Using Factorization Machines to Predict Game Difficulty

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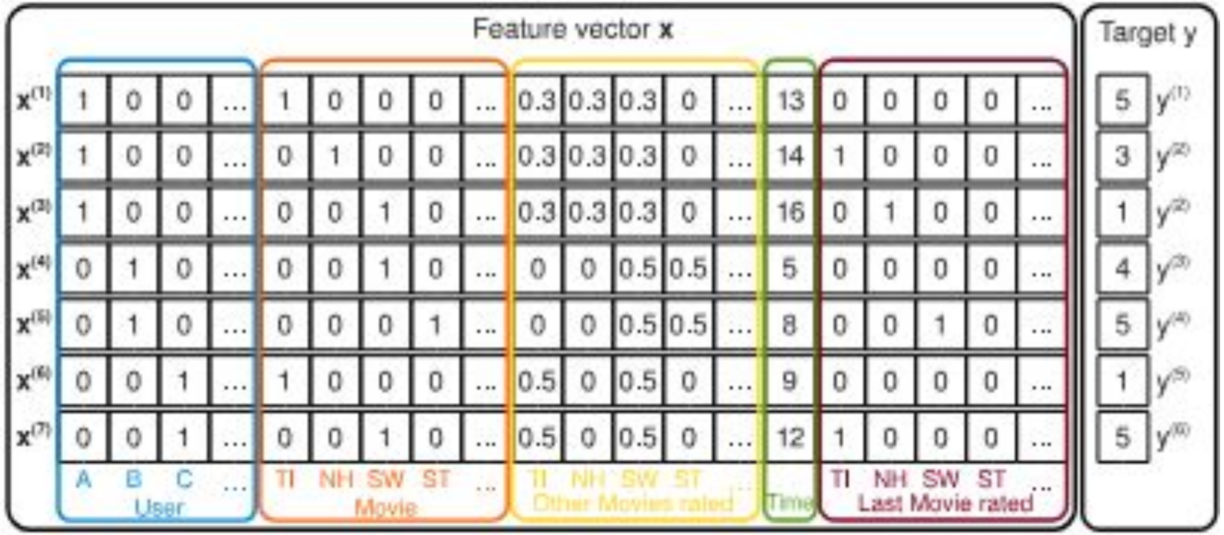
Defining Game Difficulty

- Ambiguous
- Difficult to numerically model
- Individual Difficulty too difficult to model
    - Requires small Dataset
    - Requires special Cases/game design

Models Used

- Linear Regression
- Random Forest Regression
- Factorization Machines



Source: [2]

Algorithm

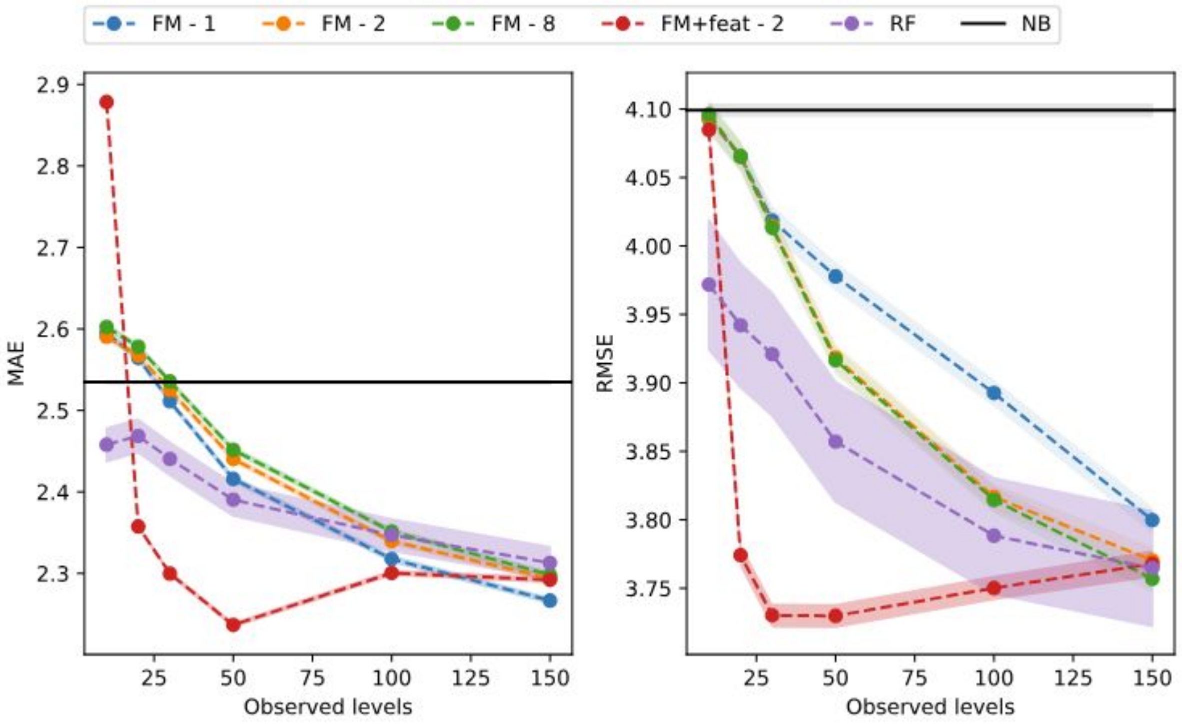
- Naive Baseline/Linear Regression
- Generate relation pattern data
- Add vector calculation to naive baseline
- Searches through dataset, but does not make them dependant of each other
- Reduces the impact of curse of dimensionality

$$\hat{y} = w_0 + \sum_{i=1}^{n} w_i x_i + \sum_{i=1}^{n} \sum_{j=i+1}^{n} \langle \mathrm{v_i}, \mathrm{v_j} \rangle x_i x_j,$$

$$\langle \mathrm{v_i}, \mathrm{v_j} \rangle = \sum_{f=1}^{k} v_{i,f} \cdot v_{j,f},$$

Source: [1]

Results - Factorization Machines are Successful



Source: [1]

Results - Comparing v1 and v2 parameters

Hard level with the highest v1

Source: [1]

Future Work - Left Kind of Underwhelmed

Source: [1]

Future Work - Dynamically Changing Difficulty

Type of feature	Name	Description
Player features	Attempts	Number of attempts on levels
	Moves used	Number of moves used relative to the move limit when completing the level
	Pre-game boosters	Boosters that can be used before starting the level
	In-game boosters	Boosters that can be used while playing the level
	Powerpieces, total	Number of power pieces created while playing the level
	Powerpieces, combos	Number of power piece combinations created while playing the level
	Rockets, solo	Number of rockets created and used on their own
	Rocket-bomb combo	Number of rocket-bomb combos created and used
	Rocket-magic combo	Number of rocket-magic combos created and used
	Bomb-magic combo	Number of bomb-magic combos created and used
Level attributes	Attempts	Average number of attempts on level by players in training set
	Color entropy	Entropy of color spawning weights; $S = -\sum_i p_i \log p_i$
	Colors	Number of unique colors in the level
	SpreadingBlocker, cg	Levels with a spreading blocker as collect goal (cg)
	LayerCake, cg	Levels with a specific blocker with 3 hitpoints as a collect goal
	ConsecutiveBlocker, cg	Levels with a blocker that requires two attacks in a row as a collect goal
	MegaMultiColorBlocker	Levels with a large blocker that requires matching multiple colors to remove
	Teleport	Levels with a teleport mechanic that transports pieces around the board

Source: [1]

Conclusion

- Paper demonstrates how factorization machines can be utilized in game development.
- It lays the groundwork for demonstrating that factorization machines are likely capable of being used to dynamically change game difficulty in real-time.

Questions?

References

[1] Kristensen, J. T., Guckelsberger, C., Burelli, P., & Hämäläinen, P. (2022, September 6). Personalized Game Difficulty Prediction Using Factorization Machines. arXiv.org. https://arxiv.org/abs/2209.13495

[2] Rendle, Steffen. "Factorization Machines", (Japan, Osaka University) https://www.ismll.uni-hildesheim.de/pub/pdfs/Rendle2010FM.pdf