

Unsupervised Deep Bug Report Summarization

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Summarize software artifacts



Over
80 million
projects



Over
3 million
applications



Over
5 million
posts

```
formatter = logging.Formatter('%(name)s - %(message)s')
logger = logging.getLogger()
logger.setLevel(logging.INFO)

dir = os.path.dirname(os.path.abspath(__file__))
if not os.path.isdir(dir):
    os.makedirs(dir)

handler = logging.handlers.TimedRotatingFileHandler(os.path.join(dir, "log.log"),
                                                    when='midnight',
                                                    backupCount=5)
```

Source code summarization

- ❑ Haiduc et al. 2010
- ❑ Moreno et al. 2013
- ❑ Sridhara et al. 2010
- ❑ McBurney and McMillan 2011

Source code comment summarization

- ❑ Rastkar et al. 2011
- ❑ Ying and Robillard 2013

The increasing software artifacts motivate a large body of work in **software artifacts summarization**



Bug report summarization

- ❑ Rastkarude et al. 2014
- ❑ Czarnecki et al. 2012
- ❑ Mani et al. 2012
- ❑ Jiang et al. 2017



Development activity summarization

- ❑ Treude et al. 2015

BACKGROUND



Bug reports are increasing



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Sun May 13 2018 04:43:58 EDT

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Changed: (is greater than or equal to) 7d **Creation date:** (changed after) 7d

212 bugs found.

ID	Product	Comp	Assignee ▲	Status	Resolution	Summary	Changed
534584	Acceleo	Core	acceleo-inbox	UNCO	---	substitute(String r, String t):String only substitutes first occurrence	Fri 11:33
534599	Buildshi	General	buildship-inbox	UNCO	---	Import Gradle project dark theme	Sat 01:35
534458	Chemclip	General	chemclipse-inbox	UNCO	---	Unify settings in openchrom and KNIME	Tue 03:03
534434	Oomph	Setup	oomph-inbox	UNCO	---	nable to read repository at http://download.eclipse.org/releases/oxygen/201804111000.org.tukaani.xz.XZFormatException: Input is not in the XZ format	Wed 16:02
534482	4DIAC	FORTE	4diac-inbox	NEW	---	remove Codtionsync	Tue 15:55
534525	Subversi	UI	a.gurov	NEW	---	Subversise does not show any console outputs	Wed 23:47
534588	Communit	API.ecli	api-inbox	NEW	---	web-api/project_release_versions.php returns "Deprecated: mysql_connect()" message	Fri 13:29
534498	BIRT	Chart	Birt-Chart-inbox	NEW	---	Charts not rendered, error	Wed 06:18
534423	CDT	cdt-core	cdt-core-inbox	NEW	---	Sort configurations in the Exclude from build dialog	Mon 06:06

A single bug repository, e.g., **Eclipse** Bugzilla repository, has already collected over **485,000** historical bug reports.

Stakeholders refer to historical bug reports

Developers



Fix newly reported bugs by referring to similar historical bug reports **for possible solutions**

Softw. Users
Testers



Wade through related bug reports before submitting a new one **to avoid duplications**

Stakeholders refer to historical bug reports

Developers



Fix newly reported bugs by referring to similar historical bug

Softw. Users
Testers



Wade through related bug reports before submitting a

Need to **read 600 sentences** (avg.), if a user refers to only **10 historical bug reports**

Summarize bug reports

Bug 170801 - Converting image from grayscale to black&white is painfully slow

Status: RESOLVED
FIXED
Product: GIMP
Component: General
Version: 2.2.x
Hardware: Other All

Reported: 2005-03-18 14:46 UTC
by Xuan Baldauf
Modified: 2008-01-15 12:50 UTC
([History](#))
CC List: 1 users ([show](#))
[See Also](#):

Importance: Normal normal
Assigned To: GIMP Bugs

Xuan Baldauf 2005-03-18 14:46:31 UTC [Description](#)

1. Open a large grayscale image of your choice (e.g.
2. Use "Tools/Color Tools/Threshold" to apply some threshold choosen.
3. Now you have a 8bit grayscale image, which actually consists only of color values "0" and color values "255".

.....
This slow speed is not acceptable for interactive image processing, and this slow, not necessary at all.

Manish Singh 2005-03-19 17:48:16 UTC [Comment 8](#)

Revision 1.156.
if (palette_type == GIMP_WEB_PALETTE ||
palette_type == GIMP_MONO_PALETTE ||
.....

Adam D. Moss 2005-03-20 12:26:09 UTC [Comment 10](#)

The 'mono' palette option doesn't even bother to start this pre-pass because it could only possibly pay off the extra effort if the entire image is pure black and pure white, which is expected to be a comparatively rare occurrence.

Xuân Baldauf 2005-03-20 13:06:07 UTC [Comment 11](#)

<quote> The 'mono' palette option doesn't
I don't think that this operation is so rare, ... and then a "convert to 1bit" operation to actually adjust the internal memory requirements.

Adam D. Moss 2005-03-20 14:01:48 UTC [Comment 12](#)

> and then a "convert to 1bit" operation to actually adjust
> the internal memory requirements.
If you mean GIMP's internal memory requirements
.....

Extracting and Highlighting
informative sentences (summary)
from description and comments

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Bug reports are special

Bug report summarization

- ❑ Rastkarude et al. 2014
- ❑ Czarnecki et al. 2012
- ❑ Mani et al. 2012
- ❑ Jiang et al. 2017

**BUG
REPORTS
are**

1

Conversation-based text
with **frequent
evaluation behaviors**

2

Consist of **different
sentence types**

3

Combined with many
predefined fields

1. Conversation-based text with frequent evaluation behaviors

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> the internal memory requirements.
If you mean GIMP's internal memory requirements ...

The **evaluated sentences** are frequently discussed and **important**

Adam D. Moss 2005-03-20 12:26:09 UTC [Comment 10](#)

The 'mono' palette option doesn't even bother to star.....

Be Evaluated

Xuân Baldauf 2005-03-20 13:06:07 UTC [Comment 11](#)

<quote> The 'mono' palette option doesn't
I don't think that this operation is so rare, ...

2. Consist of different sentence types

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If you mean GIMP's internal memory requirements ...
.....

reporter's sentences >
participators' sentences >
software sentences
('>' means more informative)

- Natural language sentences by the **reporter**;
- Natural language sentences by the **participators**;
- **Software language sentences** (code snippets and system messages).

3. Combined with many predefined fields

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If you mean GIMP's internal memory requirements

Sentences contain words in the predefined fields may be informative

Product: GIMP

Component: General

Version: 2.2.x

Hardware: Other All

Bug reports are special

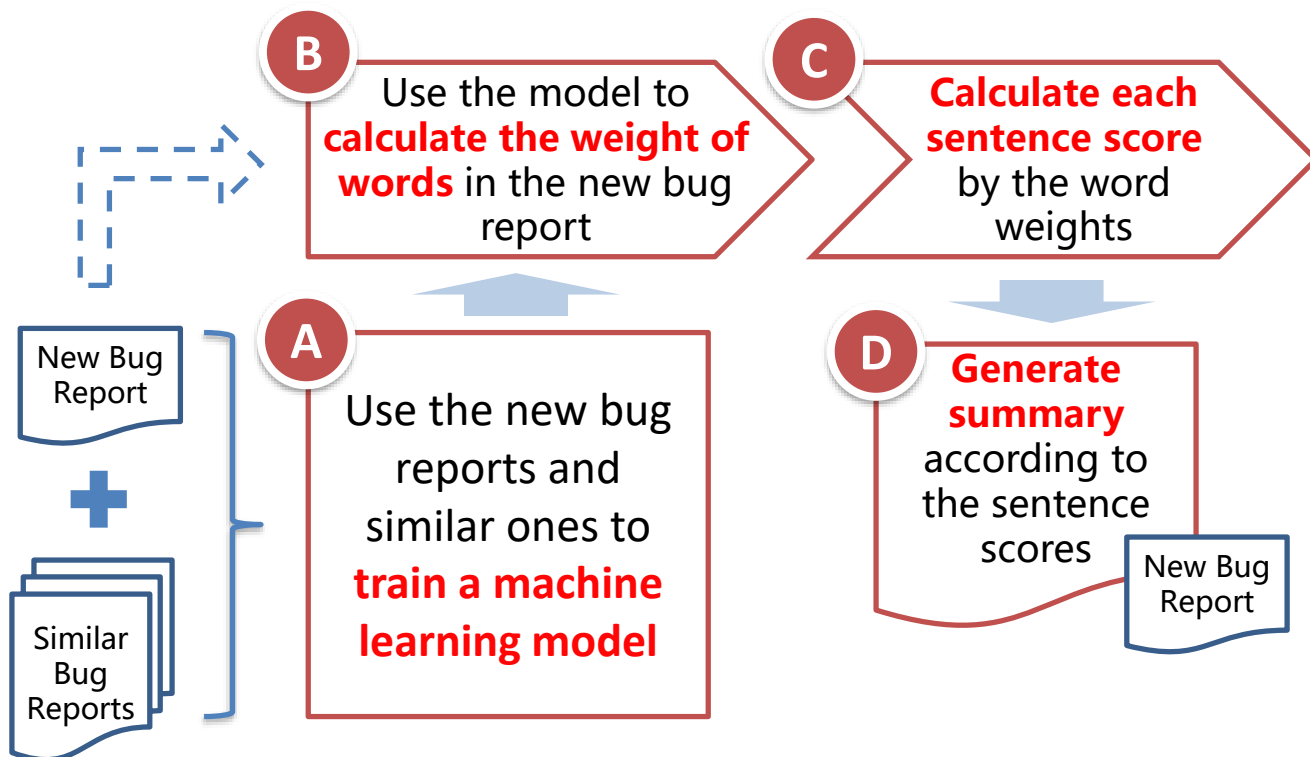
1 Conversation-based text
with **frequent
evaluation behaviors**

2 Consist of **different
sentence types**

3 Combined with many
predefined fields

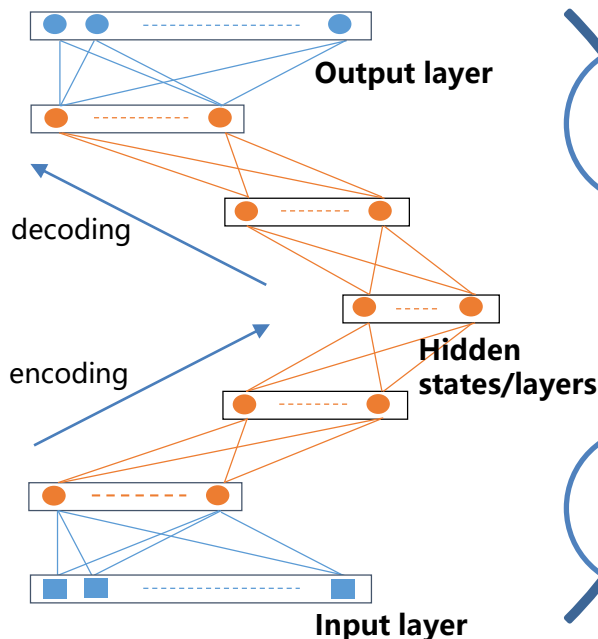
Summarize bug
reports by
considering the
special
characteristics

The framework



We select AutoEncoder as the machine learning model

A typical architecture of AutoEncoder



Why AutoEncoder?

The **output layer** is defined as a pattern to **reconstruct** the **input layer**

The **hidden state** provides a **compressed representation** of the **input layer**

The **weights of words** can be **measured** by calculating how much information of a word is reserved in the **hidden states**

The inputs are word vectors of bug reports

Description	Xuan Baldauf 2005-03-20 13:06:07 UTC	Comment 11
S1	1. Open a large image of your choice and hold to apply the chosen.	
S2	2. Use "Tools" menu to open the "Convert to 1bit" dialog and choose.	
S3	3. Now you have a grayscale image, which consists only of color values "0" and color values "255".	
S4	This slow speed is not acceptable for interactive image processing, and this slowness is not necessary at all.	
Comment	Manish Singh 2005-03-19 17:48:16 UTC	Comment 8
S5	Revision 1.156.	
S6	if (palette_type == GIMP_WEB_PALETTE	
S7	palette_type == GIMP_MONO_PALETTE	
S8	Adam D. Moss 2005-03-20 12:26:09 UTC	Comment 10
S8	The 'mono' palette option doesn't even bother to start this pre-pass because it could only possibly pay off the extra effort if the entire image is pure black and pure white, which is expected to be a comparatively rare occurrence.	
username	Xuân Baldauf 2005-03-20 13:06:07 UTC	Comment 11
S9	<quote> The 'mono' palette option doesn't	
S10	I don't think that this operation is so rare, ... and then a "convert to 1bit" operation to actually adjust the internal memory requirements.	
S11	Adam D. Moss 2005-03-20 14:01:48 UTC	Comment 12
S12	> and then a "convert to 1bit" operation to actually adjust	
S13	> the internal memory requirements.	
S13	If you mean GIMP's internal memory requirements	

S_1	0 0 ... 0
S_6	0 0 ... 1
S_7	1 0 ... 1
S_8	3 4 ... 3
S_9	3 4 ... 3
S_{10}	0 3 ... 2
S_{11}	0 2 ... 1
S_{12}	0 1 ... 2

Transform each sentence into a vector

The inputs are word vectors of bug reports

Description	
S1	Xuan Baldauf 2005-03-20 13:06:07 UTC
S2	1. Open a large image of your choice and hold to apply the chosen.
S3	2. Use "Tools" menu to open the "Convert to 1bit" operation to actually adjust the internal memory requirements.
S4	3. Now you have a grayscale image, which consists only of color values "0" and color values "255".
S5	
S6	This slow speed is not acceptable for interactive image processing, and this slowness is not necessary at all.
S7	
Comment	
S8	Manish Singh 2005-03-19 17:48:16 UTC
S9	Revision 1.156.
S10	if (palette_type == GIMP_WEB_PALETTE palette_type == GIMP_MONO_PALETTE
S11	Adam D. Moss 2005-03-20 12:26:09 UTC
S12	The 'mono' palette option doesn't even bother to start this pre-pass because it could only possibly pay off the extra effort if the entire image is pure black and pure white, which is expected to be a comparatively rare occurrence.
S13	

New Bug Report

Similar Bug Reports

Evaluation Enhancement

S_1 [0 0 ... 0]

S_6 [0 0 ... 1]

S_7 [1 0 ... 1]

S_8 [3 4 ... 3]

S_9 [3 4 ... 3]

S_{10} [0 3 ... 2]

S_{11} [0 2 ... 1]

S_{12} [0 1 ... 2]

S_9 evaluates S_8 , if cosine similarity $(S_8, S_9) > \text{threshold} (0.9)$.

Conversation-based text with frequent evaluation behaviors

The inputs are word vectors of bug reports

Description	
S1	Xuan Baldauf 2005-03-20 13:06:07 UTC
S2	1. Open a large image, which is not of your choice, and hold to apply a chosen.
S3	2. Use "Tools" menu to open the "Convert to 1bit" operation to actually adjust the internal memory requirements.
S4	3. Now you have a 1-bit image, which consists only of color values "0" and color values "255".
S5	
S6	This slow speed is not acceptable for interactive image processing, and this slowness is not necessary at all.
S7	
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S13	

New Bug Report

Similar Bug Reports

Evaluation Enhancement

S_1 [0 0 ... 0]

S_6 [0 0 ... 1]

S_7 [1 0 ... 1]

S_8 [6 8 ... 6]

S_9 [0 0 ... 0]

S_{10} [0 3 ... 2]

S_{11} [0 2 ... 1]

S_{12} [0 1 ... 2]

S_9 evaluates S_8 , if cosine similarity $(S_8, S_9) > \text{threshold} (0.9)$.

Conversation-based text with frequent evaluation behaviors

Encode vectors according to their importance

Inputs

$$S_6 + S_7$$

1 0 ... 2

Software Vector

$$S_1 + S_9 + S_{10}$$

0 6 ... 5

Participant Vector

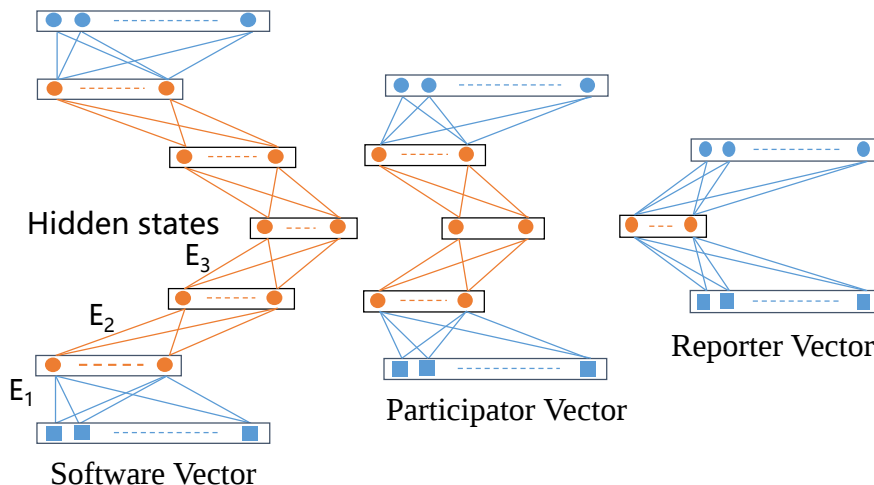
$$S_8 + S_{11} + S_{12}$$

6 8 ... 6

Reporter Vector

Encode less important sentences (software vector) three times to reduce their influence.

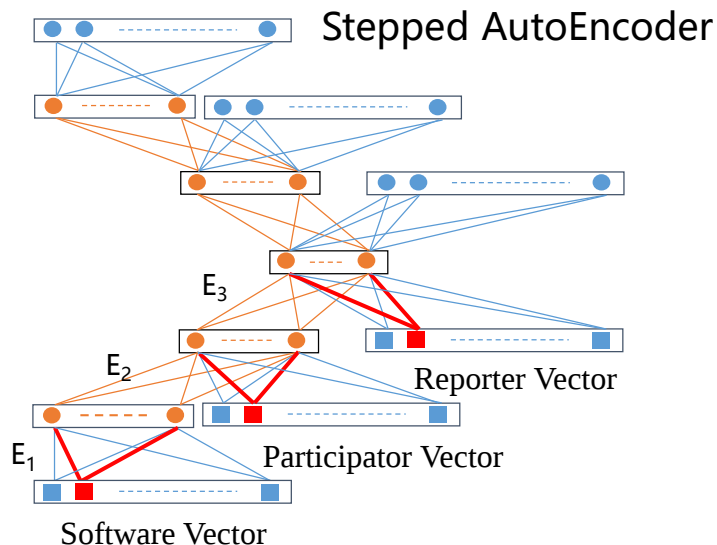
$$\text{Hidden states} = E_3(E_2(E_1(\text{Software Vector})))$$



Consist of **different sentence types**

reporter's sentences > participants' sentences > software sentences

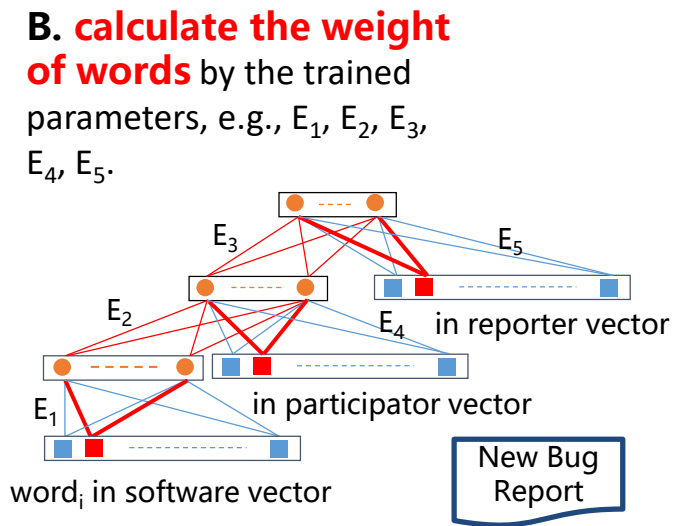
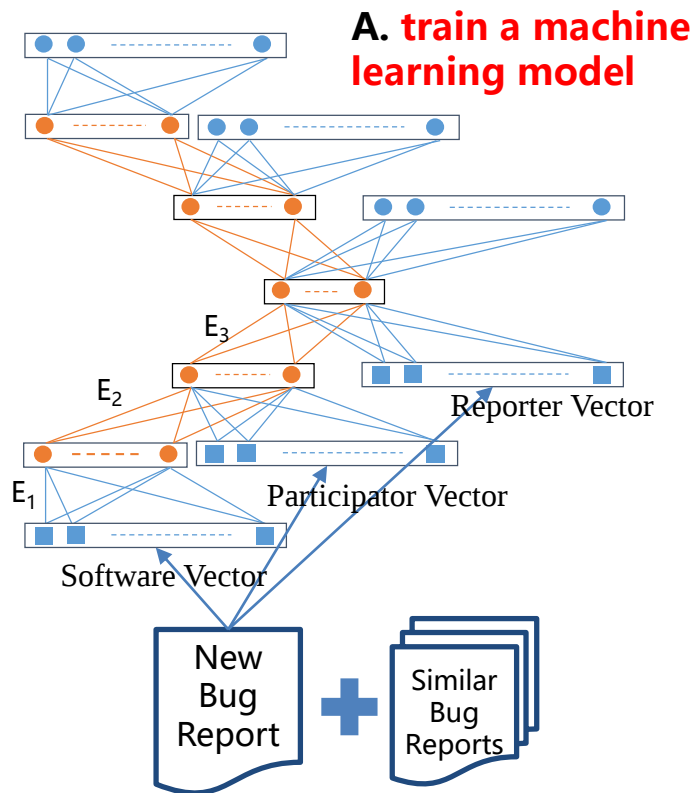
Initialize the network by predefined fields



Randomly initialize the network parameters, e.g., E_1 , E_2 , E_3 , and then maximize some parameters if it connects a word in the predefined fields (**the red element**).

Combined with many **predefined fields**

Revisit the framework (DeepSum)



Weight of word_i =

$$E_3(E_2(E_1(\text{word}_i \text{ in software vector}))) + E_3(E_4(\text{word}_i \text{ in participant vector})) + E_5(\text{word}_i \text{ in reporter vector})$$

Revisit the framework (DeepSum)

C. calculate each sentence score. sentence score =

$$\sum \text{word weight} * \text{word frequency}$$

S_1 [0 0 ... 0]

— — —

S_6 [0 0 ... 1]

S_7 [1 0 ... 1]

S_8 [6 8 ... 6]

S_9 [0 0 ... 0]

S_{10} [0 6 ... 5]

S_{11} [0 0 ... 0]

S_{12} [0 0 ... 0]

— — —



D. generate summary, select a set of sentences s_{select} by:

- (1) maximizing the total sentence score of s_{select} ;
- (2) total length of $s_{\text{select}} <$ a length limitation (25% length of the bug report)

We generate a summary of the new bug report by **dynamic programming**. The summary is **about ¼ length** of the new bug report and has **a high total sentence score**.

Evaluate with six metrics over two data sets.

- Evaluation metrics include precision, recall, F-score, pyramid, R1, R2

$$Precision = Num_{hit} / Num_{selected},$$

$$Recall = Num_{hit} / Num_{ExfRef},$$

$$F-score = \frac{2 * Precision * Recall}{Precision + Recall},$$

$$Pyramid = Num_{TotalLinks} / Num_{MaxLinks},$$

$$Rouge-n = \frac{\sum_{s \in AbsRef} \sum_{gram_n \in s} Count_{match}(gram_n)}{\sum_{s \in AbsRef} \sum_{gram_n \in s} Count(gram_n)},$$

- Data sets SDS and ADS with 36+96 manually annotated bug reports

Influence on bug report characteristics

Remove a module (do not consider this characteristic)

	A	B	Precision	Recall	F-score	Pyramid	R1	R2
SDS	✓	✓	0.621	0.388	0.462	0.624	0.563	0.177
	×	✓	0.533	0.336	0.397	0.551	0.543	0.160
	✓	×	0.600	0.381	0.450	0.598	0.552	0.166
	×	×	0.529	0.339	0.399	0.544	0.540	0.160
ADS	✓	✓	0.606	0.394	0.457	0.681	0.553	0.249
	×	✓	0.586	0.382	0.443	0.661	0.548	0.243
	✓	×	0.577	0.371	0.432	0.661	0.548	0.246
	×	×	0.558	0.359	0.418	0.639	0.543	0.242

- A: evaluation enhancement: conversation-based text with frequent evaluation behaviors
- B: predefined fields enhancement: combined with many predefined fields

Both the characteristics have positive influence on summarizing bug reports. DeepSum successfully integrates these characteristics to summarize bug reports.

Influence on calculating word weights with stepped AutoEncoder

	Precision	Recall	F-score	Pyramid	R1	R2
TF Strategy	0.583	0.380	0.445	0.581	0.556	0.167
SDS AE Strategy	0.581	0.370	0.437	0.590	0.555	0.165
DeepSum	0.621	0.388	0.462	0.624	0.563	0.177
TF Strategy	0.573	0.360	0.425	0.581	0.544	0.240
ADS AE Strategy	0.577	0.366	0.427	0.657	0.549	0.240
DeepSum	0.606	0.394	0.457	0.681	0.553	0.249

- TF Strategy: the word weights are the same as the **Term Frequency** in the new bug report
- AE Strategy: calculating word weights with **standard AutoEncoder**, not the stepped one.

DeepSum's word weighting strategy (consider different sentence types) outperforms the alternatives, i.e., TF strategy and AE strategy.

We compare DeepSum against algorithms in previous studies

	Precision	Recall	F-score	Pyramid	R-1	R-2
BRC _{LOO}	0.570	0.350	0.400	0.630	0.521	0.140
BRC _{TFCV}	0.524	0.321	0.362	0.580	0.493	0.130
ACS _{LOO}	0.595	0.337	0.400	0.604	0.516	0.135
ACS _{TFCV}	0.562	0.310	0.359	0.572	0.488	0.126
Centroid	0.536	0.269	0.343	0.460	0.471	0.126
MMR	0.617	0.353	0.429	0.551	0.498	0.145
Grasshopper	0.525	0.300	0.368	0.521	0.505	0.135
DivRank	0.591	0.301	0.378	0.546	0.500	0.139
Hurried	0.710	0.390	0.410	0.710	0.525	0.152
DeepSum	0.621	0.388	0.462	0.624	0.563	0.177

	Precision	Recall	F-score	Pyramid	R-1	R-2
BRC _{LOO}	0.568	0.350	0.412	0.659	0.517	0.201
BRC _{TFCV}	0.528	0.314	0.388	0.620	0.492	0.180
ACS _{LOO}	0.605	0.391	0.452	0.671	0.546	0.235
ACS _{TFCV}	0.556	0.343	0.400	0.625	0.520	0.211
Centroid	0.488	0.280	0.337	0.561	0.473	0.183
MMR	0.505	0.356	0.395	0.585	0.503	0.206
Grasshopper	0.446	0.337	0.362	0.548	0.504	0.201
DivRank	0.445	0.282	0.325	0.545	0.498	0.202
Hurried	0.580	0.349	0.418	0.637	0.544	0.241
DeepSum	0.606	0.394	0.457	0.681	0.553	0.249

DeepSum shows promising performance for summarizing bug reports over distinct evaluation metrics.

Bug report summarization

- ❑ Rastkarude et al. 2014
- ❑ Czarnecki et al. 2012
- ❑ Mani et al. 2012
- ❑ Jiang et al. 2017

Conclusion

- We propose an **unsupervised deep learning algorithm** for bug report summarization.
- Our model fully **leverages the characteristics of bug reports**.
- Experiments over two public bug report datasets show that our model **outperforms the comparative algorithms** by adopting domain-specific characteristics.

Future Work

- Investigate whether automatic bug report summarization is useful in **a real developing scenario**.
- Construct **large bug report data sets** to evaluate different models.

Thanks

Unsupervised Deep Bug Report Summarization

Reporter: Xiaochen Li
Dalian University of Technology, China



Authors: Xiaochen Li¹, He Jiang¹, Dong Liu¹, Zhilei Ren¹, Ge Li²

¹Dalian University of Technology, ²Peking University

