Disentanglement Beyond Static vs. Dynamic: A Benchmark and Evaluation Framework for Multi-Factor Sequential Representations

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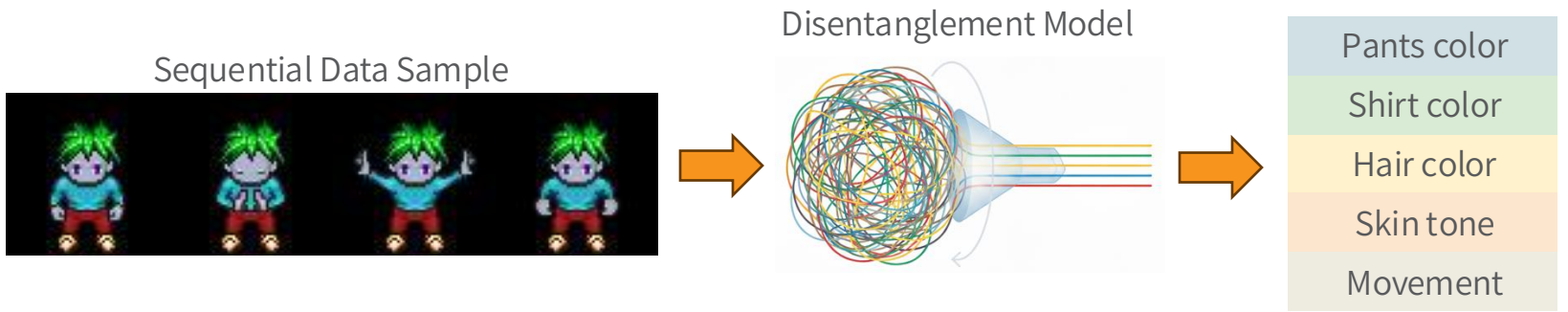
Sequential Multi-Factor Disentanglement

"Learning representations that separate multiple static and dynamic factors within temporal data into distinct, interpretable, and independently controllable components."



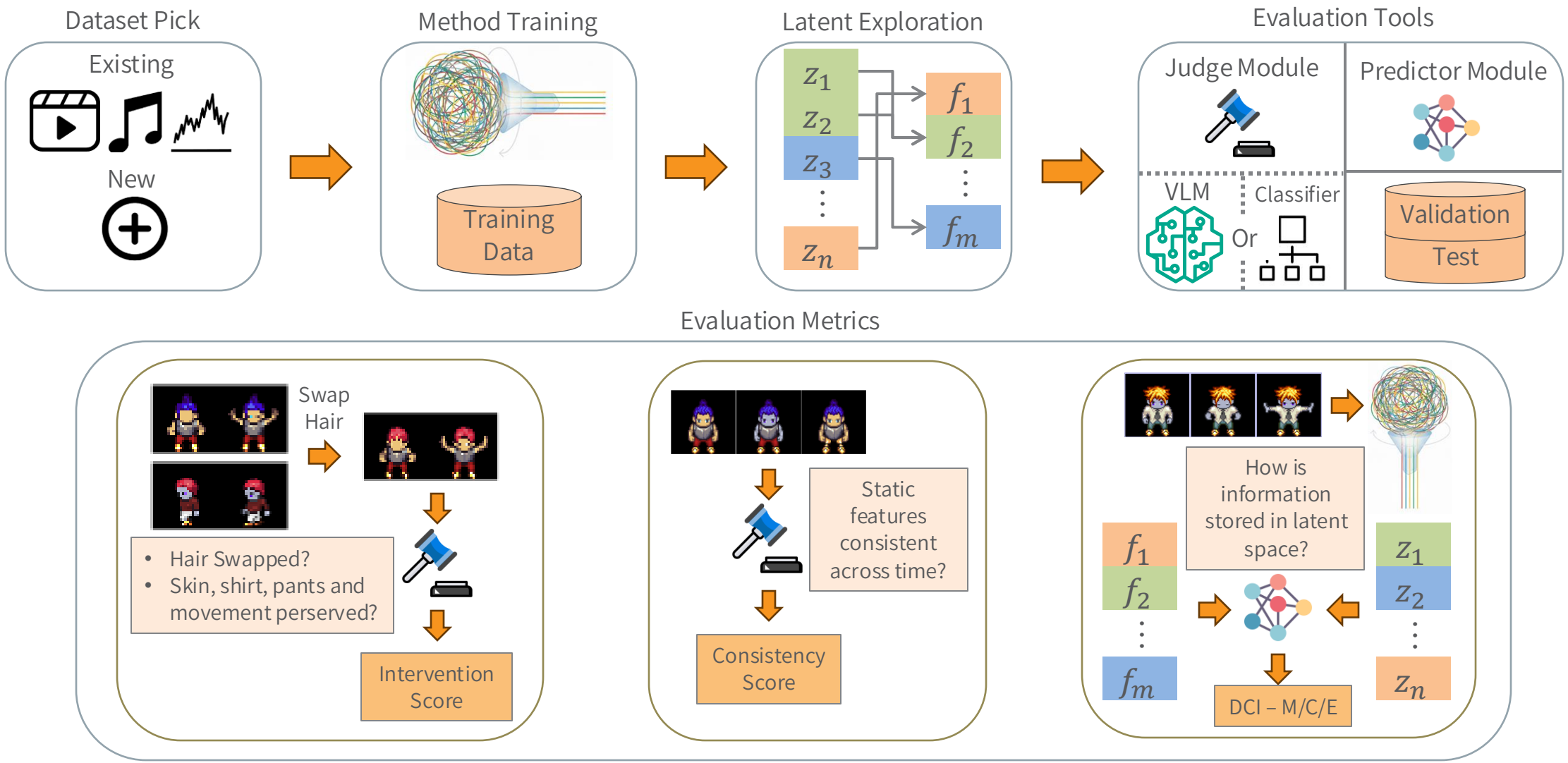
Challenges:

- **No standard framework:** fragmented datasets and inconsistent evaluation
- **Dependence on labels:** costly, domain-specific annotations required
- **Manual latent mapping:** human inspection needed to align latents and factors

Contributions

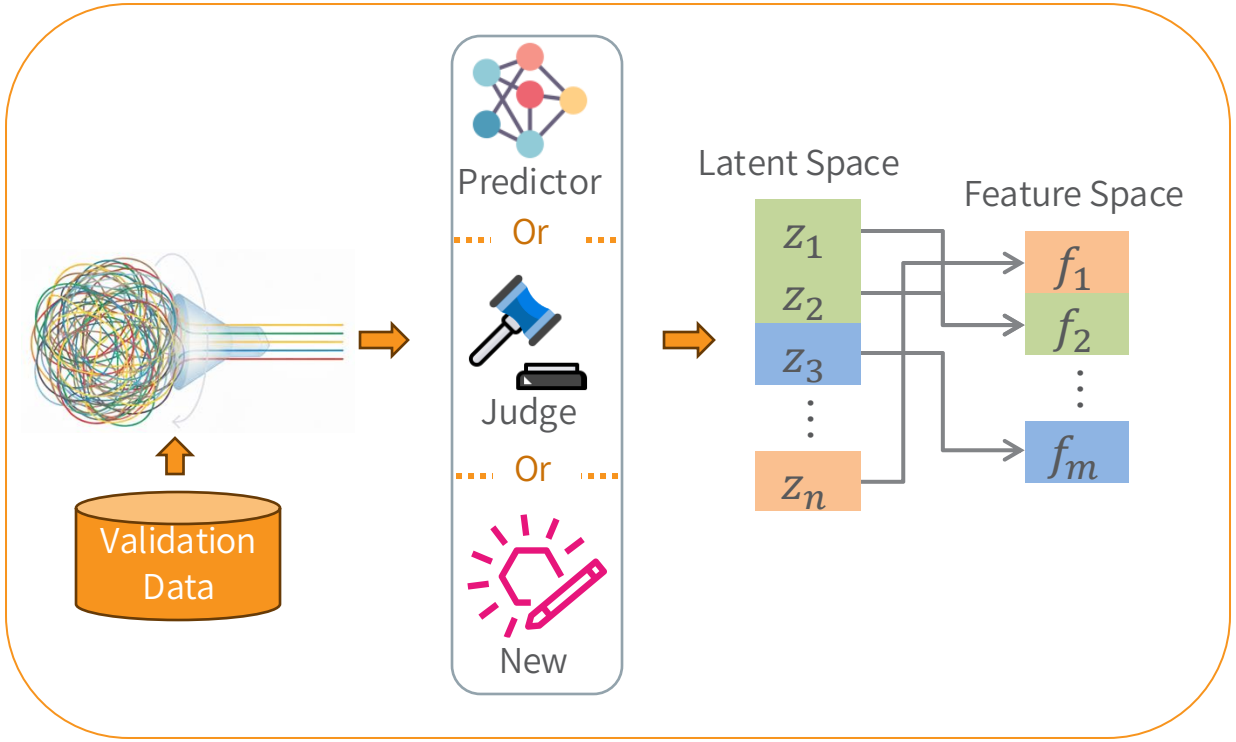
- **MSD: First benchmark** for multi-factor sequential disentanglement across video, audio, and time series
- **Ten unified metrics** evaluating factor control, structure, and consistency
- **Automated latent alignment** via a Latent Exploration Stage (LES)
- **VLM-based Tagger & Judge** for zero-shot labeling and evaluation
- **SSM-SKD model** achieving state-of-the-art results

Overview of MSD

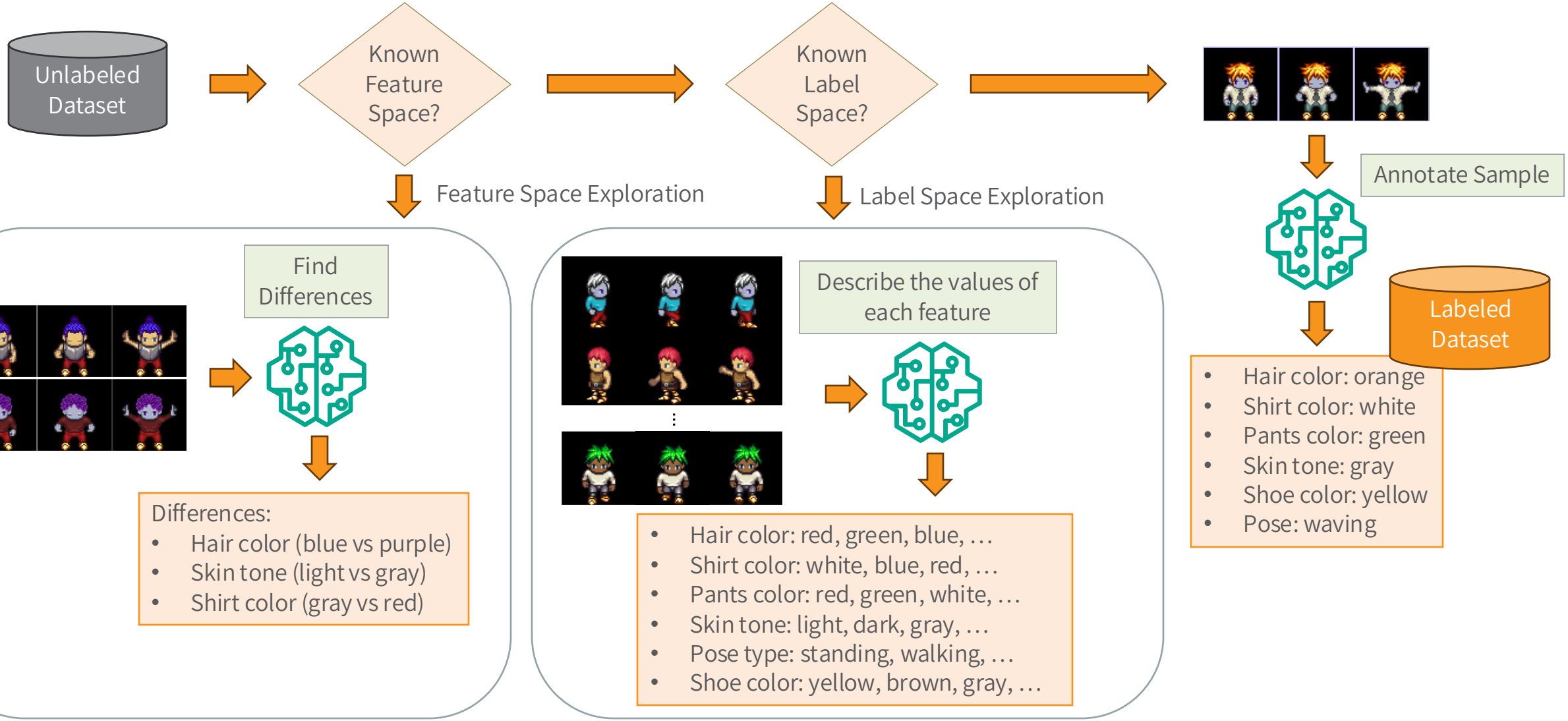


Latent Exploration Stage

- **Bridges latent and semantic spaces** - learns mappings between latent variables and interpretable factors
- **Modular interface** – includes built-in explorers and supports custom user-defined ones
- **Fully automated** – removes manual mapping and scales across modalities



VLM-Based Tagger & Judge



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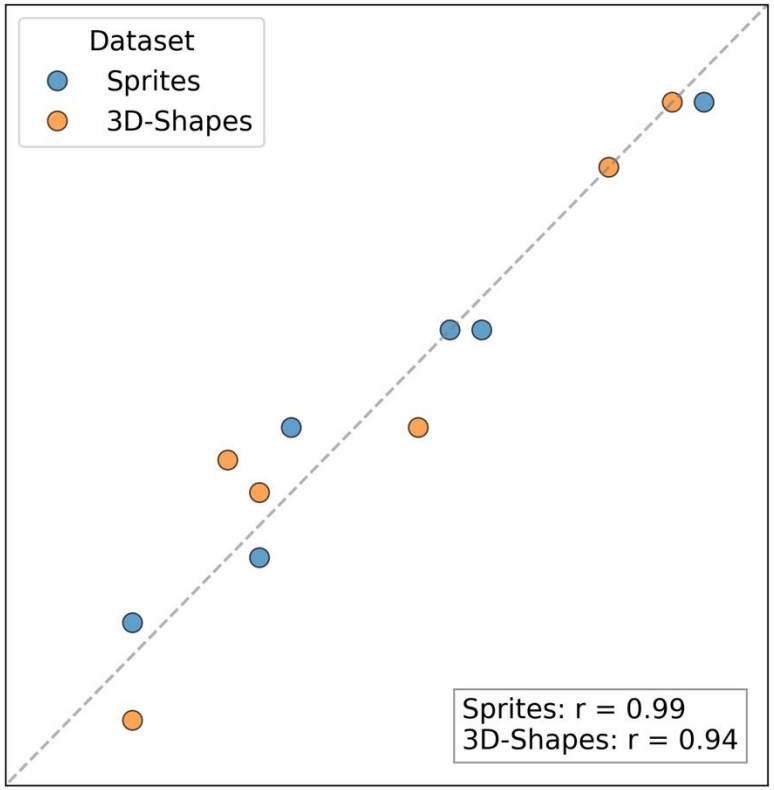
Results & Takeaways

- Consistent ranking across datasets
- VLM-based evaluation aligns with ground truth
- Reliable, label-free assessment

Dataset	Sparse-AE	VAE	β-VAE	MGP-VAE	SKD	SSM-SKD
Sprites	0.73	0.58	0.6	0.79	0.75	**0.95**
3D Shapes	0.85	0.93	0.82	0.65	0.76	**0.96**
dSprites-S	0.5	0.52	0.7	0.53	0.64	**0.83**
dSprites-D	0.68	0.63	0.65	0.53	0.64	**0.71**
dMelodies	0.47	0.45	0.52	0.35	52	**0.55**
BMS-AQ	0.36	**0.42**	**0.42**	0.17	0.36	**0.42**



Thank You.

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