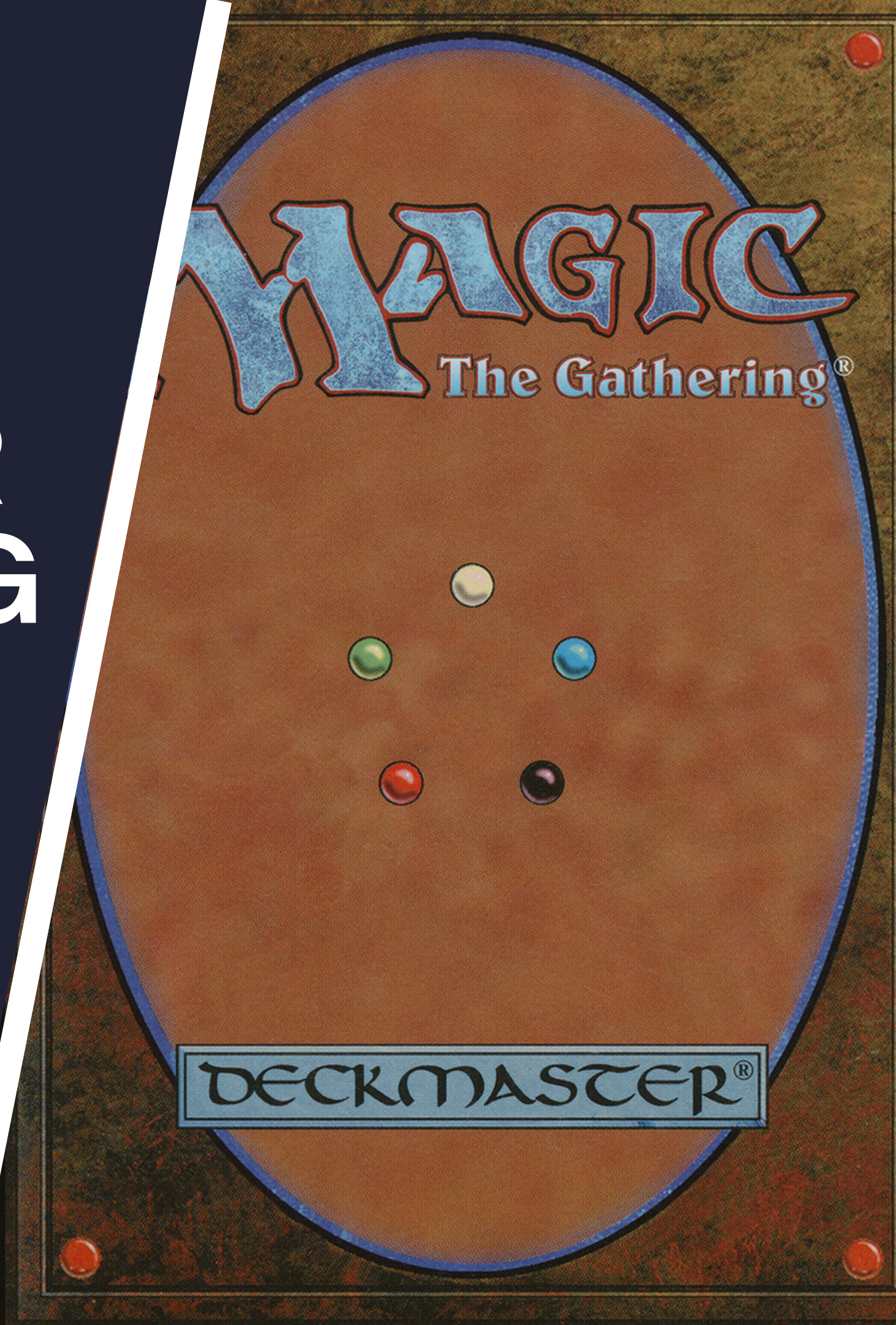


LEARNING WITH GENERALISED CARD REPRESENTATIONS FOR MAGIC: THE GATHERING

Timo Bertram, Johannes Fürnkranz, Martin Müller

Johannes Kepler University Linz, University of Alberta

IEEE Conference on Games 2024



Inkmoth Nexus



Land



☞: Add \diamond .

1: Inkmoth Nexus becomes a 1/1 Blinkmoth artifact creature with flying and infect until end of turn. It's still a land.

A decorative graphic on a dark blue background. It features a large, thick ring in the upper left corner, transitioning from teal to orange. Below it are several thick, wavy lines in the same color palette, creating a sense of movement and depth.

DECKBUILDING

Booster 2/3 13 Cards Available Select 1 (0 remaining)

0:40

SUBMIT

Navigation icons: Home, Friends, Filter, Refresh

 Creature — Human Soldier When Thraben Inspector enters, investigate. 1/2	 Creature — Frog Whenever Psychic Frog deals combat damage to a player or planeswalker, draw a card. Discard a card. Put a +1/+1 counter on Psychic Frog. Exile three cards from your gr... 1/2	 Artifact Creature — Phyre... Trample, infect, indestructible If Blightsteel Colossus would be put into a graveyard from anywhere... 11/11	 Creature — Human Wizard At the beginning of your upkeep, reveal the top card of your library and put that card into your hand. You lose life equal to its mana... Reserved 2/1	 Land Botanical Sanctum enters tapped unless you control two or fewer other lands. Add ♣ or ♠.	 Creature — Goblin Shaman Exalted Add ♣, ♠, or ♣.	 Creature — Vampire Cleric Deathtouch Whenever Preacher of the Schism attacks the player with the most life or tied for most life, create a 1/1 whi... 2/4	 Sorcery Draw two cards. Then discard a card unless you attacked this turn.	 Enchantment — Saga Kumano Faces Kakkazan deals 1 dam... When you next cast a creature spell this tur... Exile this Saga, then return it to th... 1/2	
 Instant Until end of turn, lands you control gain "Sacrifice this land: Add ♣." 1/1	 Creature — Human Cleric Sacrifice Benevolent Bodyguard: Target creature you control gains protection from the color of your choice until end of turn. 1/1	 Artifact 2, ♣ Sacrifice Expedition Map: Search your library for a land card, reveal it, put it into your hand, then shuffle.	 Instant You may return two Islands you control to their owner's hand rather than pay this spell's mana cost. Draw two cards.						

17 Total 5 Creatures 4 Land 8 Other

Last Selected: Mox Diamond

2	1	1	1	2	3	4	1	2
 Deathrite Shaman Creature — Elf Shaman Exile target land card from a graveyard. Add one mana of any color. Exile target instant or sorcery card from a gravey... 1/2	 Creature — Dauthi Rogue Shadow If a card would be put into an opponent's graveyard from anywhere, instead exile it with a void counter on it. Sacrifice Dauthi Voidwal... 3/2	 Land — Swamp Mountain As Blood Crypt enters, you may pay 2 life. If you don't, it enters tapped.	 Land Pay 1 life. Sacrifice Arid Mesa: Search your library for a Mountain or Plains card, put it onto the battlefield, then shuffle.	 Raging Ravine Land Raging Ravine enters tapped. Add ♣ or ♠. Until end of turn, Raging Ravine beco...	 Mox Diamond Bone Shards Sorcery As an additional cost to cast this spell, sacrifice a creature or discard a card. Destroy target creature or planeswalker.	 Animate Dead Abrade Instant Choose one — • Abrade deals 3 damage to target creature. • Destroy target artifact.	 Instant Devoid This spell costs 2 less to cast if an opponent controls a multicolored permanent...	 Lurrus of the Dream Legendary Creature — ... Companion — Each permanent card in your starting deck has mana value 2 or less... 3/2

Booster 2/3 13 Cards Available Select 1 (0 remaining)

0:40

SUBMIT



 Creature — Human Soldier When Thraben Inspector enters, investigate. 1/2	 Creature — Frog Whenever Psychic Frog deals combat damage to a player or planeswalker, draw a card. Discard a card. Put a +1/+1 counter on Psychic Frog. Exile three cards from your gr... 1/2	 Artifact Creature — Phyre... Trample, infect, indestructible If Blightsteel Colossus would be put into a graveyard from anywhere... 11/11	 Creature — Human Wizard At the beginning of your upkeep, reveal the top card of your library and put that card into your hand. You lose life equal to its mana... Reserved 2/1	 Land Botanical Sanctum enters tapped unless you control two or fewer other lands. Add ♣ or ♠.	 Creature — Goblin Shaman Exalted Add ♣, ♠, or ♡.	 Creature — Vampire Cleric Deathfouch Whenever Preacher of the Schism attacks the player with the most life or tied for most life, create a 1/1 whi... 2/4	 Sorcery Draw two cards. Then discard a card unless you attacked this turn.	 Enchantment — Saga Kumano Faces Kakkazan deals 1 dam... When you next cast a creature spell this tur... Exile this Saga, then return it to th... 1/2
 Instant Until end of turn, lands you control gain "Sacrifice this land: Add ♣." 1/1	 Creature — Human Cleric Sacrifice Benevolent Bodyguard: Target creature you control gains protection from the color of your choice until end of turn. 1/1	 Artifact 2, ♣, Sacrifice Expedition Map: Search your library for a land card, reveal it, put it into your hand, then shuffle.	 Instant You may return two Islands you control to their owner's hand rather than pay this spell's mana cost. Draw two cards.					

17 Total 5 Creatures 4 Land 8 Other

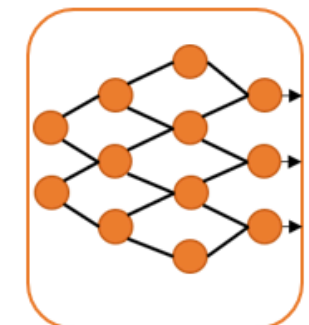
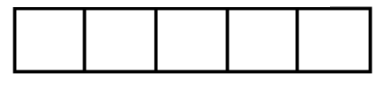
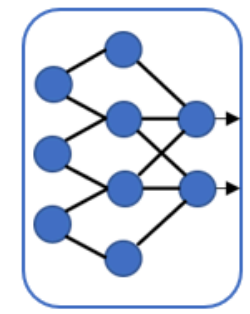
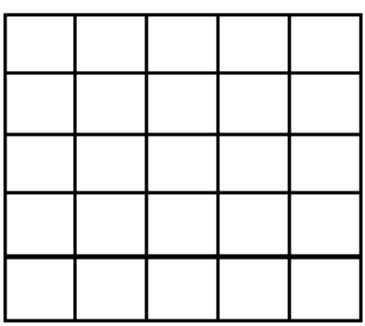
Last Selected: Mox Diamond

2	1	1	1	2	3	4	1	2
 Deathrite Shaman Creature — Elf Shaman Exile target land card from a graveyard. Add one mana of any color. Exile target instant or sorcery card from a gravey... 1/2	 Creature — Dauthi Rogue Shadow If a card would be put into an opponent's graveyard from anywhere, instead exile it with a void counter on it. Sacrifice Dauthi Voidwal... 3/2	 Land — Swamp Mountain As Blood Crypt enters, you may pay 2 life. If you don't, it enters tapped.	 Land Pay 1 life. Sacrifice Arid Mesa: Search your library for a Mountain or Plains card, put it onto the battlefield, then shuffle.	 Raging Ravine Land Raging Ravine enters tapped. Add ♣ or ♠. Until end of turn, Raging Ravine beco...	 Mox Diamond Bone Shard Sorcery As an additional cost to cast this spell, sacrifice a creature or discard a card. Destroy target creature or planeswalker.	 Animate Dead Abrade Instant Choose one — • Abrade deals 3 damage to target creature. • Destroy target artifact.	 Instant Devoid This spell costs 2 less to cast if an opponent controls a multicolored permanent...	 Lurrus of the Dream Legendary Creature — ... Companion — Each permanent card in your starting deck has mana value 2 or less... 3/2

Deck



Representation pipeline



Deck encoding

Card encoding

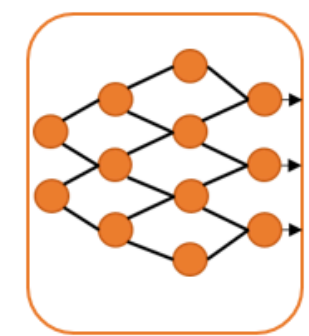
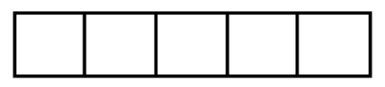
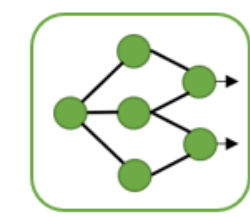
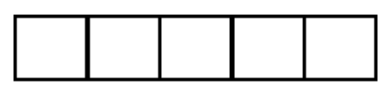
Siamese Network

Embedding space

Positive



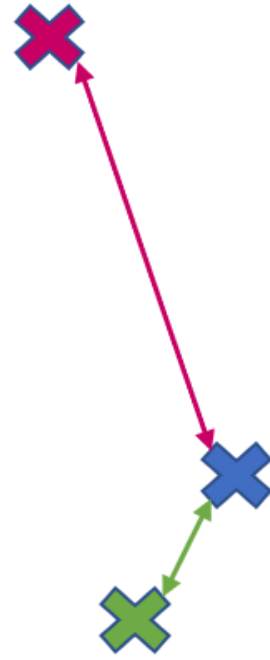
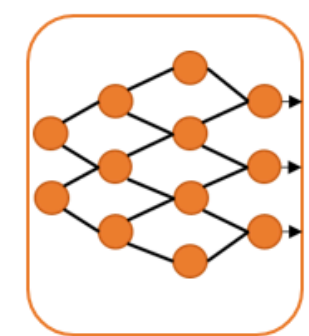
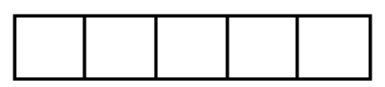
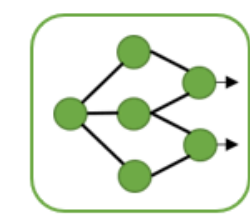
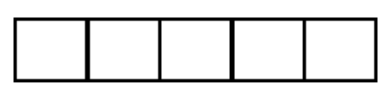
Representation pipeline

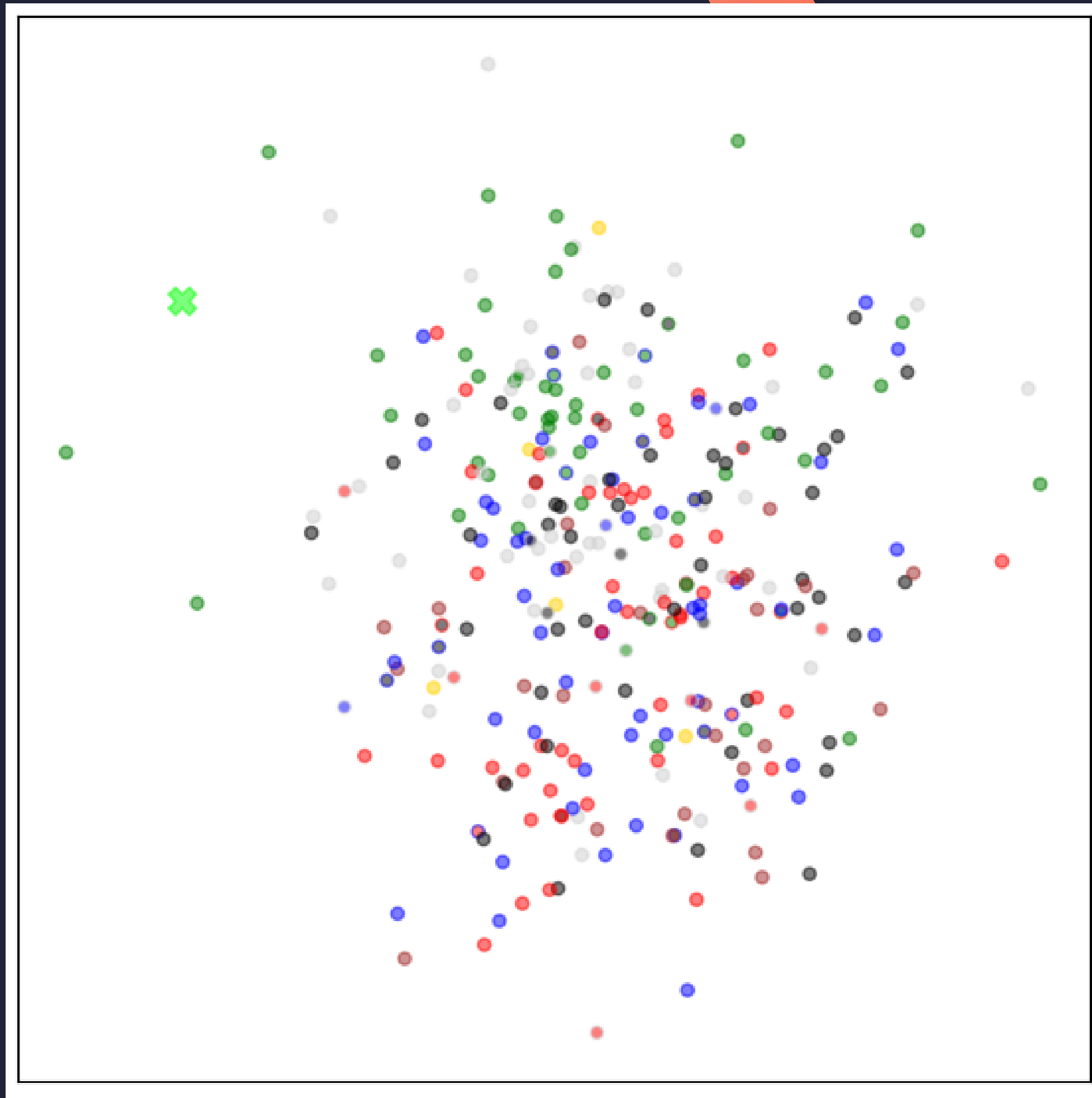


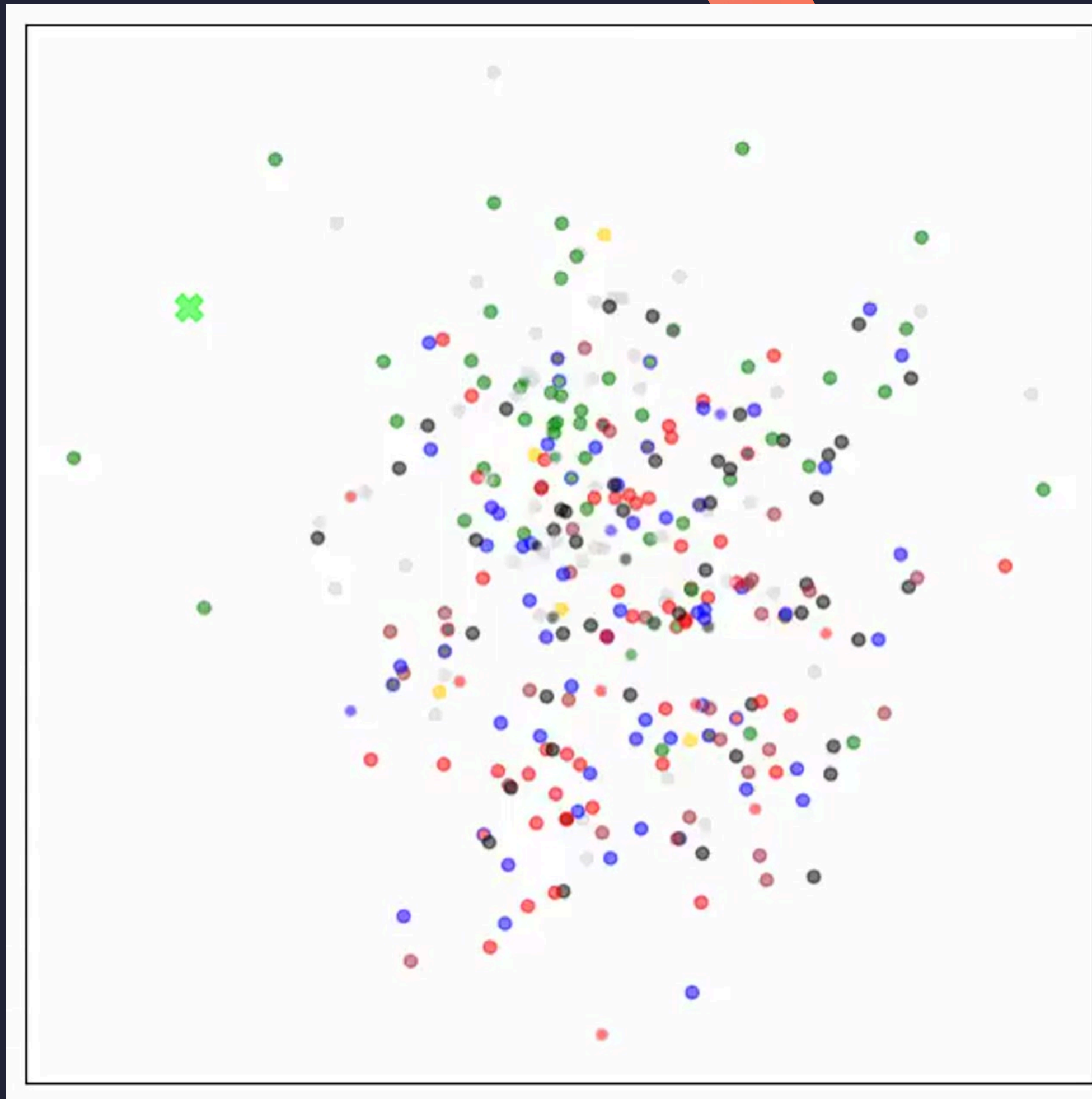
Negative



Representation pipeline









The image features a dark blue background with abstract, flowing shapes. A large, thick ring with a teal-to-orange gradient is positioned in the upper left. Below it, several thick, curved ribbons in the same gradient flow across the bottom of the frame. The word "REPRESENTATION" is centered in a bold, white, sans-serif font.

REPRESENTATION

Underdark Explorer

4 



Creature — Lizard Warrior 

Menace (This creature can't be blocked except by two or more creatures.)

When Underdark Explorer enters the battlefield, you take the initiative.

“Keep your fancy magic. All I need is a hook and a sturdy length of rope.”

5/3

Natural language
language

Visual

Categorical

Underdark Explorer

4



Creature

Lizard Warrior



Menace (This creature can't be blocked except by two or more creatures.)

When Underdark Explorer enters the battlefield, you take the initiative.

"Keep your fancy magic. All I need is a hook and a sturdy length of rope."

5/3

Numerical

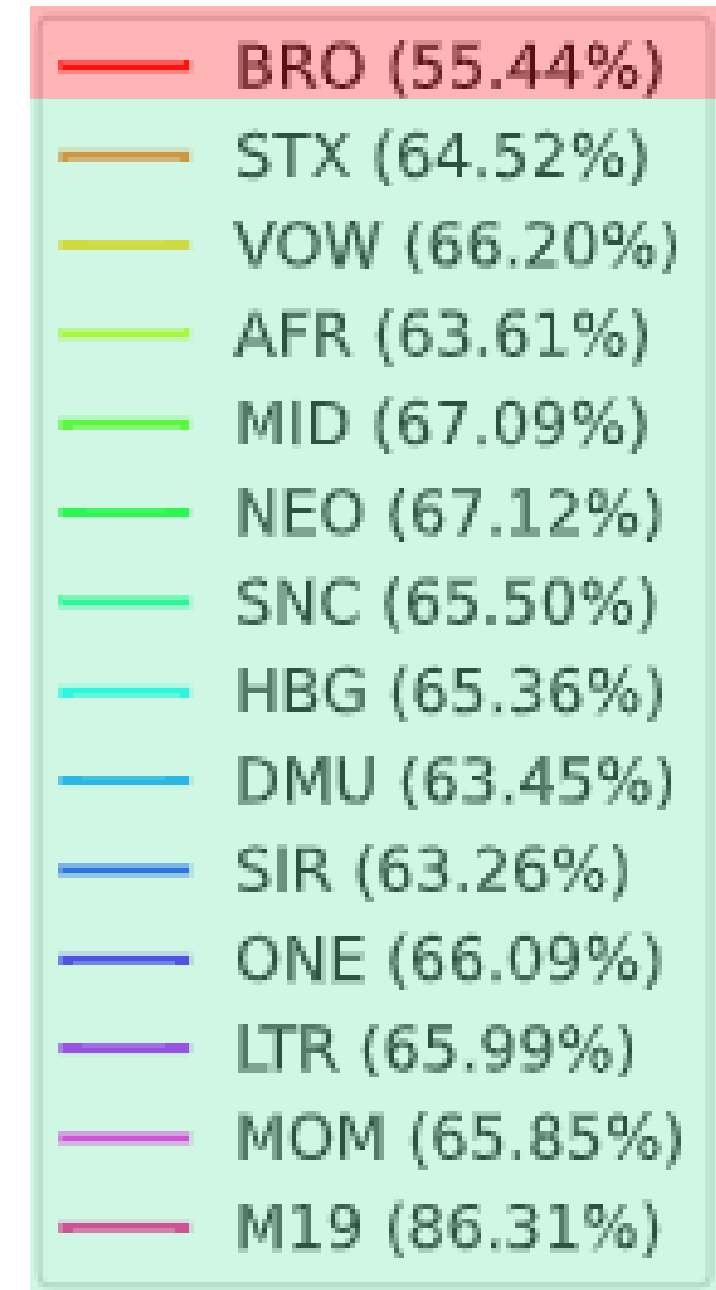
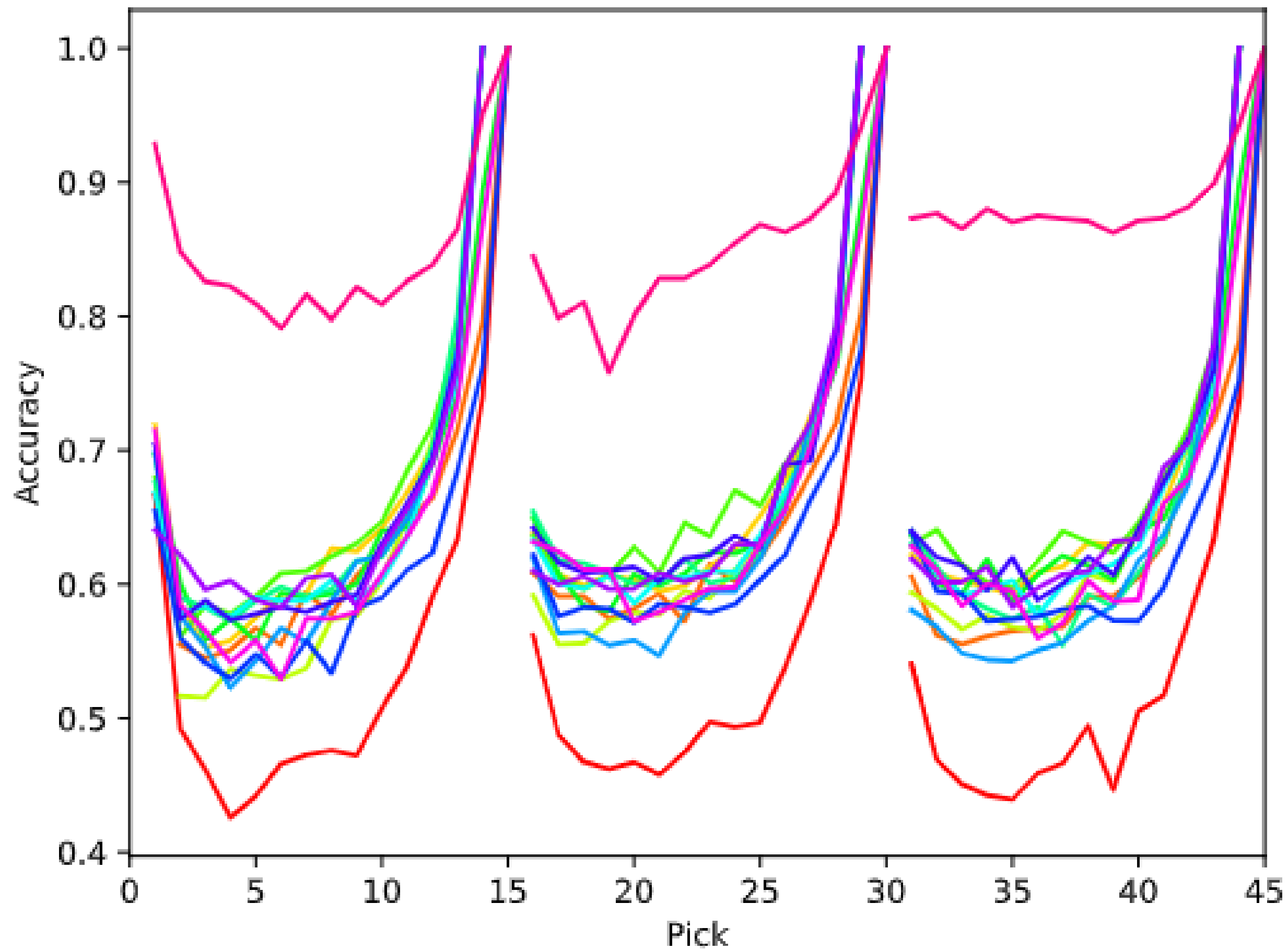
Categorical

Natural language

Numerical

Representation	Test accuracy on known cards (NEO)	Test accuracy on unknown cards
Random vectors		
Latent image encodings		
Card meta statistics		
Feature encodings		
Features + Image + Meta		

Representation	Test accuracy on known cards (NEO)	Test accuracy on unknown cards
Random vectors	67.87%	23.79%
Latent image encodings	68.09%	31.10%
Card meta statistics	64.73%	42.14%
Feature encodings	67.76%	33.57%
Features + Image + Meta	68.00%	42.87%



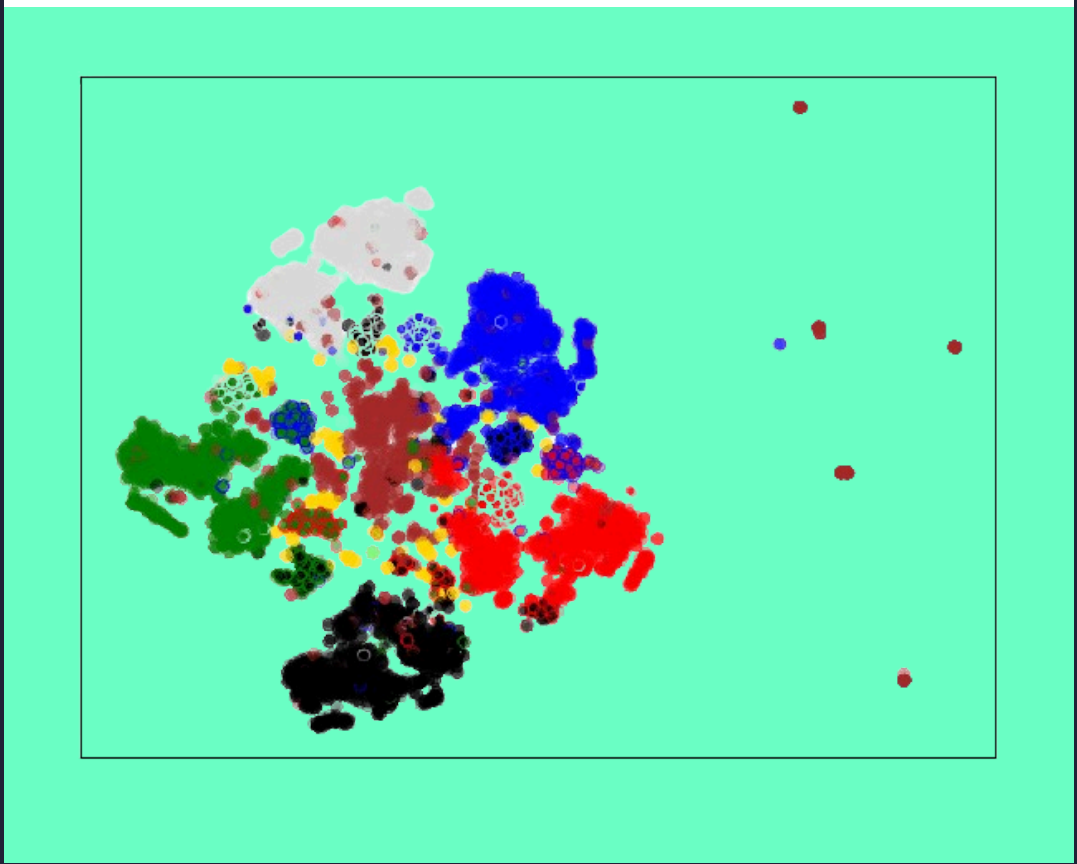


USE-CASES

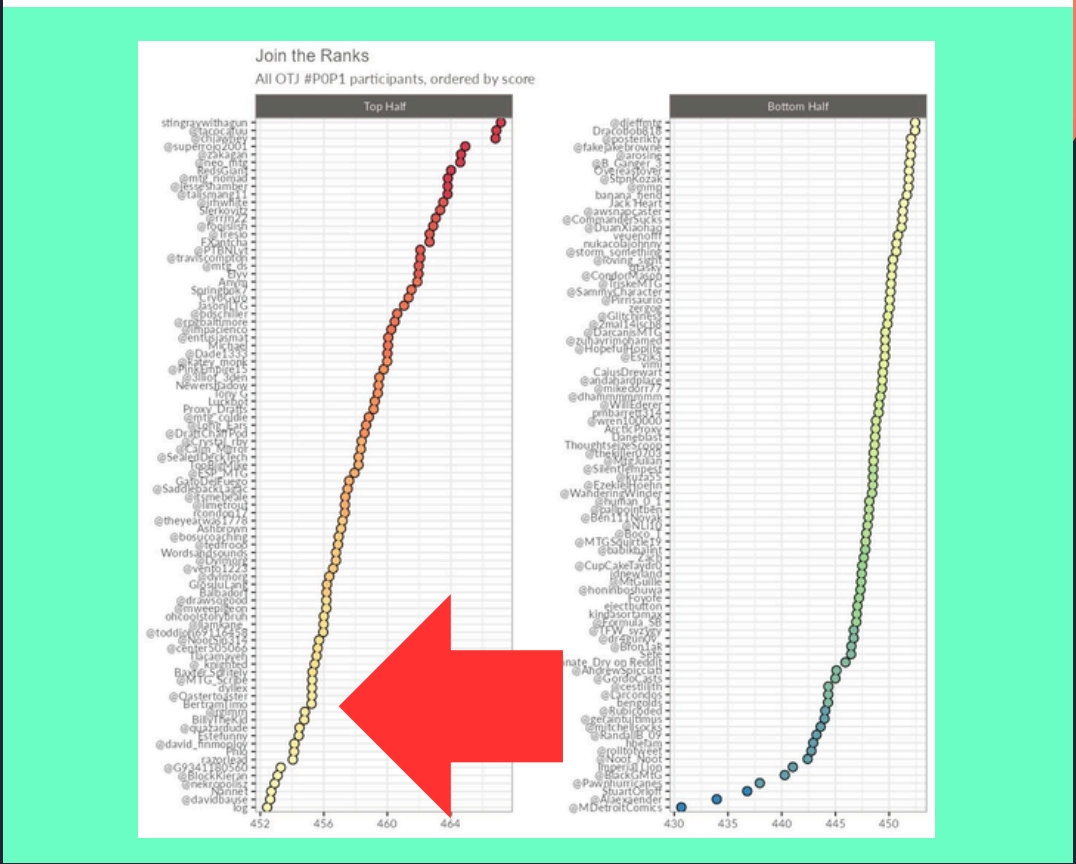
Preferences > Predictions



Meaningful embedding



Real-world applicable



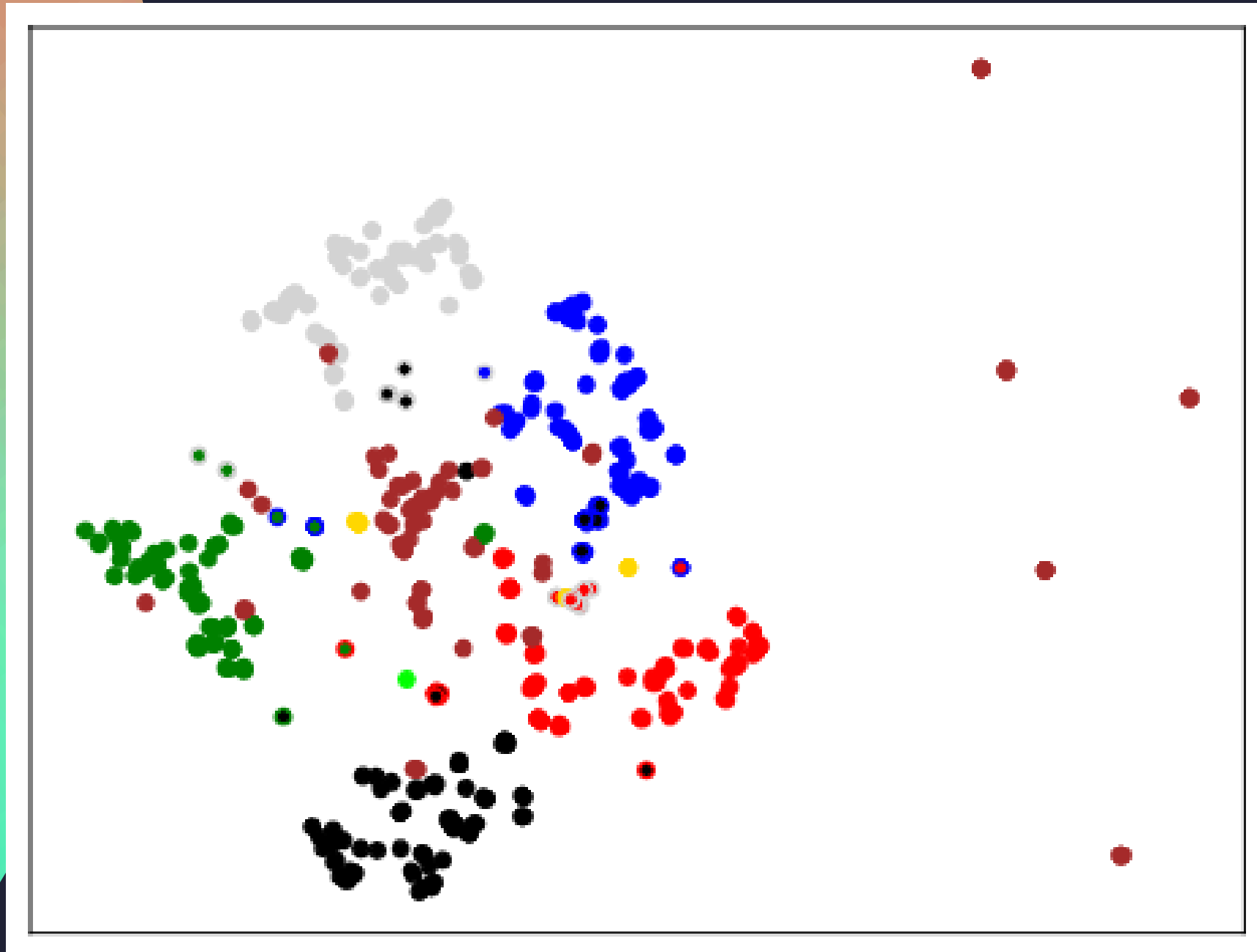


THANK YOU!

TBERTRAM@FAW.JKU.AT

@BERTRAMTIMO

Known (NEO)



Unknown (BRO)

