIERÍA

REMATCH: A NOVEL REGEX ENGINE FOR FINDING ALL MATCHES

NICOLÁS ANDRE VAN SINT JAN CAMPOS

Thesis submitted to the Office of Research and Graduate Studies
in partial fulfillment of the requirements for the degree of
Master of Science in Engineering

Advisor:

CRISTIAN RIVEROS

Santiago de Chile, October 2023

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To my parents.

ACKNOWLEDGEMENTS

Write in a sober style your acknowledgements to those persons that contributed to the development and preparation of your thesis.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	iv
LIST OF FIGURES	vi
LIST OF TABLES	vii
ABSTRACT	viii
RESUMEN	ix
1. INTRODUCTION	1
2. REQL: A REGEX QUERY LANGUAGE FOR IE	4
2.1. Documents and spans	4
2.2. Syntax	5
2.3. Semantics	6
2.4. Comparison with RegEx and Document Spanners	10
3. CHAPTER 2	12
3.1. Figures and Tables	12
3.2. Equations	13
4. CONCLUSIONS	14
REFERENCES	15
APPENDIX	17
A. First Appendix	18
B. An Interesting Short Story	19

LIST OF FIGURES

2.1	A sample document for illustration purposes.	5
2.2	Document containing a sentence from the book “What is a man?” by Mark Twain.	9
3.1	Monkey selfie	12

LIST OF TABLES

2.1	The inductive semantics of REQL queries.	7
3.1	Parameters Aliev-Panfilov	12

ABSTRACT

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Keywords: thesis template, document writing, **(Write here the keywords relevant and strictly related to the topic of the thesis).**

RESUMEN

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Palabras Claves: plantilla de tesis, escritura de documentos, **(Colocar aquí las palabras claves relevantes y estrictamente relacionadas al tema de la tesis).**

1. INTRODUCTION

Regular expressions, or RegEx, are one of the most used technologies for managing text data. The development of RegEx engines started in the early 70s (Thompson, 1968; Johnson, Porter, Ackley, & Ross, 1968), and they are now a common part of many complex information systems such as compilers, databases, or search engines. Moreover, modern RegEx engines are highly-optimized systems that are crucial for finding patterns in diverse areas like biology (Navarro & Raffinot, 2005), literature (Dorosz & Szczerbinska, 2009), or medicine (Flores, Figueroa, & Pezoa, 2021).

Given a regular expression and a document, the task of a RegEx engine is to find all occurrences, or *matches*, of the pattern in the document. For this, RegEx engines deploy the so-called *leftmost-longest* paradigm (IEEE & Group, 2018), meaning that they find the match which is the leftmost one, and from there they find the longest possible match. The process is then repeated starting from the rightmost position of the previous match¹. For example, if we want to evaluate the RegEx `aa` over the document $a_0a_1a_2a_3$ (here the subindices are for referencing positions; the document consists of the letter a repeated four times), a typical RegEx engine will output the matches a_0a_1 and a_2a_3 . In particular, RegEx engines will not output a_1a_2 since the first leftmost-longest match ends with a_1 .

The leftmost-longest semantics is standard for RegEx engines, as it captures the majority of meaningful matches, although not all of them. However, in some scenarios adopting an “all-match semantics” is a valuable and desirable feature for the users. For instance, in DNA analysis we will often need to match patterns (called motifs) onto a DNA sequence, and these can overlap. The question of finding overlapping matches with RegEx is also recurrent in user discussions (*How to find overlapping matches with a regexp?*, 2013; *How can I match overlapping strings with regex?*, 2014; Srivastava, 2017). For information extraction, the all-match semantics leaves freedom to the user to extract all positions, called

¹Although RegEx engines follow different matching rules, the leftmost-longest rule is at the core of most modern engines. For a detailed discussion see (Friedl, 2006).

spans, where there is relevant information in a document. Therefore the all-match semantics is a desirable feature for RegEx engines that, to the best of our knowledge, no engine supports natively.

To overcome the problem of finding all-matches, RegEx engines offer look-around operators, namely, operators that allows checking if a subexpression can be matched forward or backward from the current position, without advancing from the current position. For instance, by using look-around, we can modify the expression aa to $(?=(aa))$ and find the missing match a_1a_2 over the above document. Despite this example, look-around operators cannot discover all matches for every RegEx expression. For instance, given the look-around definition, one cannot extract two matches that start at the same position (for concrete examples see Section 2 and Section ??).

In terms of implementation, RegEx engines are usually divided into three categories: DFA-based, NFA-based, and recursive NFA-based (Regular expression matching can be simple and fast (but is slow in java, perl, php, python, ruby,...), 2007). DFA is generally the fastest evaluation strategy, followed by (plain) NFA. In contrast, recursive NFA-based engines use backtracking, which is susceptible to well-documented performance issues, like regular expression denial of service attacks (ReDos) (Friedl, 2006), where the engine can exhibit exponential time performance (Regular expression matching can be simple and fast (but is slow in java, perl, php, python, ruby,...), 2007). From the positive side, recursive NFA-based engines have the advantage of keeping track of the evaluation, which allows implementing operators like look-around and back-references. In summary, until now, the only way of finding all matches (in some cases) is by using look-around operators implemented by recursive NFA-based engines, which suffer from unfortunate performance issues.

To overcome these issues, this thesis presents REMatch, a RegEx engine supporting the all-match semantics, and its accompanying regular expression language REQL. Contrary to the status quo of RegEx evaluation, REMatch is based on a new evaluation strategy, inspired by the theory of enumeration algorithms (Segoufin, 2013), that allows finding all

the matches, and avoids the exponential behavior of recursive NFA evaluation. Moreover, REmatch performance is comparable to popular RegEx engines, while at the same time finding all the matches, thus obtaining the best of both worlds. Specific contributions of the thesis are as follows:

- (i) We introduce the REQL query language, which extends classical RegEx with variables and the all-match semantics.
- (ii) We present REmatch, a RegEx system whose architecture allows evaluating REQL using output-linear delay. For this, we develop a new evaluation method which extends the theoretical algorithm of (Florenzano, Riveros, Ugarte, Vansummeren, & Vrgoc, 2020) and incorporates new optimization techniques, allowing REmatch to compete with modern RegEx engines.
- (iii) We develop a set of experiments to evaluate the effect of different optimizations on REmatch performance, and compare it to existing RegEx engines. Although REmatch uses a more general semantics, we show that its performance stacks well compared to other engines.

In Section 2 we introduce REQL. We then explain each module of the REmatch architecture (see Figure ??). Section ?? presents the rewriting module, Section ?? the filtering module, and Section ?? the output module. Section ?? explains the evaluation algorithm of REmatch. Section ?? puts all components together and displays the experimental comparison with other engines. We conclude in Section ?? by discussing possible future work.

2. REQL: A REGEX QUERY LANGUAGE FOR IE

This section introduces REQL, a RegEx Query Language for information extraction, that we implement in REmatch. The language is an extension of the classical RegEx syntax (e.g. POSIX Basic Regular Expressions) familiar to most users. On the other hand, the semantics is inspired by the document spanner framework (Fagin, Kimelfeld, Reiss, & Vansummeren, 2015) that captures all appearances of a pattern in the document.

In the following, we present the formal syntax and semantics of REQL, and provide several examples of REQL queries.

2.1. Documents and spans

We follow the theoretical framework of documents and spans introduced in (Fagin et al., 2015). For us, a document d is simply a string over some finite alphabet (e.g. the ASCII charset, UTF-8, or a similar encoding scheme)¹. We write $d = a_0a_1 \dots a_{n-1}$ to denote a document of length $|d| = n$ where a_i is the i -symbol (note that the first symbol starts from 0)². An example of a document is given in Figure 2.1. A *span* of a document d (also called a *match*) is a pair $s = [i, j\rangle$ of natural numbers i and j with $0 \leq i \leq j \leq |d|$. In that case, s is associated with the continuous region of the document d whose content is the substring of d from position i to position $j - 1$. We denote this substring by $d(s)$ or $d(i, j)$. For instance, $d_1([0, 4\rangle) = \text{that}$, since this is the content of the string d in positions 0 through 3. Notice that if $i = j$, then $d(s) = d(i, j) = \epsilon$, the empty string. Given two spans $s_1 = [i_1, j_1\rangle$ and $s_2 = [i_2, j_2\rangle$ such that $j_1 = i_2$, we define their *concatenation* as $s_1 \cdot s_2 = [i_1, j_2\rangle$. The set of all spans of d is denoted by $\text{span}(d)$.

¹Note that a multi-line document is simply a single string.

²In (Fagin et al., 2015), the first position is 1. We use 0 to be compliant with programming languages and RegEx engines which use 0 as the start position.

$$d_1 := \begin{array}{c} \text{t h a t h a t h a t} \\ \text{0 1 2 3 4 5 6 7 8 9} \end{array}$$

Figure 2.1. A sample document for illustration purposes.

2.2. Syntax

Syntactically, REQL is similar to standard regular expressions, apart from a special construct $!x\{e\}$, which states that a substring matching e should be stored into the variable name x . Formally, the syntax of REQL queries can be defined as follows:

$$\begin{aligned} e &:= a \mid . \mid [w] \mid [\sim w] \mid !x\{e\} \mid \\ &\quad ee \mid e|e \mid e^* \mid e^+ \mid e? \mid e\{n,m\} \end{aligned}$$

Here, a is a character (e.g., ASCII charset or UTF-8), the dot symbol is a wildcard for any character, and $[w]$ or $[\sim w]$ are a char class or the negation of a char class, respectively, where w declares a set of characters. We use the standard notation of ranges of ASCII characters found in POSIX for declaring char classes (e.g. $[a-z]$, $[A-Z0-9apt]$, etc) and write $\text{set}(w)$ to denote the set of characters represented by w (e.g. $\text{set}(a-z) = \{a, b, \dots, z\}$). Moreover, x is a variable name where the character $!$ is used to differentiate a variable name from a letter or string of the alphabet. This, along with the use of $\{$ and $\}$ for delimiting the captured subregex is the only special notation where we differ from POSIX. Finally, n and m are numbers such that $0 \leq n \leq m$. In the REmatch system, REQL also allow the usual regex abbreviations for character classes (e.g. $\backslash d$ for a digit, or $\backslash w$ for a word, etc), however, we do not include them in the formal definition in order to keep the presentation concise³.

Example 2.1. *To give a preliminary example of how REQL works, assume that we would like to extract all the occurrences of the word “that” from a text document. This can be done in REQL as follows:*

$$e0 := !x\{that\}$$

³We remark that the start-of-file symbol (\wedge) and end-of-file symbol ($\$$) are currently not supported in REmatch. However, adding them is a straightforward exercise.

Intuitively, the query captures the positions of a substring *that* into the variable x . This query also illustrates a key feature of our semantics (defined below): there can be overlapping matches. To make this more clear, consider the document d_1 in Figure 2.1. The query above will result in precisely three matches for the variable x , corresponding to the three occurrences of the substring *that* in the document we are processing. The first match will be in positions $[0, 4)$, the second in $[3, 7)$, and the last match in $[6, 10)$. We notice that the middle match $[3, 7)$ will not be captured by most regular expression tools, unless some sort of a look-around operator is used.

The reader could notice that the above syntax is so general that one can define the capture of the same variable multiple times. For instance, a query like $!x\{a!x\{b\}\}$ defines the capture of x twice. For this reason, REQL has some simple syntactic restrictions to use variables correctly. Let $\text{var}(e)$ be the set of all variables names used in e . We say that a REQL query is *well-designed*⁴ if every subquery e satisfies the following four conditions: (1) if $e = !x\{e_1\}$, then $x \notin \text{var}(e_1)$, (2) if $e = e_1 e_2$, then $\text{var}(e_1) \cap \text{var}(e_2) = \emptyset$; (3) if $e = e_1|e_2$, then $\text{var}(e_1) = \text{var}(e_2)$; and (4) if e is equal to e_1^* , e_1^+ , $e_1^?$ or $e_1\{n, m\}$, then $\text{var}(e_1) = \emptyset$. One can easily check that queries $!x\{a!x\{b\}\}$, $!x\{a\}!x\{b\}$, $a|!x\{b\}$, or $(!x\{a\}b)^*$ are not well-designed. Instead, queries like $!x\{a\}!y\{b\}$, $!x\{a\}!|x\{b\}$, or $!x\{a\}(b)^*$ do satisfy all conditions and then are well-designed. Note that, as shown in (Fagin et al., 2015), the well-designed condition does not diminish the query language’s expressive power. Then from now on, we will consider all the queries we evaluate to be well-designed.

2.3. Semantics

We define the matches extracted by REQL in terms of mappings. Formally, a *mapping* for a document d is a (partial) function μ from variables to spans of d . Intuitively, a mapping represents a single match that a REQL query makes on a document d . For instance, in our previous example, the query e_0 will produce three mappings as its output:

⁴In (Fagin et al., 2015), expressions satisfying these conditions are called *functional*.

$$\begin{aligned}
\llbracket e \rrbracket_d &= \{ \mu \mid (s, \mu) \in \llbracket e \rrbracket_d \} \\
\llbracket a \rrbracket_d &= \{ (s, \emptyset) \mid s \in \text{span}(d) \text{ and } d(s) = a \} \\
\llbracket \cdot \rrbracket_d &= \{ ([i, i+1], \emptyset) \mid 0 \leq i < |d| \} \\
\llbracket [w] \rrbracket_d &= \{ (s, \emptyset) \mid s \in \text{span}(d) \text{ and } d(s) \in \text{set}(w) \} \\
\llbracket [\hat{w}] \rrbracket_d &= \{ (s, \emptyset) \mid s \in \text{span}(d) \text{ and } d(s) \notin \text{set}(w) \} \\
\llbracket !x\{e\} \rrbracket_d &= \{ (s, \mu) \mid \exists (s, \mu') \in \llbracket e \rrbracket_d : d(s) \neq \varepsilon, \\
&\quad x \notin \text{dom}(\mu') \text{ and } \mu = \mu' \cup [x \rightarrow s] \} \\
\llbracket e_1 e_2 \rrbracket_d &= \{ (s, \mu) \mid \exists (s_1, \mu_1) \in \llbracket e_1 \rrbracket_d. \exists (s_2, \mu_2) \in \llbracket e_2 \rrbracket_d : \\
&\quad s = s_1 \cdot s_2 \text{ and } \mu = \mu_1 \cup \mu_2 \} \\
\llbracket e_1 | e_2 \rrbracket_d &= \llbracket e_1 \rrbracket_d \cup \llbracket e_2 \rrbracket_d \\
\llbracket e^* \rrbracket_d &= \llbracket \varepsilon \rrbracket_d \cup \llbracket e \rrbracket_d \cup \llbracket ee \rrbracket_d \cup \llbracket eee \rrbracket_d \cup \dots \\
\llbracket e^+ \rrbracket_d &= \llbracket e(e^*) \rrbracket_d \\
\llbracket e? \rrbracket_d &= \llbracket e \rrbracket_d \cup \{ ([i, i], \emptyset) \mid 0 \leq i \leq |d| \} \\
\llbracket e\{n, m\} \rrbracket_d &= \llbracket e \overset{\text{n-times}}{\dots} e(e?) \overset{(m-n)\text{-times}}{\dots} (e?) \rrbracket_d
\end{aligned}$$

Table 2.1. The inductive semantics of REQL queries.

μ_1 , with $\mu_1(x) = [0, 4]$, μ_2 , with $\mu_2(x) = [3, 7]$, and μ_3 , with $\mu_3(x) = [6, 10]$. We write $\text{dom}(\mu)$ to denote the domain of μ and $\mu_1 \cup \mu_2$ for the disjoint union of mappings whenever $\text{dom}(\mu_1) \cap \text{dom}(\mu_2) = \emptyset$. We also use the notation $[x \rightarrow s]$ to define the singleton mapping that only maps x to the span s (e.g., $\mu_1 = [x \rightarrow [0, 4]]$), and use \emptyset for the trivial empty mapping (where the domain is the empty set).

With the formalism of mappings, we can give a concise declarative semantics for REQL, similarly as in (Maturana, Riveros, & Vrgoc, 2018). This is done in Table 2.1. The semantics is defined by structural induction on e and has two layers. The first layer, $\llbracket e \rrbracket_d$, defines the set of all pairs (s, μ) with $s \in \text{span}(d)$ and μ a mapping such that (1) e successfully matches the substring $d(s)$ and (2) μ results as a consequence of this successful match. For example, the REQL query a matches all substrings of input document d equal to a , but results in only the empty mapping. On the other hand, $!x\{e\}$ matches all substrings that are matched by e , but assigns to x the *non-empty* span s that delimits the substring being matched, while preserving the previous variable assignments. Similarly,

in the case of concatenation $e_1 e_2$ we join the mapping defined on the left with the one defined on the right. Notice that these mappings will not share any variables, given that the expression is assumed to be well-formed. The second layer, $\llbracket e \rrbracket_d$, then simply gives us the mappings that e defines when matching the entire document. Note that when e is an ordinary regular expression (i.e., no variables), then the empty mapping is output if the entire document matches e , and no mapping is output otherwise.

In the following, we provide several examples from English text analysis to grasp the power of REQL for information extraction and to see its differences concerning classical RegEx. The reader can test these examples and other REQL queries in our REmatch beta demo available on www.rematch.cl.

Example 2.2. *A typical task in language analysis is detecting words with particular roots, or more precisely lexemes, which are basic units of meaning. For example, one could be interested in words in the English language that start with the prefix ‘a’. To extract all such words from a text, we can simply use the following REQL expression:*

$$e1 = _!word\{[Aa]\backslash w+\}[_.]$$

where $_$ denotes a single white space, and $\backslash w$ denotes the char class of words characters, as commonly used is Perl-compatible regular expressions. Note that in $[_.]$ the $.$ denotes the dot symbol and not a wildcard. This is consistent with the classic RegEx syntax, since a wildcard symbol is useless for defining a char class.

In $e1$ we are looking for a word staring with the letter ‘a’. To assure we will capture the entire word, we preceded it by a space, and we require that after reading it we see either a space or a dot symbol⁵. If we evaluate $e1$ over document d_2 in Figure 2.2, we will get four mappings assigning the variable *word* to the spans $[4,7)$, $[11,13)$, $[14,21)$, and $[22,31)$, representing the words “ant”, “an”, “amazing”, and “architect”, respectively.

⁵This example is for illustration purposes. The actual expression would allow arbitrary spacing and sentence punctuation, and allow matching the first word in the sentence.

$d_2 :=$	T	h	e		a	n	t		i	s		a	n		a	m	a	z	i	n	g		a	r	c	h	i	t	e	c	t	.
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Figure 2.2. Document containing a sentence from the book “What is a man?” by Mark Twain.

In classical RegEx, round parentheses denote a capture group for extracting a substring. That is, (R) will extract what is matched by the RegEx R . We could therefore try to express $e1$ from Example 2.2 by the expression: $\sqcup([Aa]\backslash w+)\sqcup[.]$ which replaces REQL’s capture variables with a capture group. However, when evaluated over the document d_2 in Figure 2.2, one fewer output will be produced; namely: the span $[14, 21)$ corresponding to the word “amazing” will be missing. This is due to leftmost-longest match semantics deployed by classic RegEx engines, which will consume the white space following the word “an”, therefore preventing the expression from matching “amazing”. A typical workaround for this problem is the use of *look-ahead operators*, which allow to check whether a string is present starting from some position. A RegEx expression equivalent to $e1$ would then be $\sqcup([Aa]\backslash w+)(?=[.])$ which upon matching a word will look-ahead for a space or a dot, without advancing with the current match. In general, using look-ahead operators is somewhat cumbersome, and, as we show below, is not sufficient to capture all the matches in some cases. In contrast, REQL supports the all-match semantics by default: it returns a match for *every* span in the document where the specified pattern occurs.

Example 2.3. Suppose that the user wants to process the English text into k -grams (i.e., k consecutive words in a text) that satisfy some particular pattern. Specifically, suppose this user wants to extract all 2-grams where each word begins with the letter ‘a’. We can extract them by running the following REQL query:

$$e2 := \sqcup!w1\{[Aa]\backslash w+\}\sqcup!w2\{[Aa]\backslash w+\}\sqcup[.]$$

Note that $e2$ is the extension of $e1$ where now we use two variable names, called $w1$ and $w2$, for obtaining the substrings of the first and second words, respectively. For instance,

if we run $e2$ over d_2 in Figure 2.2 we will get mappings:

$$[w1 \mapsto [11, 13], w2 \mapsto [14, 21]] \quad [w1 \mapsto [14, 21], w2 \mapsto [22, 31]]$$

representing the 2-grams “an amazing” and “amazing architect”.

Note that the previous query cannot be obtained by any RegEx engine without “look-arounds”, given that 2-grams can overlap.

Example 2.4. We end by showing another capacity of REQL for extracting contextual information, another feature not supported by RegEx. Suppose that, in addition to the 2-grams, the user wants to extract the sentence where the match happens. This additional information could be useful for understanding the context where these 2-grams are used. For this, we can modify our query $e2$ as follows:

$$e3 := \backslash . !sent \{ [^{\wedge} .] * _ !w1 \{ [Aa] \backslash w+ \} _ !w2 \{ [Aa] \backslash w+ \} (_ [^{\wedge} .] *) ? \backslash . \}$$

Here, the new variable *sent* will store the information containing the sentence where the 2-gram occurs. The reader can check that if we evaluate $e3$ over d_2 , then we will obtain the mappings of Example 2.3 where each mapping will have in addition the variable *sent* maps to $[0, 31]$, which represents the whole sentence. Interestingly, this semantics context of a match cannot be extracted by RegEx, even if we use look-ahead operators. The main issue for look-ahead operators is that due to the leftmost-longest semantics, no two matches starting at the same position can be returned, which is an issue in our case.

2.4. Comparison with RegEx and Document Spanners

As previously explained, we base REQL on RegEx syntax and the semantics of the Document Spanners framework. The purpose of reusing RegEx syntax is that users feel familiar with the query language and operators. However, as the previous examples show, the all-match semantics differs from the leftmost-longest semantics from classical RegEx.

Therefore, we introduce REQL as a new query language rather than presenting it as an extension of RegEx.

The class of regular expressions with extraction variables was first introduced by Fagin et al. (Fagin et al., 2015). Their framework is called Document Spanners, and it formalizes the process of extracting relations from text documents. We base REQL semantics on Document Spanners, although there are several differences. First, while Document Spanners are a theoretical tool for information extraction, REQL is a user-oriented query language with a programming syntax based on RegEx. Second, the semantics proposed in Document Spanners is anchored at the beginning and end of the document (like regular expressions in theory), where REQL is unanchored; namely, the query is evaluated anywhere in the document (similar to RegEx engines). Third, REQL semantics disallows capturing ε substrings (see $\llbracket !x\{e\} \rrbracket_d$ in Table 2.1), where Document Spanners allow this. We decided to remove ε -substring capturing since it is not very helpful for users, and its removal simplifies several optimization procedures in REmatch.

Comparing REmatch with classical RegEx engines, they both use classical operators and shortcuts, and match a substring from any position in the document, as opposed to the theoretical approaches to regular expressions. The main difference comes from capture variables and the all-match semantics. As we have seen, the combination of the two prevent simulating REQL’s capture variables in RegEx using capture groups. Similarly, all-match semantics lies outside of the scope of RegEx, since matches starting at the same position cannot be simulated even using the look-around operators. As a minimal example for this, consider the document $d = aaa$, and the REQL expression $e = !\{a^*\}$, which will produce six matches in this case, each one corresponding to a non-empty substring of d . On the other hand, using look-ahead will not help us to capture this in RegEx. The most obvious way would be to use an expression of the form $(?=(a^*))$, however, at position 0, only the match $[w1 \mapsto [0, 3]]$ will be produced, and, for example $[w1 \mapsto [0, 1]]$ will be omitted, since they both start at the same position.

3. CHAPTER 2

3.1. Figures and Tables

In Figure 3.1 we can see a selfie taken by a macaque.



Figure 3.1. This picture is not copyrighted

Blandit incorrupte quaerendum in quo, nibh impedit id vis, vel no nullam semper audiam. Ei populo graeci consulatu mei, has ea stet modus phaedrum. Inani oblique ne has, duo et veritus detraxit. Tota ludus oratio ea mel, offendit persequeris ei vim. Eos dicat oratio partem ut, id cum ignota senserit intellegat. Sit inani ubique graecis ad, quando graecis liberavisse et cum, dicit option eruditi at duo. Homero salutatus suscipiantur eum id, tamquam voluptaria expetendis ad sed, nobis feugiat similique usu ex.

And now, Table 3.1 shows some parameter for the Aliev-Panfilov model.

Table 3.1. Parameter values considered for the Aliev-Panfilov model of ionic current.

α	c_1	c_2	μ_1	μ_2	b	γ
0.05	52	8	0.1	0.3	0.25	0.002

There are 12 figures in order to show that the List of Figures works fine.

3.2. Equations

Finally, an equation

$$x^2 + 1 = 0 \tag{3.1}$$

We can notice that $x = \pm i$ are the solutions of Equation (3.1).

4. CONCLUSIONS

Nothing to say. Be happy.

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APPENDIX

A. FIRST APPENDIX

We can write equations here too:

$$\int_0^\infty e^{-x^2} dx \tag{A.1}$$

And more...

B. AN INTERESTING SHORT STORY

Let us enjoy reading this story of Hunting With The Lion.

It was a dry summer. The animals in the forest were beginning to find it difficult to get food.

A bear, a wolf and a jackal thought it would be better to join hands with a lion and do the hunting. They approached lion and he too agreed. The four of them went off hunting.

The hunting party came across a buffalo. The fox and wolf chased the buffalo. The bear intercepted the buffalo. The lion killed him.

The fox made shares out of the buffalo. When they were about to take their shares the lion roared and said, "Well friends, the first share is mine for my leadership. The second share is mine for, it is I who killed. The third share is also mine for I need it for my cubs. Anyone who needs a share can take the fourth. But before that you will have to win me."

All the three left the place without a single word.

MORAL : If you are might, you are right.