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Advances in Recommender Systems for Some Applications

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This thesis is submitted to University College Dublin in fulfilment of the requirements for the degree of Doctor of Philosophy

School of Computer Science

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January, 2024

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LISTINGS

ACRONYMS

DRY Don't Repeat Yourself

RS recommender system

CF collaborative filtering

ABSTRACT

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

DECLARATION

I hereby certify that the submitted work is my own work, was completed while registered as a candidate for the degree stated on the Title Page, and I have not obtained a degree elsewhere on the basis of the research presented in this submitted work.

Eolas MacDalta,

July 9, 2024

COLLABORATIONS

This work was conducted in collaboration with the following:

- Dr. A. N. Other The work in Chapter 3 was conducted while visting the laboratory of Dr. A. N. Other.

PUBLICATIONS

Swap these out for your own publication list (FrontBackmatter/MyPublications.bib).

[1] Xiangnan He, Lizi Liao, Hanwang Zhang, Liqiang Nie, Xia Hu, and Tat-Seng Chua. "Neural collaborative filtering". In: *Proceedings of the 26th international conference on world wide web*. 2017, pp. 173–182.

[2] Yehuda Koren, Robert Bell, and Chris Volinsky. "Matrix factorization techniques for recommender systems". In: *Computer*. Vol. 42. 8. IEEE. 2009, pp. 30–37.

[3] Steffen Rendle. "Factorization machines". In: *2010 IEEE International Conference on Data Mining*. IEEE. 2010, pp. 995–1000.

[4] Francesco Ricci, Lior Rokach, and Bracha Shapira. "Introduction to recommender systems handbook". In: *Recommender systems handbook* (2011), pp. 1–35.

[5] Badrul Sarwar, George Karypis, Joseph Konstan, and John Riedl. "Item-based collaborative filtering recommendation algorithms". In: *Proceedings of the 10th international conference on World Wide Web*. 2001, pp. 285–295.

[6] J Ben Schafer, Dan Frankowski, Jon Herlocker, and Shilad Sen. "Collaborative filtering recommender systems". In: *The adaptive web* (2007), pp. 291–324.

[7] Yunhong Zhou, Dennis Wilkinson, Robert Schreiber, and Rong Pan. "Large-scale parallel collaborative filtering for the netflix prize". In: *Proceedings of the 4th international conference on Algorithmic Aspects in Information and Management (AAIM)*. Springer. 2008, pp. 337–348.

We have seen that computer programming is an art,
because it applies accumulated knowledge to the world,
because it requires skill and ingenuity, and especially
because it produces objects of beauty.

— Donald E. Knuth [3]

ACKNOWLEDGMENTS

Put your acknowledgments here.

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Ohana means family.

Family means nobody gets left behind, or forgotten.

— Lilo & Stitch

Dedicated to the loving memory of Rudolf Miede.

1939 – 2005

1

INTRODUCTION

In an era marked by an exponential growth of information and digital content, recommender system (RS) have emerged as pivotal tools in helping users navigate through the vast sea of choices. These systems are integral to numerous applications, from online shopping and streaming services to social media and personalized news feeds. By leveraging advanced algorithms and data-driven techniques, recommender systems aim to predict user preferences and deliver highly relevant content, thereby enhancing user experience and engagement [4].

The inception of recommender systems can be traced back to the early days of collaborative filtering (CF), which relied on user and item similarities to generate recommendations. Since then, the field has witnessed substantial advancements, incorporating sophisticated models such as matrix factorization, neural networks, and hybrid approaches that blend multiple recommendation strategies. These developments have significantly improved the accuracy and efficiency of recommendations, catering to diverse user needs and preferences [5].

Despite the remarkable progress, several challenges remain in the design and implementation of recommender systems. Issues such as scalability, cold-start problems, diversity, and fairness continue to pose significant hurdles. Furthermore, the rapid evolution of user behaviors and the dynamic nature of content necessitate continuous adaptation and innovation in recommendation methodologies [1].

This thesis aims to contribute to the ongoing discourse in the field of recommender systems by addressing key challenges and proposing novel solutions that enhance recommendation quality and user satisfaction. Through a comprehensive exploration of state-of-the-art techniques and rigorous empirical evaluations, this research endeavors to advance our understanding of effective recommendation strategies and their practical applications.

The structure of this thesis is as follows: Chapter 2 provides a detailed overview of the historical development and foundational concepts of recommender systems. Chapter 2 delves into the various algorithmic approaches [2], highlighting their strengths and limitations [3].

Chapter 3 addresses the pressing challenges in the field and reviews contemporary solutions proposed in the literature. Chapter 4 presents the proposed methodologies and experimental setups, followed by a thorough analysis of results in Chapter 5. Finally, Chapter 6 concludes the thesis with a summary of findings, implications, and directions for future research.

By systematically investigating and addressing the complexities of recommender systems, this thesis aspires to contribute valuable insights and practical advancements to the field, ultimately fostering more personalized and effective user experiences across digital platforms.

2 BACKGROUND

2.1 SECTION A

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- First item in a list
- Second item in a list
- Third item in a list

LABITUR BONORUM PRI NO	QUE VISTA	HUMAN
fastidii ea ius	germano	demonstratea
suscipit instructior	titulo	personas
quaestio philosophia	facto	demonstrated

Table 2.1: Autem usu id.

2.1.1 *Subsection B*

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Part I

PART I

3 TOPIC A

3.1 SECTION A

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- Second item in a list
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suscipit instructior	titulo	personas
quaestio philosophia	facto	demonstrated

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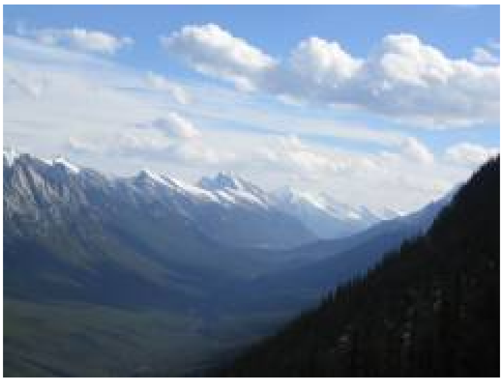
Lo sed apprende instruite. Que altere responder su, pan ma, i. e., signo studio. Figure 3.1b Instruite preparation le duo, asia altere tentation web su. Via unic facto rapide de, iste questiones methodicamente o uno, nos al.

$$\mathbf{A} = \begin{bmatrix} \mathbf{0} & \mathbf{R} \\ \mathbf{R}^T & \mathbf{0} \end{bmatrix} \tag{3.1}$$

(a) Asia personas duo.

(b) Pan ma signo.



(c) Methodicamente o uno.

(d) Titulo debitas.

Figure 3.1: Tu duo titulo debitas latente. Don't Repeat Yourself (DRY)

4

TOPIC B

4.1 SECTION A

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

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Part II

PART II

5 TOPIC C

5.1 SECTION A

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6 CONCLUSION

6.1 SECTION A

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Part III

APPENDIX

A

APPENDIX

A.1 SECTION A

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COLOPHON

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1 UCD Thesis Style