Math Problem Generation

Aakarsh Jain, Vikrant Chap, Vaibhav Charan, Priyanka Kyi Soe & Christopher Tan

BACKGROUND & MOTIVATION

This unique math learning application offers a revolutionary approach to education. Students can easily scan and convert math problems into digital format and receive customized practice problems tailored to their difficulty level. This personalized learning experience greatly enhances comprehension and understanding of complex mathematical concepts by breaking it down into simpler parts and offering visual aids to help students learn better. This reinforces their understanding, particularly for abstract ideas. Beyond benefiting students, teachers alike can utilize this tool to offer targeted support to their students, and track their progress and identify concepts that need better understanding/more practice. Thus, **our math learning application seamlessly integrates OCR and NLP technologies to provide tailored practice problems and optional visual aids, enhancing comprehension and engagement in math education, and benefiting students in the long run.**

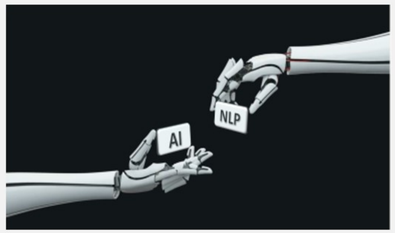
RESEARCH METHODOLOGY

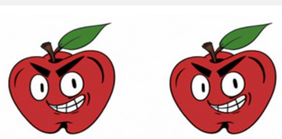
Tesseract OCR | Python

We use the PyTesseract Library's image_to_string function to get the text sections from the image. We initially used the image_to_data function, but saw better results with the former.

Generated problems are created using a fine-tuned large language model (LLM). The fine-tuning process trains on a dataset consisting of >10000 test math problems and learns from similarities between the problems. After learning from the data, the model generates problems in the correct style and to match the level of difficulty of the input.

To generate images, we first process the operational word problems. We begin with classification of the word problems, then extraction of key entities that aid our image generation using Spacy and NLTK (Natural Language Toolkit). The key entities we extract are the numerical quantity(s), the subject(s), and the operation, and this is done through an original algorithm based on the sentence dependencies in each word problem.





How many apples does Janet have?

Once processed, we use Dall-e 3, a diffusion-based text-to-image model to generate the subject(s), then stitch the quantity of each subject together to create a conceptual image.

All these technologies are integrated and deployed using a local Python Django server that enables seamless transition between html pages, and has built in functionalities like logins, live image displaying and input validation using forms.

LITERATURE REVIEW

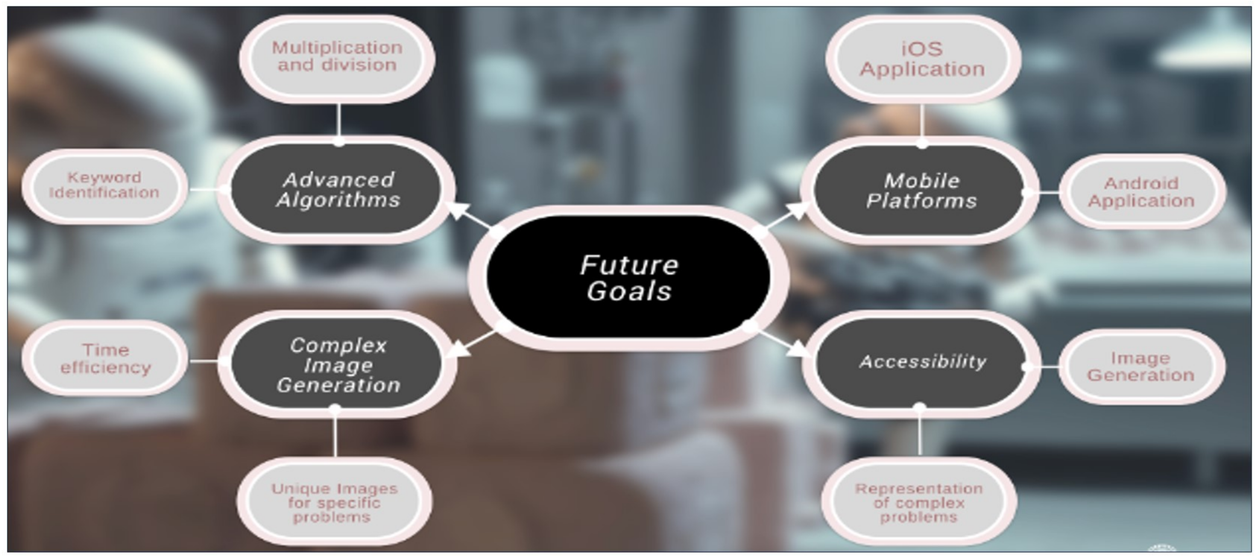
Existing studies are not practice-oriented!

1. A theme-rewriting approach for algebra word problems for personalized learning (Koncel-Kedziorski et al., 2016)
2. Topic-aware math problem generations (Zhao et al., 2023)
3. Math problem solver with problem type classification (Yao et al., 2023)
4. Automatic math problem solvers (Zhang et al., 2023)
5. An intelligent math problem solver (Mandal & Naskar, 2021)

CONCLUSIONS

Key Features

1. Digitization of math problems with OCR
2. Math word problem classification through semantic segmentation with NLP
3. Accurate image splicing
4. Meaningful practices of math word problems
5. Personalized learning experience
6. Web application with Django server backend and HTML frontend



REFERENCES & ACKNOWLEDGEMENTS

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1. Koncel-Kedziorski, R., Konstas, I., Zettlemoyer, L., & Hajishirzi, H. (2016). A theme-rewriting approach for generating algebra word problems. arXiv preprint arXiv:1610.06210.
2. Mandal, S., & Naskar, S. K. (2021). Classifying and solving arithmetic math word problems—an intelligent math solver. IEEE Transactions on Learning Technologies, 14(1), 28-41.
3. Yao, J., Zhou, Z., & Wang, Q. (2023, October). Solving math word problem with problem type classification. In CCF International Conference on Natural Language Processing and Chinese Computing (pp. 123-134). Cham: Springer Nature Switzerland.
4. Zhang, D., Wang, L., Zhang, L., Dai, B. T., & Shen, H. T. (2019). The gap of semantic parsing: A survey on automatic math word problem solvers. IEEE transactions on pattern analysis and machine intelligence, 42(9), 2287-2305.
5. Zhao, T., Chai, C., Liu, J., Li, G., Feng, J., & Liu, Z. (2023, April). A Topic-Aware Data Generation Framework for Math Word Problems. In International Conference on Database Systems for Advanced Applications (pp. 286-302). Cham: Springer Nature Switzerland.