Categorizing the Content of GitHub README Files

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Summary of Contributions:

* 1. Data Collection

**Bhavyai** developed script that downloads the README.md file from random GitHub repositories using GitHub API. The script was initially written as .py script, and then later modified to run on Databricks. Once few hundred README.md files are downloaded, **Michael** selected 86 files with a total of 1000 sections for manual annotation. Each of the author of this project annotated all the 1000 sections. **Kayode** is the facilitator to make sure we reach an agreement of what final manual annotations should be used as well as calculating the statistics such as the Cohen Kappa analysis to show our overall process. **Michael** is responsible for extracting the sections from README files and to feed the new annotated data back to the database for modelling and analysis.

* 1. **Coding**

**Bhavyai** is responsible for developing script to download all new README files needed for this project. **Michael** is responsible for the initial draft of modifying the original code from the author to work on databricks.

**Kayode** is responsible for creating the notebook for comparing the results of the old and old plus the new annotated data using the original research models.

**Michael** is responsible for creating the notebook for comparing the results of the old and new annotated datasets using previously unexplored models.

**Bhavyai** is responsible for creating the notebook for hyperparameter optimization of the models.

**Writeup**

The breakdown of the report writeup work can be found in the table below:

|  |  |
| --- | --- |
| Section | Resource |
| Page 1 contents | Mike |
| Abstract/Intro/conclusion | Bhavyai |
| How was the new data labeled/collected? | Kayode |
| How does the newly added data compare with the original data? | Kayode |
| How was the data preprocessed? | Bhavyai |
| Preparing the model on Databricks with old+new data | Mike |
| How do the models perform on the original data vs the new + original data? | Mike |
| How does the performance of the models change based on the choice of hyper parameters? | Mike |
| How are the misclassifications of the best performing model distributed? | Kayode/Bhavyai |
| Discussion | All |

**Databricks Notebook**

1. README downloader: <https://databricks-prod-cloudfront.cloud.databricks.com/public/4027ec902e239c93eaaa8714f173bcfc/279226329024279/3713457635192600/4593657877666368/latest.html>
2. Original Model Comparison
   1. ENSF612 Final Project with Original Models - Old Data: <https://databricks-prod-cloudfront.cloud.databricks.com/public/4027ec902e239c93eaaa8714f173bcfc/4199039841175524/4424314020178626/1115343936761319/latest.html>
   2. ENSF612 Final Project with Original Models – Old + New Data: https://databricks-prod-cloudfront.cloud.databricks.com/public/4027ec902e239c93eaaa8714f173bcfc/4199039841175524/4424314020178662/1115343936761319/latest.html
3. New Model Comparison:
   1. ENSF612 Final Project with Unexplored Models - Old Data: <https://databricks-prod-cloudfront.cloud.databricks.com/public/4027ec902e239c93eaaa8714f173bcfc/4199039841175524/4424314020178557/1115343936761319/latest.html>
   2. Histogram Gradient Boost – Old Data: <https://databricks-prod-cloudfront.cloud.databricks.com/public/4027ec902e239c93eaaa8714f173bcfc/4199039841175524/4424314020178505/1115343936761319/latest.html>
   3. Histogram Gradient Boost – Old+New Data: <https://databricks-prod-cloudfront.cloud.databricks.com/public/4027ec902e239c93eaaa8714f173bcfc/4199039841175524/4424314020178533/1115343936761319/latest.html>
4. Hyperparameter Optimization
5. ABSTRACT
   1. Context

README files play an essential role in shaping a developer’s first impression of a software repository and in documenting the software project that the repository hosts. Yet, we lack a systematic understanding of the content of a typical README file as well as tools that can process these files automatically.

* 1. Objective

In this project, we replicate the research paper on “Categorizing the Content of GitHub README Files”. We also extend the work done in the paper by running more ML classifier models and tuning their hyper-parameters to explore the better performance.

* 1. Methods

The new template enables you to import required indexing concepts for your article from the [ACM Computing Classification System (CCS)](http://www.acm.org/publications/class-2012) using an [indexing support tool](http://dl.acm.org/ccs/ccs.cfm?) found in the ACM Digital Library (DL). The tool generates formatted text after you have selected your terms. To insert CCS terms into your document, copy and paste the formatted text from the CCS tool using the “<https://dl.acm.org/ccs/ccs.cfm>” link into the “CCS CONCEPTS” section.

An additional step is necessary to ensure that the proper CCS terms are added to the Digital Library citation page: from the “view CCS TeX Code” listing, click on “Show the XML Only.” Highlight and copy the XML code from the window. You must insert the XML code into your Word document’s properties: from your Word document, click on “**File**”, then click on the “**Info**” tab on the left-hand side panel, then click “**Properties**” and select “**Show All Properties.**” Click within the “Comments” metadata field and paste the XML data.

* 1. Results

Thissubmission version of your paper should not have headers or footers, these will be added when your manuscript is processed after acceptance. It should remain in a one-column format—please do not alter any of the styles or margins.

* 1. Conclusions

Through this work, Thissubmission version of your paper should not have headers or footers, these will be added when your manuscript is processed after acceptance. It should remain in a one-column format—please do not alter any of the styles or margins.

1. INTRODUCtion

The next subsections provide instructions on how to insert figures, tables, and equations in your document.

* 1. Tables

Tables are “float elements” which should be inserted after their first text reference and have specific styles for identification. Do not use images to present tables, or they will be inaccessible to readers using assistive technologies.

Authors can insert tables by using the MS Word option (INSERT ->Table) and providing the required row and column size. Every table must have a caption (title) above it, which must have the **“TableCaption**” style applied. Please note that tables **should not** be supplied as image files, but if they are images they must have the “Image” style applied. As an example, Table 1 shows all the styles available in this template, to be applied to the respective element of your text.

Table 1: Styles available in the Word template

| Style Tag | Definition | Style Tag | Definition |
| --- | --- | --- | --- |
| Title\_document | main title of article | ListParagraph | list items |
| Subtitle | subtitle of article | Statements | math statements |
| Authors | author name | Extract | block quotations |
| Affiliation | author affiliation information | Algorithm Caption | caption for algorithm |
| AuthNotes | footnote to author(s) | AckHead | heading for acknowledgements |
| Abstract | abstract text | AckPara | acknowledgements text |
| CCSHead | heading for CSS Concepts | GrantSponsor | sponsor of grant |
| CCSDescription | CSS terms | GrantNumber | number for the grant |
| KeyWordHead | heading for keywords | ReferenceHead | heading for references |
| Keywords | keywords text | Bib\_entry | references |
| ORCID | author's ORCHID # | AppendixH1 | appendix heading level 1 |
| Head1 | heading level 1 | AppendixH2 | appendix heading level 2 |
| Head2 | heading level 2 | AppendixH3 | appendix heading level 3 |
| Head3 | heading level 3 | TableCaption | title of table |
| PostHeadPara | first paragraph after a heading | TableHead  TableFootnote | column head of table  footnote to table |
| Para | Subsequent paragraphs of general text | Image | figures |
| ParaContinue  DisplayFormula | flush left text after display items like math equations, lists etc.  numbered math equation | DOI | Digital object identifier |
| DisplayFormulaUnnum | unnumbered equations | Label | labela |
| ComputerCode | Display Computer codes | In-text code | intext computer code |
| Short Title | Short title of article | History | Dates of article |

a This is example of table footnote.

Tables can be very difficult for people using screen reader technology to understand unless they include markup that explicitly defines the relationships between all the parts (i.e.: headers and data cells). *A key to making data tables accessible to screen reader users is to clearly identify column and row headers.* In Word, authors should identify which row or rows contain column headers. Below are the steps to do this:

1. Select that table’s row, then right-click the row and select “Table Properties”;
2. In the *Table Properties* window, click the *Row* tab and select the box that says “Repeat as header row at the top of each page.”

Or

Apply the “table head” style by highlighting the respective row and applying the “**TableHead**” style found in the “Body Element” section of the ACM Master Article Template.

* 1. Figures

Figures are “float elements” which should be inserted after their first text reference, and have specific styles for identification. Insert a figure and apply the “**Image**” paragraph style to it. For the figure caption, apply the style “**FigureCaption.**”

To accommodate readers with color vision differences, figures should still be usable when printed in grayscale. Refer to elements of the figure with non-color terms, for example “indicated as squares” instead of “indicated in blue”. Use different patterns in bar charts, different line patterns in graphs, and different shapes in plots to distinguish groups of elements and reinforce color differences.

* + 1. Half Width Figures.

Figure 1 is an example of a figure and caption spanning the half-page width (one column in a two column format) with the styles applied. If your figure contains third-party material, you must clearly identify it as such, as shown in the example below.



Figure 1: 1907 Franklin Model D roadster. Photograph by Harris & Ewing, Inc. [Public domain], via Wikimedia Commons. (https://goo.gl/VLCRBB)

* + 1. Full Width Figures.

Figure 2 is an example of a figure and caption spanning the full-page width with the styles applied. If your figure contains third-party material, you must clearly identify it as such, as shown in the examples.



Figure 2: Mockup of a bombe machine at Bletchley Part. Photograph by Sarah Hartwell. [Public domain], via Wikimedia Commons. (<https://commons.wikimedia.org/wiki/File:TuringBombeBletchleyPark.jpg>)

* + 1. Multi-part figure.

Authors can also insert a multi-part figure above a single caption. Every inserted figure must have the “Image” style applied. Below are instructions regarding how to insert a multi-part figure in your paper.

* If the author wants to insert two multi-part images, they must draw a one row and one column table and insert the images one-by-one in the cells.
* If the author wants to insert three multi-part images, they must draw a one-row and three-column table and insert the images one by one in all three cells.
* If the author wants to insert four multi-part images, they must draw a two-row and two-column table and insert the images one-by-one in all four cells. (see the following example):

| Figure 2: The layout of multipart images should be as per the above example within the table in image 1. | Figure 2: The layout of multipart images should be as per the above example within the table in image 2. |
| --- | --- |
| Figure 2: The layout of multipart images should be as per the above example within the table in image 3. | Figure 2: The layout of multipart images should be as per the above example within the table in image 4. |

Figure 3: The layout of multipart images should be as per the above example within the table. All images must have the “Image” style applied.

* + 1. Figure Descriptions.

Every figure should have a figure description unless it is purely decorative. These descriptions convey what’s in the image to someone who cannot see it. They are also used by search engine crawlers for indexing images, and when images cannot be loaded.

A figure description must be unformatted plain text less than xxx characters long. Figure descriptions should not repeat the figure caption – their purpose is to capture important information that is not already provided in the caption or the main text of the paper. For figures that convey important and complex new information, a short plain text description may not be adequate. More complex alternative descriptions can be placed in an appendix and referenced in a short figure description. For example, provide a data table capturing the information in a bar chart, or a structured list representing a graph. For additional information regarding how best to write figure descriptions and why doing this is so important, please see [https://www.acm.org/accessibility.](https://www.acm.org/accessibility)

The instructions below describe the required steps authors need to follow in order to insert descriptive text for figures (alt-txt value) in **MS Word 2019 on Windows or Word 2016 and later on Mac**:

1. Insert a picture in the document.
2. Right-click the image and select “Edit Alt Text”.
3. In the “alt text” section, provide your text description of the image.

Below are the steps to insert figure descriptions in **MS Word 2013 and 2016**:

1. Insert a picture in the document.
2. Right click on the inserted picture and select the **Format Picture** option.
3. In the settings at the right side of the window, click on the “Layout & Properties” icon (3rd option).
4. Expand **Alt Txt** option.
5. In the “Title” and “Description” text boxes, type the text you want to represent the figure, and then click “Close.”

Below are steps to insert the alt-txt value in **MS Word 2010/2011 for Windows\***:

1. Insert a picture in the document.
2. Right click on the inserted picture and select the **Format Picture** option.
3. Select the **Alt Txt** option from the left-side panel options.
4. In the “Title” and “Description” text boxes, type the text you want to represent the picture, and then click “Close.”  
   \* The Mac 2011 version 14.0.0 and later allows the option for inserting “alt-text.” In the MAC version of Word 2016, right-click on the image and select “Edit Alt Text” from the pop-up menu and then enter the description for the alt text.
   1. Quotations and Extracts

There are styles for block quotations, which should be used for quotes that are separated from in-line text. Below is an example.

“Microsoft tried to revive the idea of an assistant with Clippy, who began popping up in Microsoft Office in 1997. Its creator, Kevan Atteberry, was actually contracted by Microsoft to design Clippy, which, funnily enough, he did on a Mac … Sure, people could disable Clippy, but the fact he was on by default angered people.” [10]

* 1. Equations

There are two types of math equations: the *numbered display math equation* and the *un-numbered display math equation*. Below are examples of both.

* + 1. DisplayFormula.

The **DisplayFormula** style is applied in the numbered math equation. A numbered display equation always has an equation number (label) on the right.

(1)

* + 1. DisplayFormula.Unnum.

The **DisplayFormulaUnnum** style is applied only in unnumbered equations. An unnumbered display equation never contains an equation number Bertot and Grimes (2012) on the right—this element distinguishes it from the numbered equation.

Please note: the subsequent text after the **DisplayFormula** (numbered equation) or **DisplayFormulaUnnum** (unnumbered equation) must have the paragraph style **ParaContinue** applied.

* 1. Math statements

Math statements should have the “Statement” style applied.

**Theorem/Proof/Lemma.** Math statements should have the “**Statement**” style applied. This paragraph is an example of the “**Statement**” style.

* 1. Algorithms

Algorithms use the styles “AlgorithmCaption” and “Algorithm”.

ALGORITHM 1: Iterative Algorithm

current\_position center

current\_direction up

current\_position is inside circle

while current\_position is inside circle, do

neighborhood all grid hexes within two hexes from current\_position

for each hex in neighborhood, do

for each neuron in hex do

convert neuron\_orientation to vector

scale vector by neuron\_excitation

vector\_sum vector\_sum + vector

end

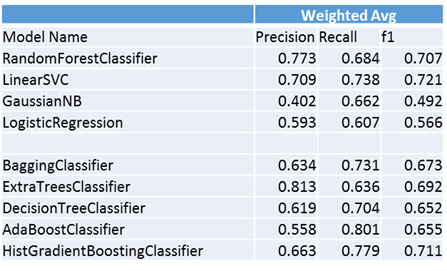
end

normalize vector\_sum

end

1. Results
   1. How was the new data labeled/collected?
   2. How does the newly added data compare with the original data?
   3. How was the data preprocessed?
   4. How do the models perform on the original data vs the new + original data?

With the original data, we have performed model analysis of the weighted average of precision, recall and f1 score for the following models:



The first four models, namely RandomForestClassifier, LinearSVC, GaussianNB and LogisticRegression were used in the original paper.

The last five models, BaggingClassifier, ExtraTreesClassifier, DecisionTreeClassifier, AdaBoostClassifier and HistGradientBoostingClassifier are models that have not been experimented by the original paper. Note that initially the original GradientBoost model is used but Databricks terminated the cluster before the model can finish running. HistGradientBoostingClassifier is also significantly longer to complete than the other models (took 5 hours compared to 2.35hrs for RandomForest and 11.5 minutes for LinearSVC), but it can successfully complete with the scores calculated.

As can be seen from the previous table, ExtraTrees classifier has the highest precision whereas AdaBoostClassifier has the highest Recall.

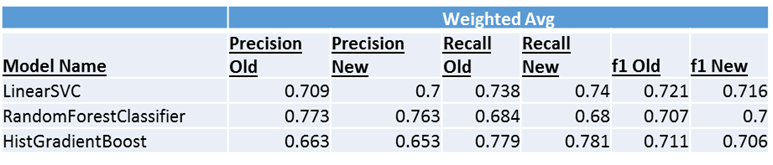
Recall that Precision = (True Positive/Total Predicted Positive) and Recall = (True Positive)/(Total Actual Positive), Extra Trees Classifier is the best model to use when the cost of any false positive is high and AdaBoost should be used if we want to filter out the most false negatives.

Now, for overall performance we should instead look at what we call the f1 score, which is a function of Precision and Recall where the formula is:

F1 = 2\*(Precision\*Recall)/(Precision + Recall)

From the table, the top 3 models that have the highest weighted average f1 score are: LinearSVC (f1 score = 0.721), RandomForestClassifier (f1 score = 0.707) and HistGradientBoost (f1 score = 0.711).

For the new combined data, due to additional processing time required for the addition of the new dataset, we only perform validation on the top 3 models with the highest f1 score:



As can be seen, the Precision, Recall and f1 scores drop slightly when additional data are added, but they do not affect the order of the performance ranking of these models.

* 1. How does the performance of the models change based on the choice of hyperparameters?

Attempts have been made to explore the hyperparameters for the project. We first explore the performance of the LinearSVC model based on the choice of hyper parameters. With LinearSVC, we explored the regularization parameter, or the C parameter of the model. We will explore the effects on the model when parameter C is set to 0.001, 1, 100 and 10000.

For the purpose of conducting gridsearch, we developed a new method perform\_grid\_search as found below:



However, it seems like only the default C value (1) can be successfully completed as the other C values fails to converge:



* 1. How are the misclassifications of the best performing model distributed?

1. Discussions
   1. Michael Lee’s Discussion the implications of the developed models

One useful scenario that may be useful for real-life application of this model is that it can be used to gauge the effectiveness of the Readme files. For example, in the world of internet marketing, we gauge the effectiveness of copywriting by its ability to sale their products or what they call the conversion rate. Similarly, we can adopt this method by linking our model with statistics such as the number of stars in the repository or visitor stats to see what kind of information, if included in their readmes, will increase people to visit, branch or star the repositories, therefore giving information to developers as to what information they should include in their readme files to maximize the effectiveness and increase popularity of their repository.

1. Conclusions
2. Citing Related Work

This section cites a variety of journal [5, 15], conference [1, 6, 8, 12, 13], and magazine [3] articles to illustrate how they appear in the references section. It also cites books [9, 10], a technical report [7], a PhD dissertation [4], an online reference [14], a software artifact [11], and a dataset [2].

As you build your article, you should note where you will be placing citations. If you are using numbered citations and references, the reference number - "...as shown in [5]..." is sufficient. If you are using the "author year" style, a reasonable placeholder is the primary author's last name and the year of publication - "...as shown in [Harel 1978]..." - we will be updating this placeholder later in the process with the citation label as generated by the Word macros in the "master template.

ACKNOWLEDGMENTS

Acknowledgments are placed before the references. Add information about grants, awards, or other types of funding that you have received to support your research. Author can capture the **grant sponsor information**, by selecting the grant sponsor text and apply style ‘GrantSponsor’. After this, select grant no and apply ‘GrantNumber’ from style panel. Example of Grant sponsor: Competitive Research Programme and example of Grant no: CRP 10-2012-03.

1. HISTORY DATES

In case of submissions being prepared for Journals or PACMs, please add history dates after References as (*please note revised date is optional*):

Received November 2019; revised August 2020; accepted December 2020

REFERENCES

1. G. A. A. Prana, C. Treude, F. Thung, T. Atapattu, and D. Lo, “Categorizing the Content of GitHub README Files - Empirical Software Engineering,” SpringerLink, 12-Oct-2018. [Online]. Available: https://link.springer.com/article/10.1007/s10664-018-9660-3. [Accessed: 11-Dec-2021].
2. Gprana. “Gprana/READMEClassifier.” GitHub, https://github.com/gprana/READMEClassifier.

A  APPENDICES

In the appendix section, three levels of Appendix headings are available.

A.1 General Guidelines (AppendixH2)

1. Save as you go and backup your file regularly.
2. Do not work on files that are saved in a cloud directory. To avoid problems such as MS Word crashing, please only work on files that are saved locally on your machine.
3. Equations should be created with the built-in Microsoft® Equation Editor included with your version of Word. (Please check the compatibility at <http://tinyurl.com/lzny753> for using MathType.)
4. Please save all files in DOCX format, as the DOC format is only supported for the Mac 2011 version.
5. Tables should be created with Word’s “Insert Table” tool and placed within your document. (Tables created with spaces or tabs will have problems being properly typeset. To ensure your table is published correctly, Word’s table tool must be used.)
6. Do not copy-and-paste elements into the submission document from Excel such as charts and tables.
7. Footnotes should be inserted using Word’s “Insert Footnote” feature.
8. Do not use Word’s “Insert Shape” function to create diagrams, etc.
9. Do not have references appear in a table/cells format as it will produce an error during the layout generation process.
10. MS Word does not consistently allow the original formatting to be modified in the text. In these cases, it is best to copy all the document’s text from the specific file and paste into a new MS Word document and then save it.
11. At times there are font problems such as “odd” stuff/junk characters that appear in the text, usually in the references. This can be caused by a variety of reasons such as copying-and-pasting from another file, file transfers, etc. Please review your text prior to submission to make sure it reads correctly.

A.1.1 Preparing Graphics (AppendixH3)

1. Accepted image file formats: TIFF (.tif), JPEG (.jpg).
2. Scalable vector formats (i.e., SVG, EPS and PS) are greatly preferred.
3. Application files (e.g., Corel Draw, MS Word, MS Excel, PPT, etc.) are NOT recommended.
4. Images created in Microsoft Word using text-box, shapes, clip-art are NOT recommended.
5. IMPORTANT: All fonts must be embedded in your figure files.
6. Set the correct orientation for each graphics file.

A.2 Placeholder Text

Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Vulputate sapien nec sagittis aliquam. Malesuada fames ac turpis egestas sed tempus urna. Posuere sollicitudin aliquam ultrices sagittis orci. Consequat id porta nibh venenatis cras sed felis eget. Pellentesque eu tincidunt tortor aliquam nulla facilisi cras fermentum odio. Tincidunt nunc pulvinar sapien et ligula ullamcorper malesuada proin. Tincidunt lobortis feugiat vivamus at augue. Eget nunc lobortis mattis aliquam faucibus. Egestas diam in arcu cursus euismod quis.

Erat pellentesque adipiscing commodo elit at imperdiet. In hac habitasse platea dictumst quisque sagittis purus. At lectus urna duis convallis. Eu mi bibendum neque egestas congue. Est ullamcorper eget nulla facilisi etiam dignissim diam. Sed ullamcorper morbi tincidunt ornare massa eget. Aenean vel elit scelerisque mauris pellentesque. Ullamcorper dignissim cras tincidunt lobortis feugiat vivamus. Cras fermentum odio eu feugiat pretium nibh. Congue eu consequat ac felis donec et odio pellentesque diam. Velit sed ullamcorper morbi tincidunt ornare massa eget egestas. In metus vulputate eu scelerisque felis imperdiet proin fermentum leo. Nulla malesuada pellentesque elit eget gravida cum.

Nullam ac tortor vitae purus faucibus ornare suspendisse. Libero enim sed faucibus turpis in eu mi bibendum neque. Sodales ut etiam sit amet nisl purus. Egestas diam in arcu cursus. Aliquet porttitor lacus luctus accumsan tortor. Pharetra magna ac placerat vestibulum lectus. Sit amet mauris commodo quis imperdiet massa tincidunt. In nisl nisi scelerisque eu ultrices vitae auctor. Nisi vitae suscipit tellus mauris a diam. Dui vivamus arcu felis bibendum ut tristique. Laoreet suspendisse interdum consectetur libero id.

Enim eu turpis egestas pretium. Nulla aliquet enim tortor at auctor urna. Id aliquet risus feugiat in. Non enim praesent elementum facilisis leo. Integer feugiat scelerisque varius morbi enim nunc faucibus. Egestas dui id ornare arcu odio ut sem nulla pharetra. Montes nascetur ridiculus mus mauris. Orci dapibus ultrices in iaculis. Enim sed faucibus turpis in eu mi bibendum neque. Faucibus pulvinar elementum integer enim neque volutpat ac tincidunt vitae. Et ultrices neque ornare aenean euismod elementum. Et pharetra pharetra massa massa ultricies mi quis hendrerit dolor. Tempus iaculis urna id volutpat lacus laoreet non curabitur gravida. Est velit egestas dui id ornare arcu odio. Eu facilisis sed odio morbi quis commodo odio. Lectus vestibulum mattis ullamcorper velit sed ullamcorper morbi tincidunt.

Eu non diam phasellus vestibulum lorem sed risus ultricies. Convallis aenean et tortor at risus viverra adipiscing at. Mauris pellentesque pulvinar pellentesque habitant morbi. Elementum sagittis vitae et leo duis. Massa enim nec dui nunc. Nisl tincidunt eget nullam non nisi est sit amet. Amet nisl purus in mollis nunc sed id semper. Fermentum leo vel orci porta non pulvinar neque laoreet suspendisse. Diam vel quam elementum pulvinar etiam non quam. Sagittis orci a scelerisque purus semper eget. Aliquet porttitor lacus luctus accumsan tortor. Integer vitae justo eget magna fermentum iaculis eu non diam. Egestas pretium aenean pharetra magna ac. Cursus metus aliquam eleifend mi in nulla. Cursus mattis molestie a iaculis at erat pellentesque adipiscing. Pulvinar pellentesque habitant morbi tristique senectus. Gravida cum sociis natoque penatibus et magnis dis parturient montes. In aliquam sem fringilla ut. Ut consequat semper viverra nam libero justo laoreet. Pellentesque diam volutpat commodo sed egestas.

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