



**UNIVERSITÀ
DEGLI STUDI
DI TRIESTE**

**Dipartimento di Matematica,
Informatica e Geoscienze**

CONTEXTUAL PREFERENCE RANKING PER RACCOMANDAZIONI DI CARTE IN MAGIC: THE GATHERING

Laureando:

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Relatrice:

T. Petrov

Giochi e Intelligenza Artificiale

Giochi da tavolo e videogiochi: un terreno fertile per la ricerca in ambito IA

- Giochi a informazione perfetta e non stocastici: teoricamente risolvibili, agenti artificiali hanno superato le capacità umane in diverse aree



Febbraio 1996, Garry Kasparov viene battuto dal supercomputer Deep Blue di IBM: è la prima vittoria di un'intelligenza artificiale contro un grande maestro umano



Marzo 2016, il programma AlphaGo di Google DeepMind supera il campione Lee Sedol in un gioco a lungo considerato dominio esclusivo dell'intuito umano

- I giochi a informazione imperfetta presentano ancora sfide significative

Intelligenza Artificiale in Magic: The Gathering

Complessità derivante da due parti complementari:

FASE DEL GIOCO

Informazioni parziali, componenti stocastiche, componenti sociali, alto livello di interazione tra giocatori ...

Magic: The Gathering is Turing Complete

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Abstract—*Magic: The Gathering* is a popular and famously complicated trading card game about magical combat. In this paper we show that optimal play in real-world *Magic* is at least as hard as the Halting Problem, solving a problem that has been open for a decade [1], [10]. To do this, we present a methodology for embedding an arbitrary Turing machine into a game of *Magic* such that the first player is guaranteed to win the game if and only if the Turing machine halts. Our result applies to how real *Magic* is played, can be achieved using standard-size tournament-legal decks, and does not rely on stochasticity or hidden information. Our result is also highly unusual in that all moves of both players are forced in the construction. This shows that even recognising who will win a game in which neither player has a non-trivial decision to make for the rest of the game is undecidable. We conclude with a discussion of the implications for a unified computational theory of games and remarks about the playability of such a board in a tournament setting.

successful and highly flexible framework for modelling games as computations.

The core of this paper is the construction presented in Section IV: a universal Turing machine embedded into a game of *Magic: The Gathering*. As we can arrange for the victor of the game to be determined by the halting behaviour of the Turing machine, this construction establishes the following theorem:

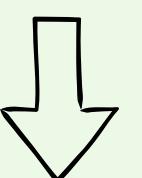
Theorem 1: Determining the outcome of a game of *Magic: The Gathering* in which all remaining moves are forced is undecidable.

A. Previous Work

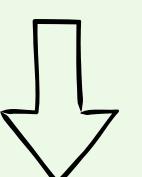
Prior to this work, no undecidable real games were known to exist. Demaine and Hearn (2009) [10] note that almost every

FASE DI COSTRUZIONE DEL MAZZO

Problema di ottimizzazione combinatoria vincolata su oltre 30 000 elementi unici



Strumenti online per costruzione di mazzi

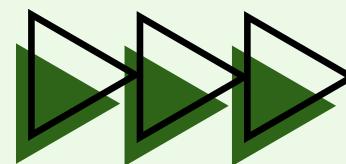


Posso creare un'alternativa?

PANORAMICA DEL PROCESSO

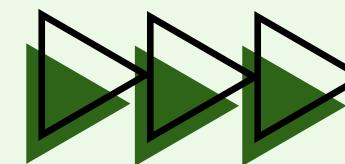
1. Acquisizione Dati

- Carte (Scryfall)
- Mazzi (Archidekt)
- Articoli (EDHREC)



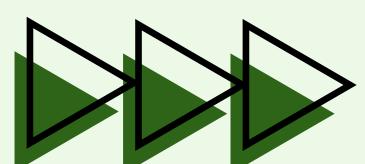
2. Realizzazione Modelli

- Definizione Dataset e Modelli
- Modelli Linguistici
- Modelli CPR



3. Sviluppo Sistema

- Database Vettoriale
- Sistema di Raccomandazione



4. Demo e Valutazione

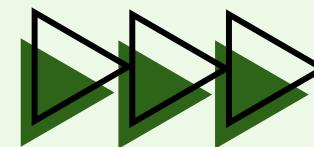
- Demo On-line
- Raccolta Feedback Utenti

1. ACQUISIZIONE DEI DATI

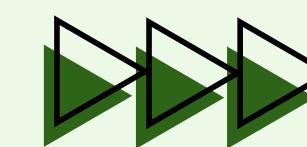
Carte: blocco fondamentale per l'apprendimento



Scryfall

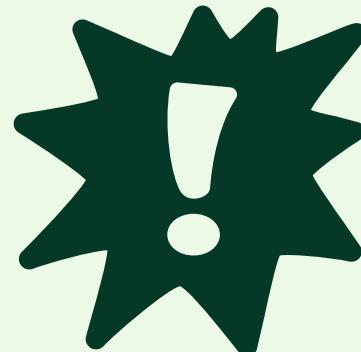


Informazioni sulle carte

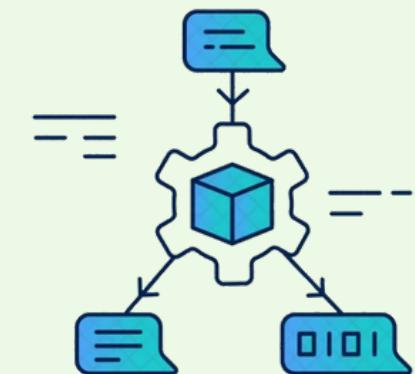
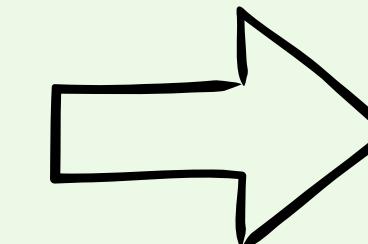


tensor([3.0000e+00, 1.8566e-01,
0.0000e+00, -4.3157e-03, ...

Rappresentazioni vettoriali



Il testo delle carte definisce come queste si comportano durante il gioco



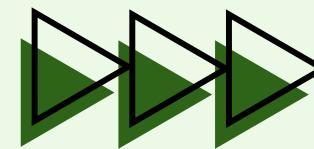
Modello linguistico specializzato

1. ACQUISIZIONE DEI DATI

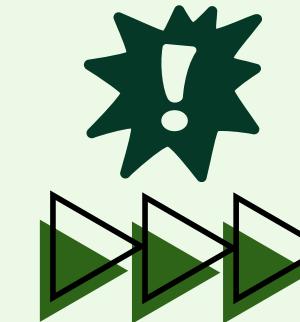
Carte: blocco fondamentale per l'apprendimento



Scryfall



Informazioni sulle carte



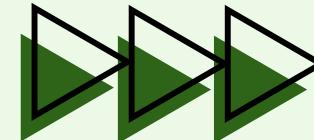
tensor([3.0000e+00, 1.8566e-01,
0.0000e+00, -4.3157e-03, ...

Rappresentazioni vettoriali

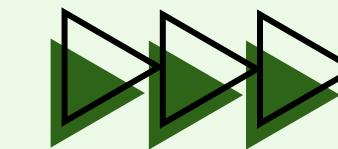
Articoli: scaricati da EDHREC, decomposti in paragrafi e filtrati per rilevanza.

Accostati al **regolamento** e ai **testi delle carte** per allenare il modello linguistico

Mazzi: ciò che il modello CPR imparerà a ricostruire



Lista di mazzi di carte



tensor([[3.0000e+00, 1.8566e-01,
0.0000e+00, -4.3157e-03, ...

Rappresentazioni vettoriali

METRIC LEARNING CON RETI SIAMESI

Branca dell'apprendimento supervisionato che mira a imparare una funzione di distanza che rispecchi la similità reale tra oggetti

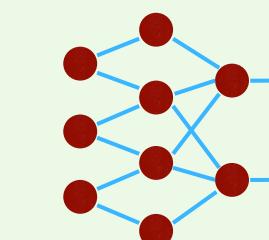
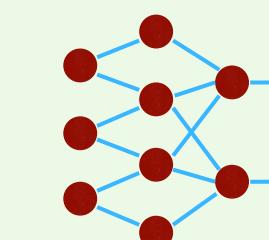
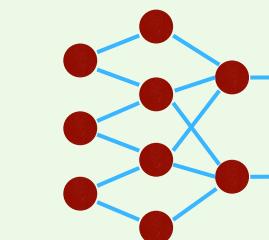
Riferimento



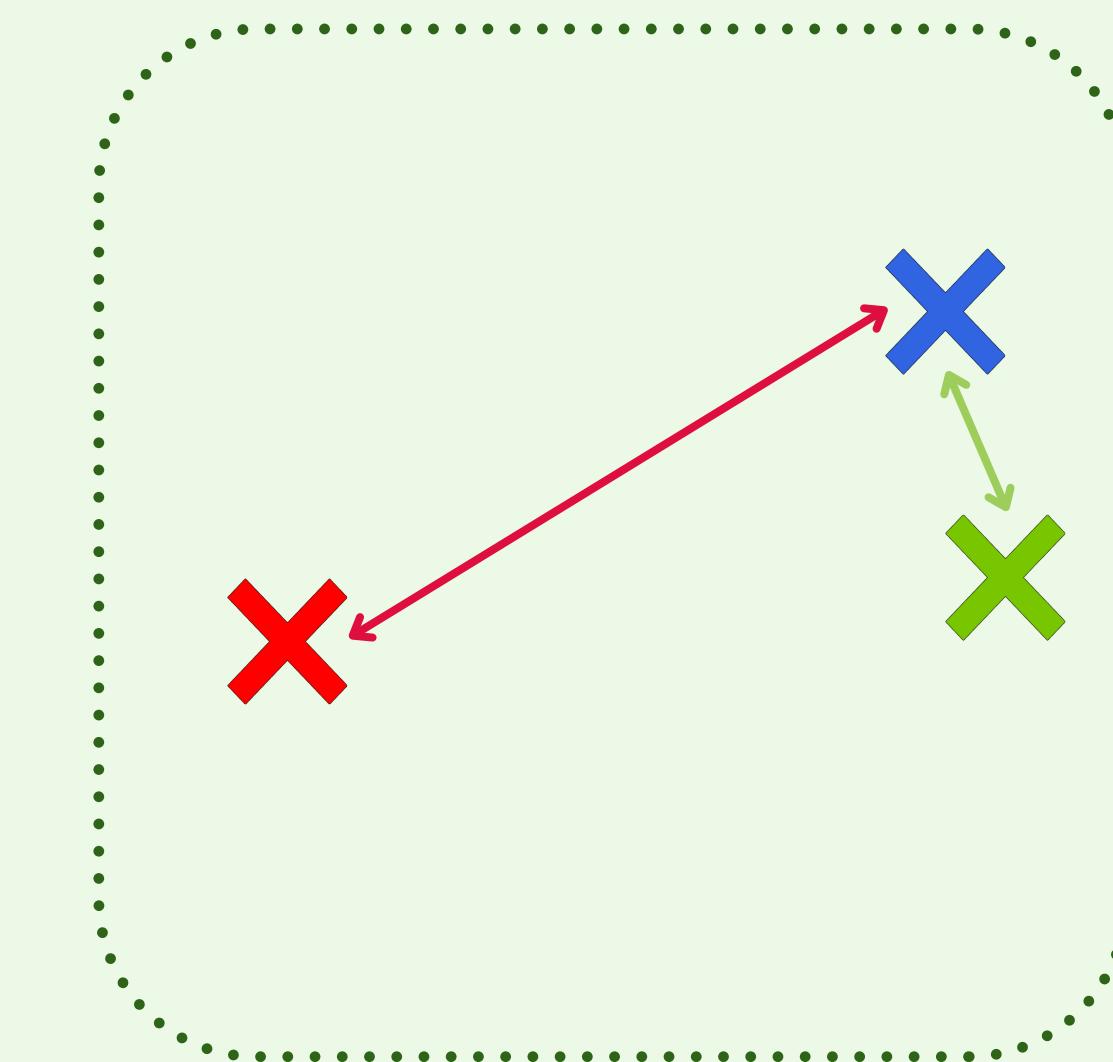
Elemento simile



Elemento dissimile



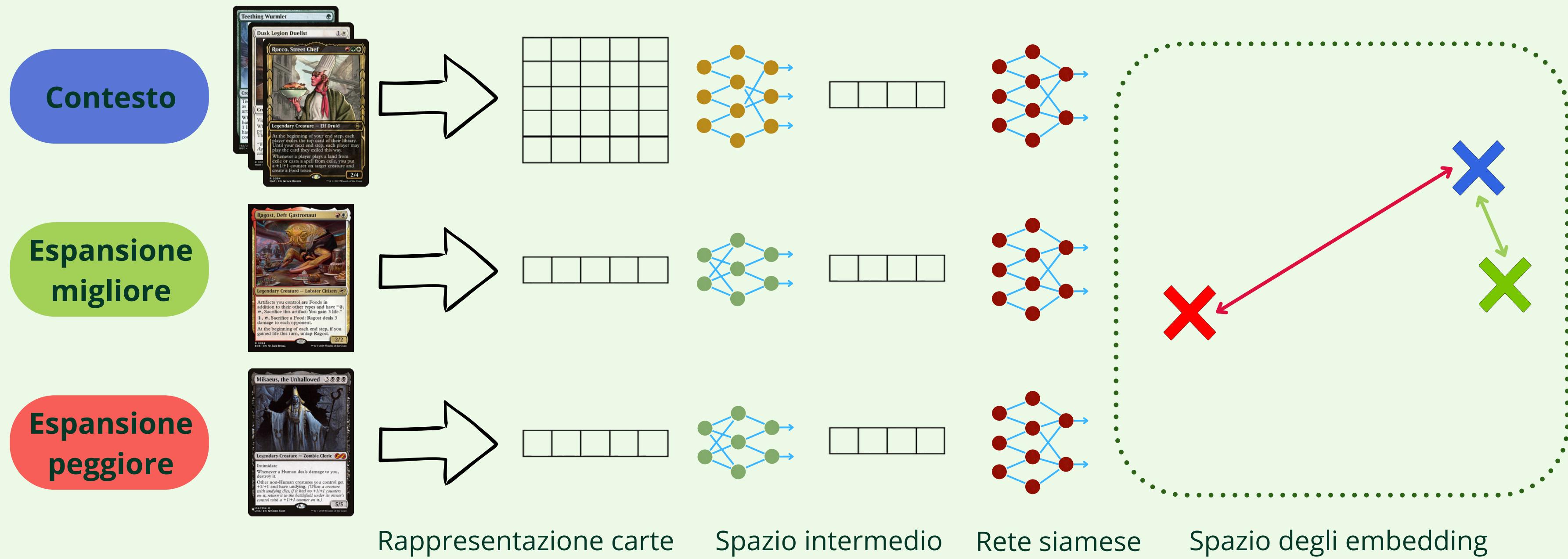
Rete siamese



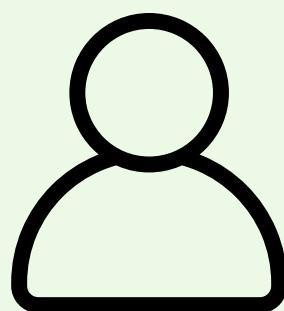
Spazio degli embedding

2. ADDESTRAMENTO MODELLO CPR

Obiettivo: imparare una rappresentazione degli oggetti (carte) ed dei contesti (mazzi) condivisa, tale per cui gli oggetti più vicini ad un contesto sono quelli che lo espandono meglio



3. SVILUPPO DEL SISTEMA



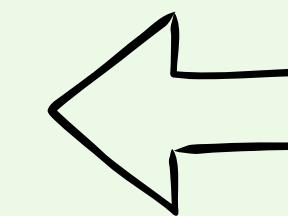
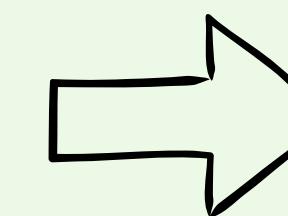
Utente



Mazzo incompleto
+
Prompt (opzionale)



Carte consigliate



Modello CPR

Embedding del mazzo
+
Contesto del prompt

Database
Vettoriale

Prima batch di consigli

Diversificazione

4. DEMO E VALUTAZIONE

MTG Card Recommender System (with Feedback)

Archidekt Deck URL
https://archidekt.com/decks/5096356/animar_colorless

Optional Prompt

Select Model Version
Complete Dataset (200 Epochs, InfoNCE) s2

Get Recommendations

Recommended Cards

Card Name	Card Description
vernal equinox	Aura player may play creature and enchantment spells any turn for as long as this card is on the battlefield.
wumpus aberration	Creature — Eldrait Beast
tyrannid prime	Creature — Tyroid
thunderous snapper	Creature — Turtle Hydra
the thirteenth doctor	Legendary Creature — Time-Lord Doctor
wastescape battlemage	Creature — Eldrait Wizard
susan foreman	Legendary Creature — Time Lord
clockwork hydra	Artifact Creature — Hydra
basilisk gate	Land — Gate
skyrider elf	Creature — Elf Warrior Ally

Rate the Recommendations
Please rate each card on a scale of 1 (bad) to 5 (excellent).

Card Name	Rating Scale
vernal equinox	1 to 5
wumpus aberration	1 to 5
tyrannid prime	1 to 5
thunderous snapper	1 to 5
the thirteenth doctor	1 to 5
wastescape battlemage	1 to 5
susan foreman	1 to 5
clockwork hydra	1 to 5
basilisk gate	1 to 5
skyrider elf	1 to 5

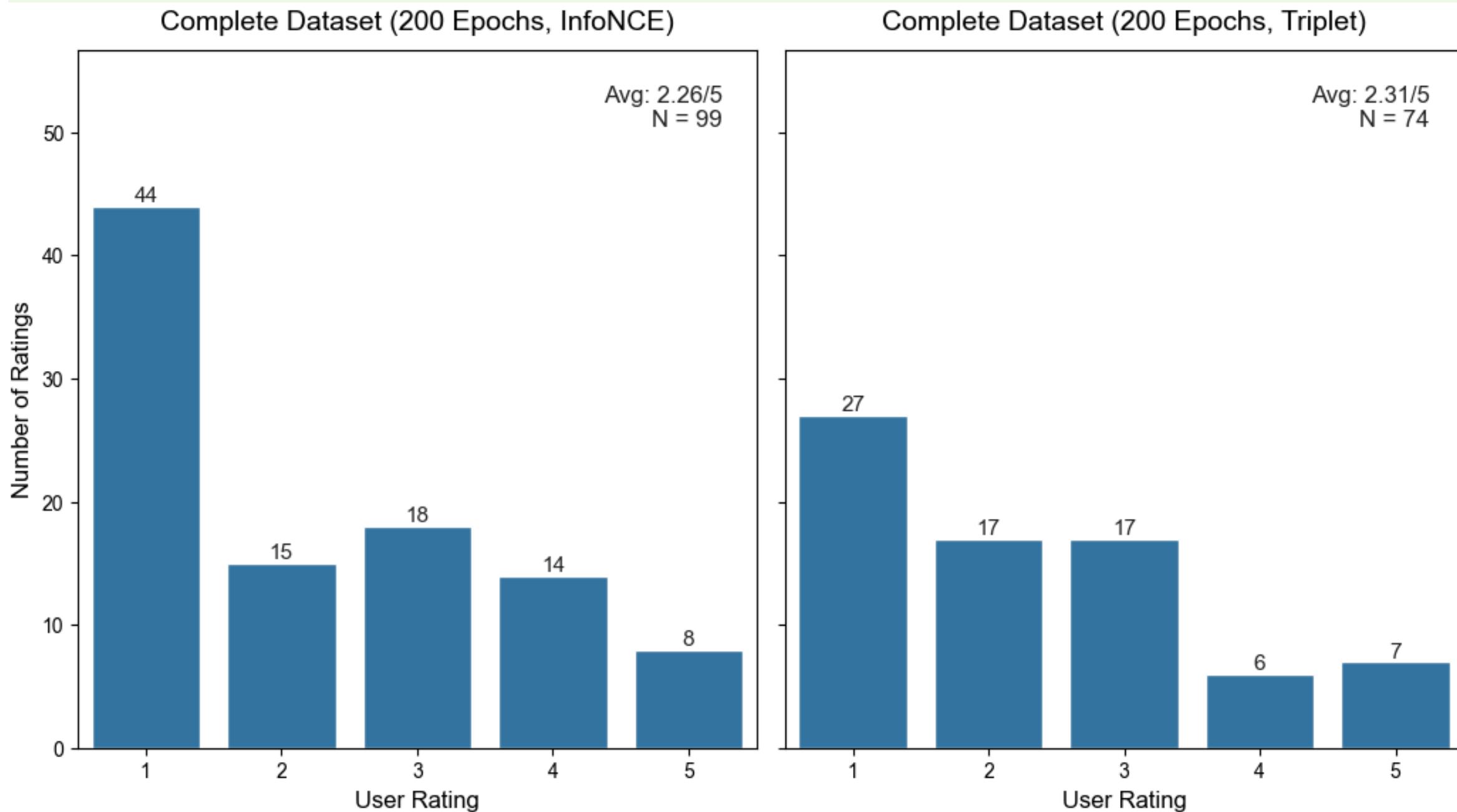
Submit Feedback Status

Schermata presa durante l'utilizzo della demo: l'utente fornisce il link al suo mazzo, il sistema recupera ed espone le raccomandazioni

L'utente può fornire feedback sulle prestazioni del modello scelto valutando le carte consigliate

4. DEMO E VALUTAZIONE

L'utilità percepita da parte degli utenti è risultata superiore rispetto ai risultati legati alla valutazione delle carte



Grafici raffiguranti i risultati, forniti da utenti esperti attraverso la demo, di due dei modelli meglio performanti

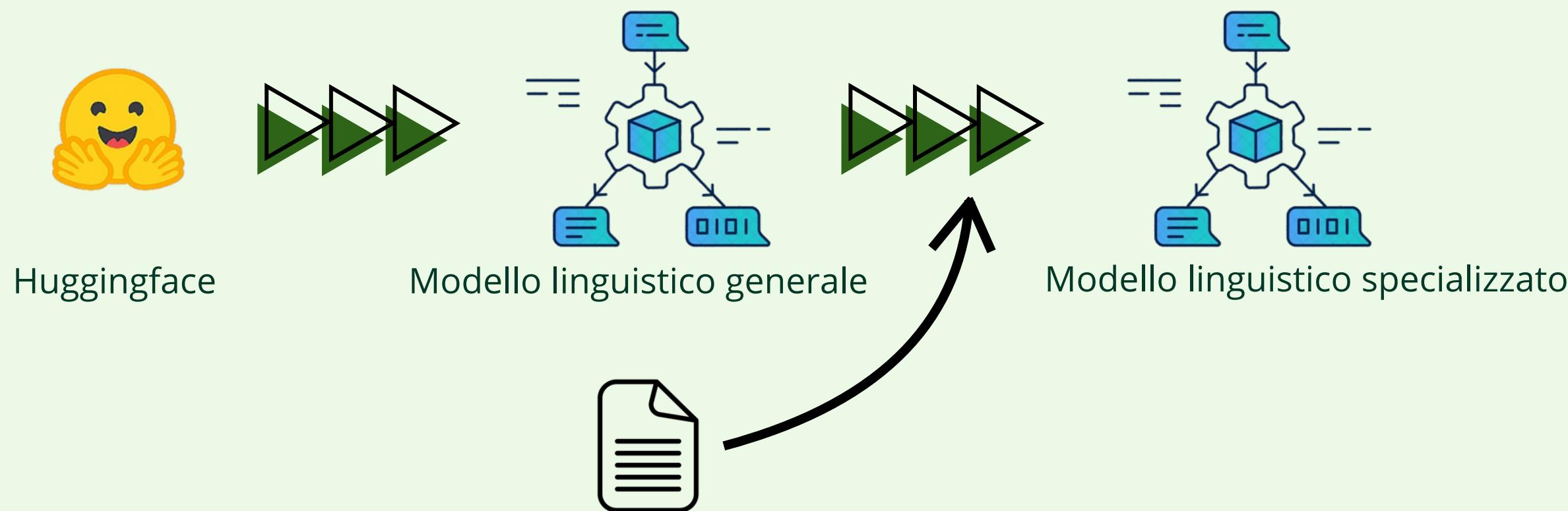


GRAZIE PER L'ATTENZIONE

EXTRA: ADDESTRAMENTO MODELLO LINGUISTICO

Problema: Modelli linguistici generici non catturano il lessico specifico di Magic

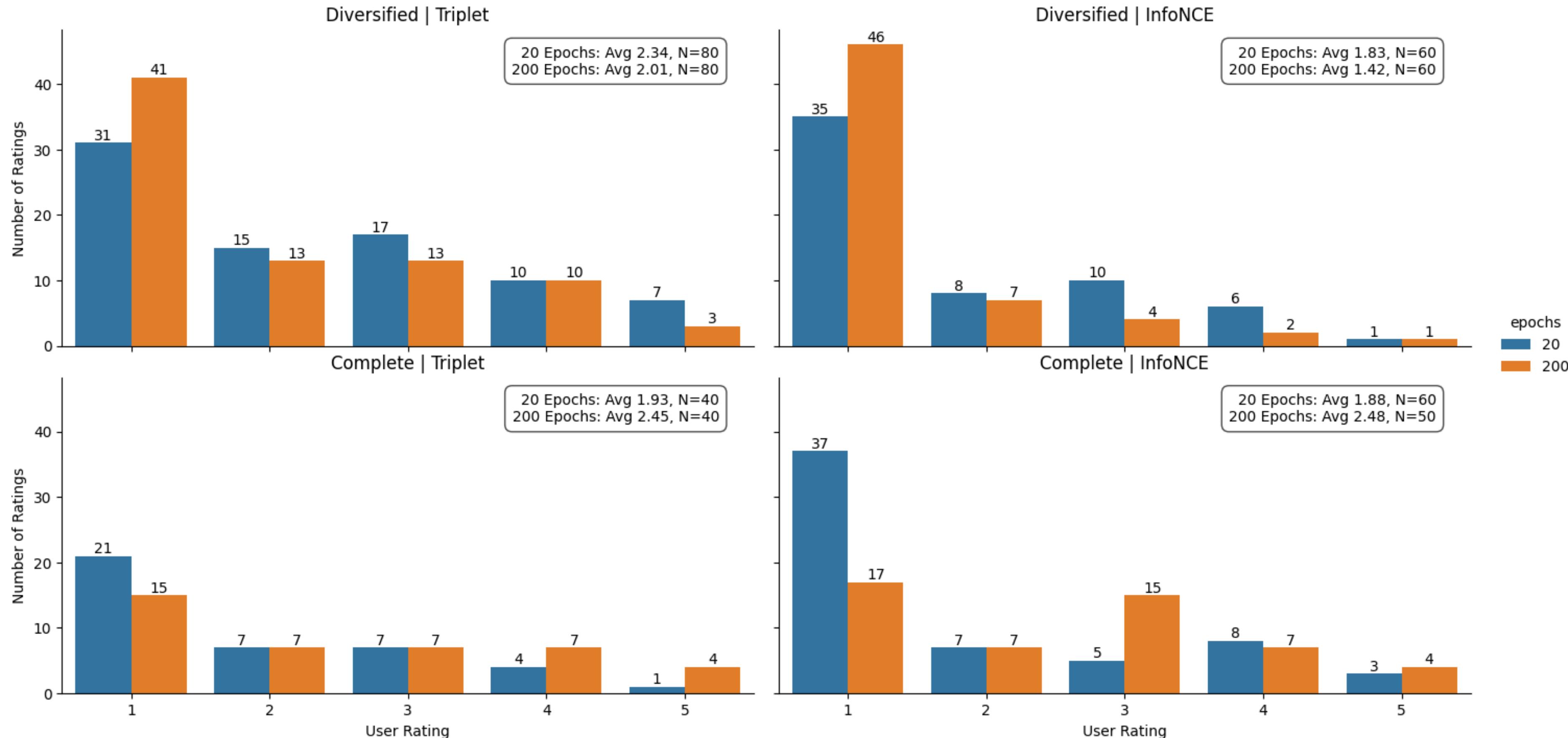
Soluzione: Fine-tuning di un modello preallenato



- Regolamento
- Testi oracle
- articoli rilevanti

EXTRA: VALUTAZIONE MODELLI

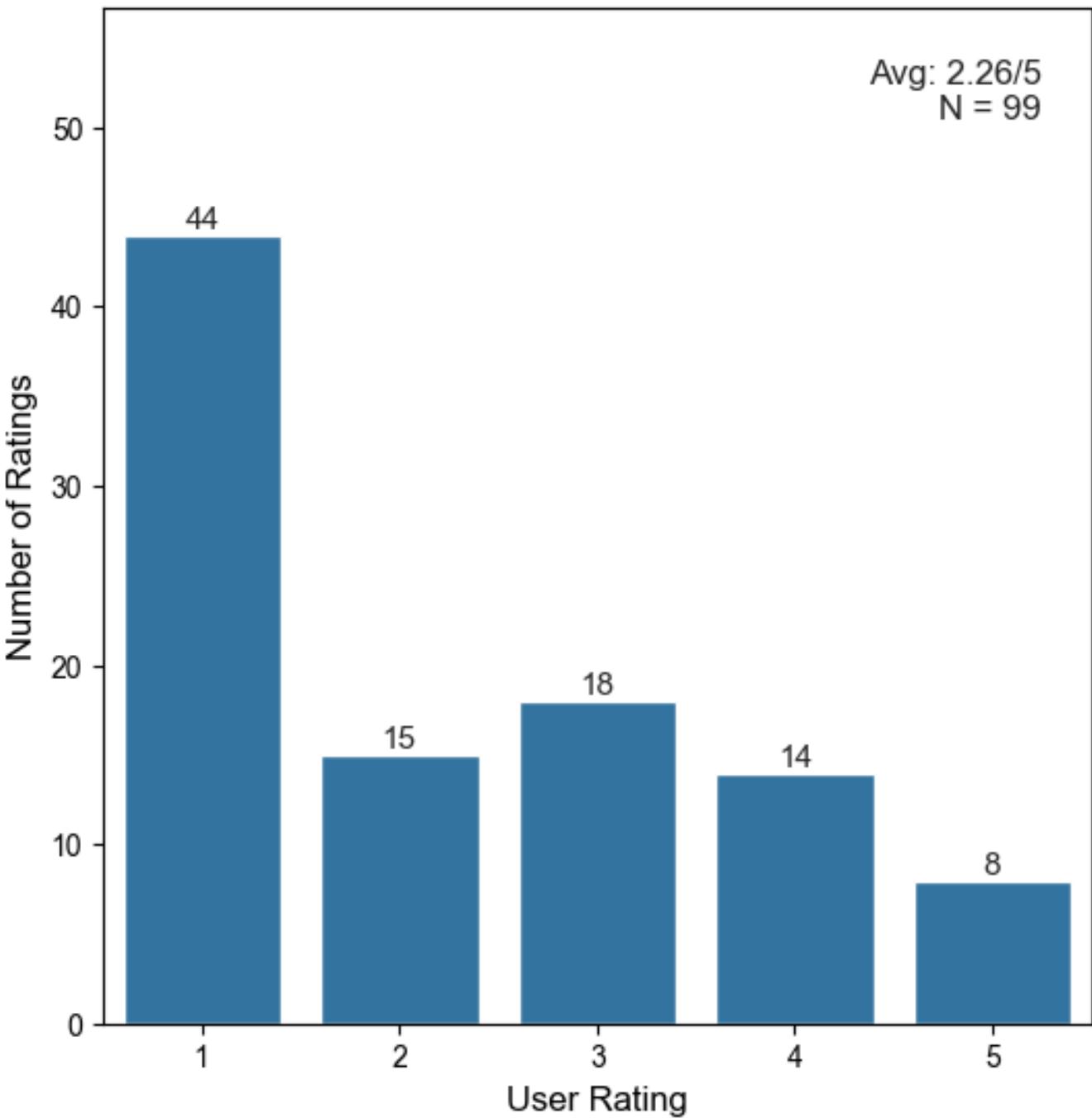
User Feedback Analysis by Training Configuration



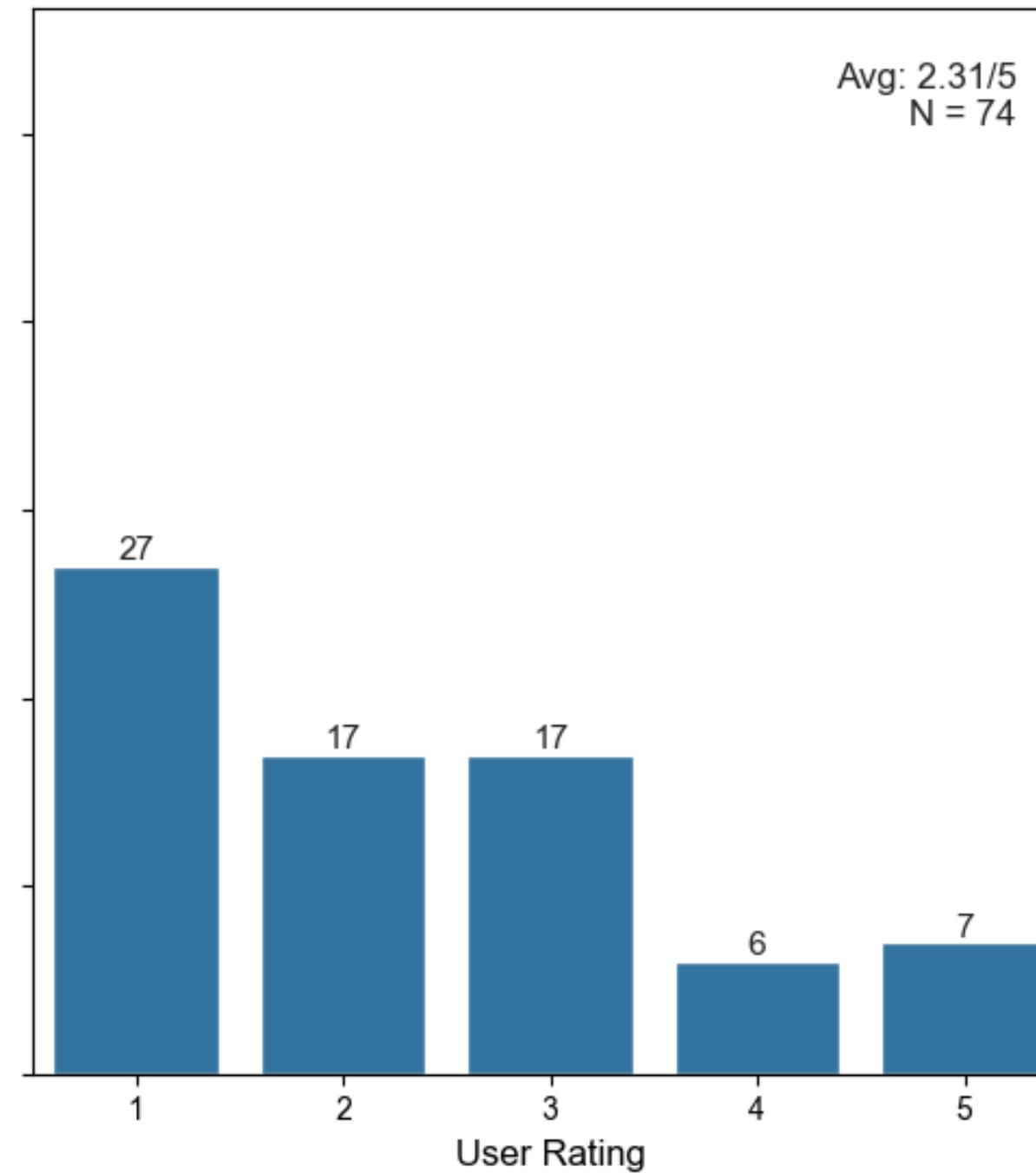
EXTRA: VALUTAZIONE MODELLI

Final Model Performance Comparison based on User Ratings

Complete Dataset (200 Epochs, InfoNCE)



Complete Dataset (200 Epochs, Triplet)



Diversified Dataset (20 Epochs, Triplet)

