Encrypted Search

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Encrypted Search

- Searching against encrypted information
- Everything happens server-side
- Secure way of searching through ciphertex
- No client-side decryption
  - Encrypted search can be compatible with a cloud server

The Cloud

- Many new software releases today are cloud-based
- Email providers store their data in the cloud, allowing you to access it from any location
- Security is the main inhibitor of companies adopting cloud storage
  - If the cloud server is compromised, everybody's data is compromised at the same time

Client-side Decryption

- Wait until the client needs to access a particular item in the database before decrypting it

- Inefficient for large data sets due to complications with search

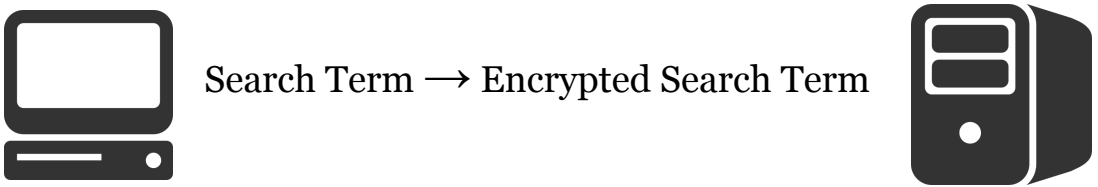
Encryption

- Every character in a character set (ASCII, Unicode, etc.) is assigned a “code point”
- This is a unique number used to identify the *character* (not the letter)
  - ASCII: ‘A’ = 65 ‘a’ = 97
- The code point is the starting point for any encryption algorithm

Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
0	00	Null	32	20	Space	64	40	@	96	60	`
1	01	Start of heading	33	21	!	65	41	A	97	61	a
2	02	Start of text	34	22	"	66	42	B	98	62	b
3	03	End of text	35	23	#	67	43	C	99	63	c
4	04	End of transmit	36	24	$	68	44	D	100	64	d
5	05	Enquiry	37	25	%	69	45	E	101	65	e
6	06	Acknowledge	38	26	&	70	46	F	102	66	f
7	07	Audible bell	39	27	'	71	47	G	103	67	g
8	08	Backspace	40	28	(	72	48	H	104	68	h
9	09	Horizontal tab	41	29	)	73	49	I	105	69	i
10	0A	Line feed	42	2A	*	74	4A	J	106	6A	j
11	0B	Vertical tab	43	2B	+	75	4B	K	107	6B	k
12	0C	Form feed	44	2C	,	76	4C	L	108	6C	l
13	0D	Carriage return	45	2D	-	77	4D	M	109	6D	m
14	0E	Shift out	46	2E	.	78	4E	N	110	6E	n
15	0F	Shift in	47	2F	/	79	4F	O	111	6F	o
16	10	Data link escape	48	30	0	80	50	P	112	70	p
17	11	Device control 1	49	31	1	81	51	Q	113	71	q
18	12	Device control 2	50	32	2	82	52	R	114	72	r
19	13	Device control 3	51	33	3	83	53	S	115	73	s
20	14	Device control 4	52	34	4	84	54	T	116	74	t
21	15	Neg. acknowledge	53	35	5	85	55	U	117	75	u
22	16	Synchronous idle	54	36	6	86	56	V	118	76	v
23	17	End trans. block	55	37	7	87	57	W	119	77	w
24	18	Cancel	56	38	8	88	58	X	120	78	x
25	19	End of medium	57	39	9	89	59	Y	121	79	y
26	1A	Substitution	58	3A	:	90	5A	Z	122	7A	z
27	1B	Escape	59	3B	;	91	5B	[	123	7B	{
28	1C	File separator	60	3C	<	92	5C	\	124	7C	|
29	1D	Group separator	61	3D	=	93	5D	]	125	7D	}
30	1E	Record separator	62	3E	>	94	5E	^	126	7E	~
31	1F	Unit separator	63	3F	?	95	5F	_	127	7F	□

Encrypted Search

- Send a search term “Text” to the server
  - Client side encrypts it, sends it to the server, the server searches through its database to find matches



- **Problem:** this will not return “text” or “TEXT” - Case sensitive; only exact matches

Normalization

- This problem would exist with non-encrypted search if not for normalization

- Remove capitalization, punctuation, etc.
  - “Jimmy’s” → “JIMMYS”

- When you send a server your search term, it normalizes the text and matches it against text in its database which has already been normalized when it was stored

Normalization

- Doesn’t work on encrypted text because once it’s encrypted there is no connection between the plaintext and the ciphertext
  - “text” = “VqnpDGjH” “Text” = “5g+UNPod”
- You would need to decrypt, normalize, then re-encrypt before you could search
- **Not possible on large data sets**

Related Work

- There is a solution to the case-sensitivity issue in the creation of an **encrypted index**

- This involves normalizing before encrypting, then encrypting each word separately to allow a search engine to scan through it

References: 1, 2, 3, 4, 5, 7, 8, 9

Other Things to Consider

- Perfecting algorithms
  - Ranked keyword search
  - Conjunctive keyword search
  - Fuzzy keyword search
  - Wildcard search

- Loss of security

Related Work

Ranked Keyword Search

- Record number of matched keywords in a message
- Order the search results by rank (e.g. sort by relevance)

References: 2, 3, 4, 9

Related Work

Conjunctive Keyword Search

- Take a string of words as search input
- Search each word individually (unless multiple words are enclosed by quotation marks) and give results based on the highest number of matched keywords
- Extension of ranked search

References: 3, 4

Related Work

Fuzzy Keyword Search

- Add support for common misspellings
  - Specifically one letter errors (add, drop, or replace)
- Will increase the size of the index, potentially by a huge amount
- Need to find a balance between functionality and the index's increase in size

References: 1

Related Work

CASTLE:

{AASTLE, BASTLE, … YASTLE, ZASTLE},
{CBSTLE, CCSTLE, … CYSTLE, CZSTLE},
{CAATLE, CABTLE, … CAYTLE, CAZTLE},
etc.

Related Work

- This particular method would add $n(25n + 1)$ letters to the index for every word of length n
- This example only accounts for character dropping and replacement (not addition)
- For a word of length 6, that's 906 additional letters to add to the index
- Obviously **not practical**, but this is what fuzzy keyword search is trying to accomplish

Related Work

Wildcard Search

- Search for any words that contain a specified set of letters
- ex. Searching “Cas*” will return “Castle” as well as any other words that start with “cas”

References: 1

Related Work

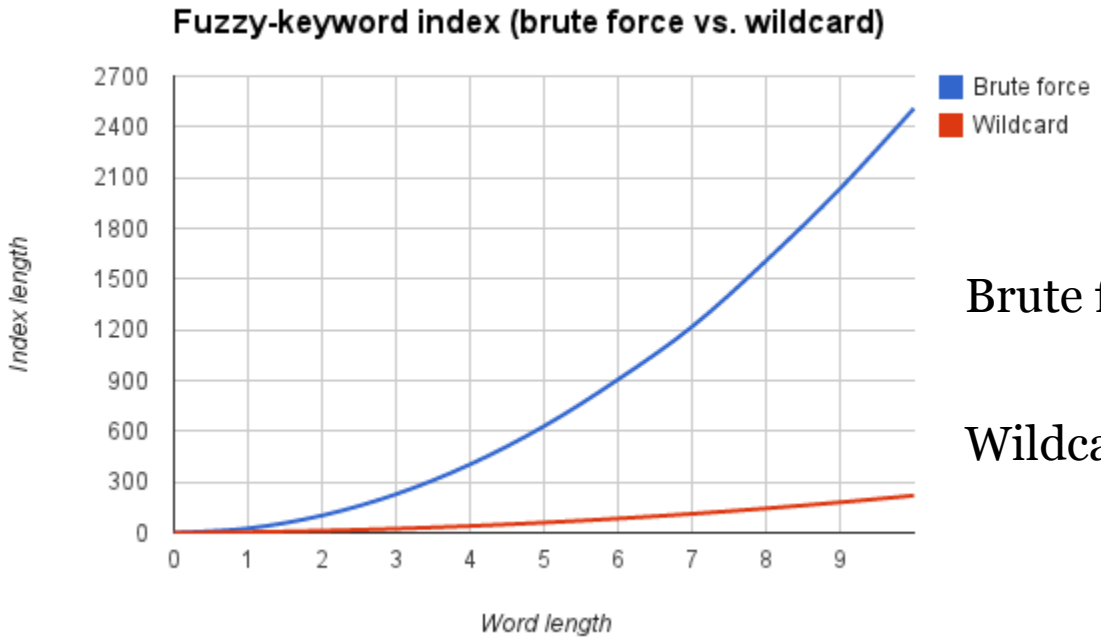
CASTLE:

CASTLE *CASTLE *ASTLE C*ASTLE
C*STLE CA*STLE CA*TLE CAS*TLE
CAS*LE CAST*LE CAST*E CASTL*E
CASTL* CASTLE*

Related Work

- Using just the previous method will increase the index by $n(2n+2)$ for every word of length n
- CASTLE, a word of length 6, would add 84 additional letters to the index
- While this isn't perfect, it does solve the problem with fuzzy keyword search

Related Work



Brute force: $n(25n + 1)$

Wildcard: $n(2n+2)$

Problem/Goals

The goal of this project is to combine case-insensitive search (encrypted index) and wildcard support to create a unique form of encrypted search

- It will also include other considerations for search algorithms, but the project will be successful if it can produce these two features

Solution

- First, scan through each word in the email and create a normalized index
  - Encrypt each word separately
  - Will consider case-insensitivity as well as ranked, conjunctive, and wildcard search

- Next, encrypt the body of the email message
  - Do this all as one string (will minimize information leakage)

Building the Index

Here is a sample email message.

Building the Index

Here is a sample email message.

HERE

Building the Index

Here is a sample email message.

HERE

Building the Index

Here is a sample email message.

HERE

Building the Index

Here is a sample email message.

HERE SAMPLE

Building the Index

Here is a sample email message.

HERE SAMPLE EMAIL

Building the Index

Here is a sample email message.

HERE SAMPLE EMAIL MESSAGE

Building the Index

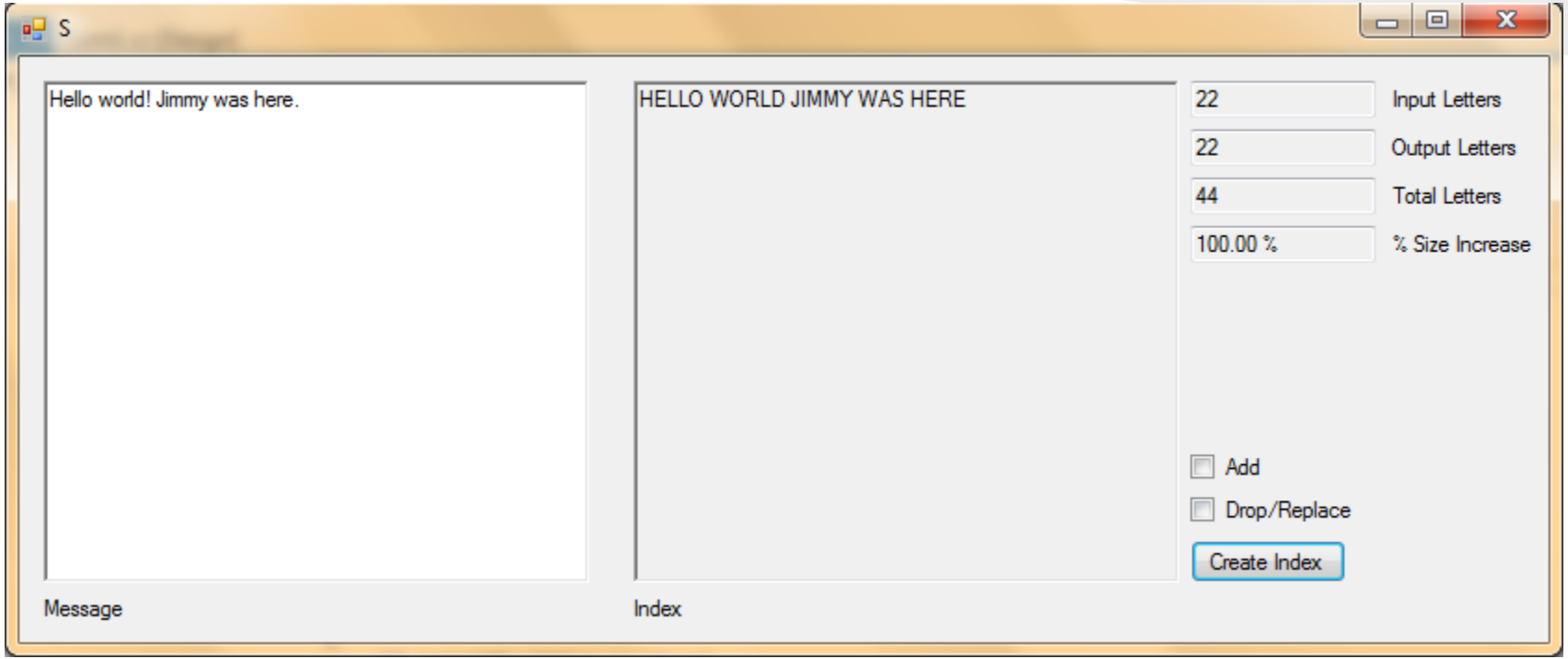
Here is a sample email message.

HERE SAMPLE EMAIL MESSAGE

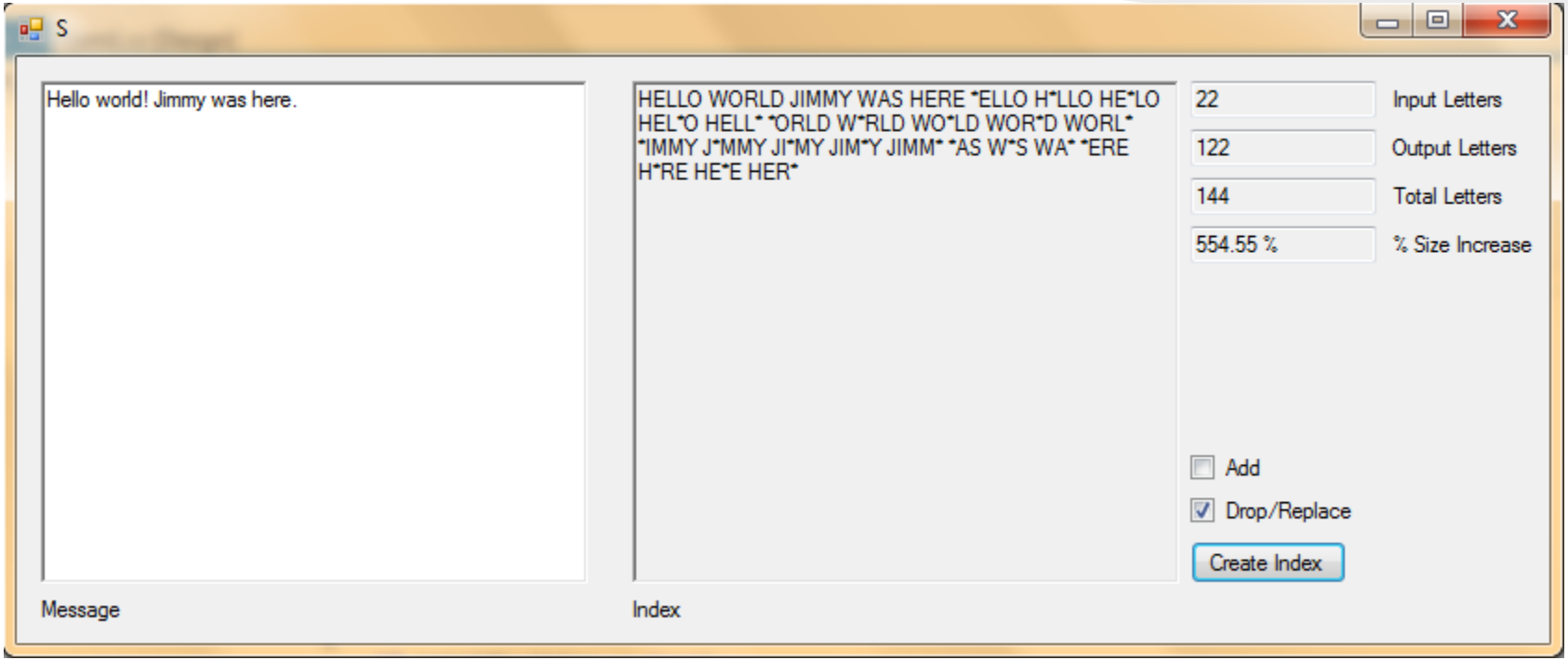
Algorithms

- Fuzzy-keyword search will only support single letter misspellings, not full wildcard support
- Duplicates and words less than 3 characters will not be added to the index
- Will check against a list of common 3-character words to exclude from the index

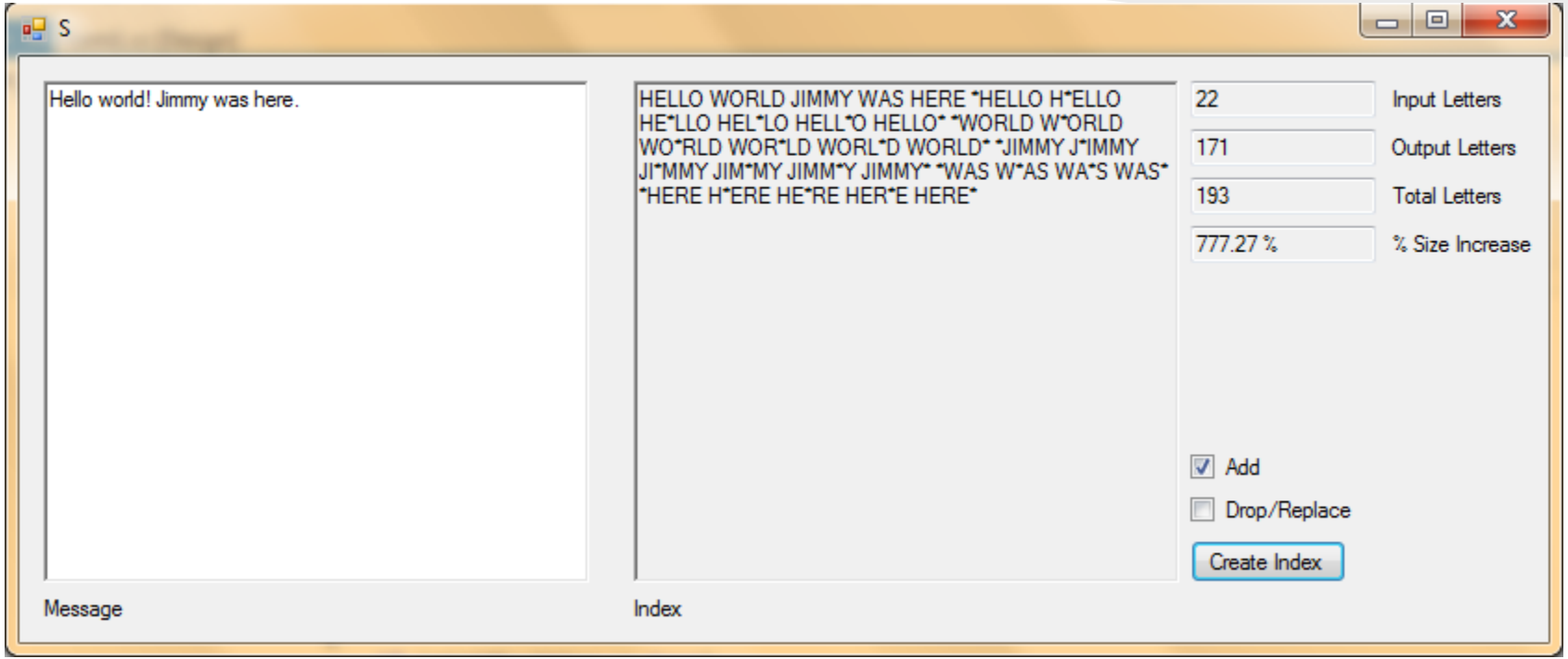
Algorithms


S
Hello world! Jimmy was here.
HELLO WORLD JIMMY WAS HERE
22
Input Letters
22
Output Letters
44
Total Letters
100.00 %
% Size Increase
Add
Drop/Replace
Create Index
Message
Index

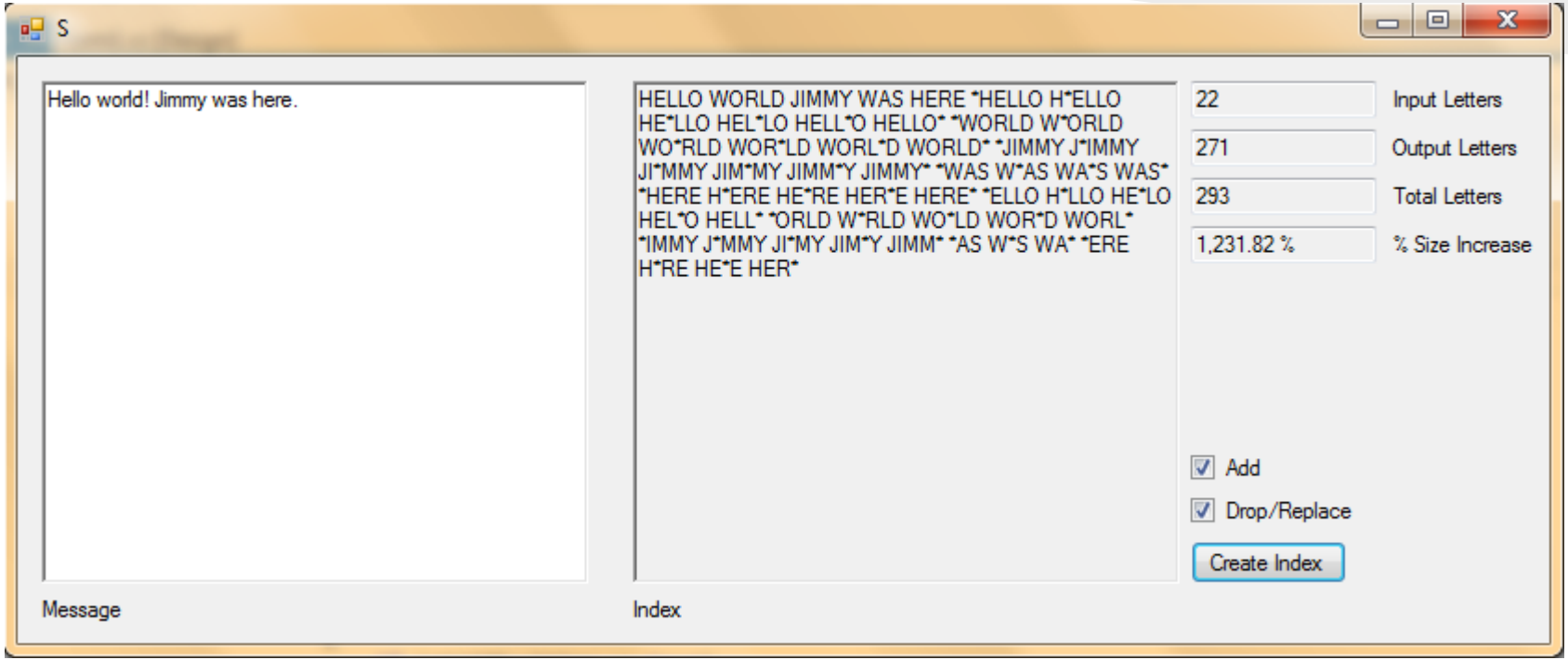
Algorithms


S
Hello world! Jimmy was here.
HELLO WORLD JIMMY WAS HERE *ELLO H*LLO HE*LO HEL*O HELL* *ORLD W*RLD WO*LD WOR*D WORL* *IMMY J*MMY JI*MY JIM*Y JIMM* *AS W*S WA* *ERE H*RE HE*E HER*
22
Input Letters
122
Output Letters
144
Total Letters
554.55 %
% Size Increase
Add
Drop/Replace
Create Index
Message
Index

Algorithms


S
Hello world! Jimmy was here.
HELLO WORLD JIMMY WAS HERE *HELLO H*ELLO HE*LLO HEL*LO HELL*O HELLO* *WORLD W*ORLD WO*RLD WOR*LD WORL*D WORLD* *JIMMY J*IMMY JI*MMY JIM*MY JIMM*Y JIMMY* *WAS W*AS WA*S WAS* *HERE H*ERE HE*RE HER*E HERE*
22
Input Letters
171
Output Letters
193
Total Letters
777.27 %
% Size Increase
Add
Drop/Replace
Create Index
Message
Index

Algorithms


S
Hello world! Jimmy was here.
Message
HELLO WORLD JIMMY WAS HERE *HELLO H*ELLO HE*LLO HEL*LO HELL*O HELLO* *WORLD W*ORLD WO*RLD WOR*LD WORL*D WORLD* *JIMMY J*IMMY JI*MMY JIM*MY JIMM*Y JIMMY* *WAS W*AS WA*S WAS* *HERE H*ERE HE*RE HER*E HERE* *ELLO H*LLO HE*LO HEL*O HELL* *ORLD W*RLD WO*LD WOR*D WORL* *IMMY J*MMY JI*MY JIM*Y JIMM* *AS W*S WA* *ERE H*RE HE*E HER*
Index
22
Input Letters
271
Output Letters
293
Total Letters
1,231.82 %
% Size Increase
Add
Drop/Replace
Create Index

Architecture

- Simulation of two machines:
  - Mock server will store encrypted messages
  - Mock client will be able to send messages to the server, which will be formatted and encrypted client-side

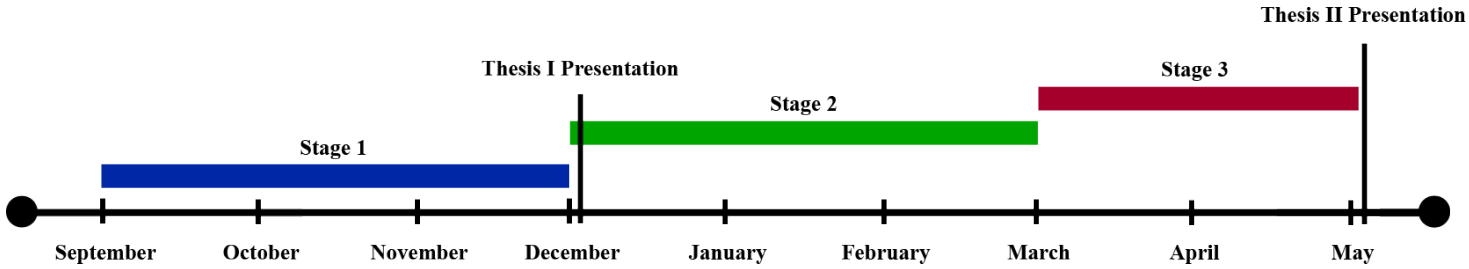
- Web protocol will make it possible for client to perform searches on the server

Architecture

- Two virtual machines
  - Web server and client
- Server will use IIS or Apache
- Client will use HTTP (WebDAV?) to perform searches on the web server

Timeline

- Stage 1: Planning/Design
- Stage 2: Development
- Stage 3: Testing/Implementation



Questions

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