Exploring Experimental Machine Learning in Film Restoration

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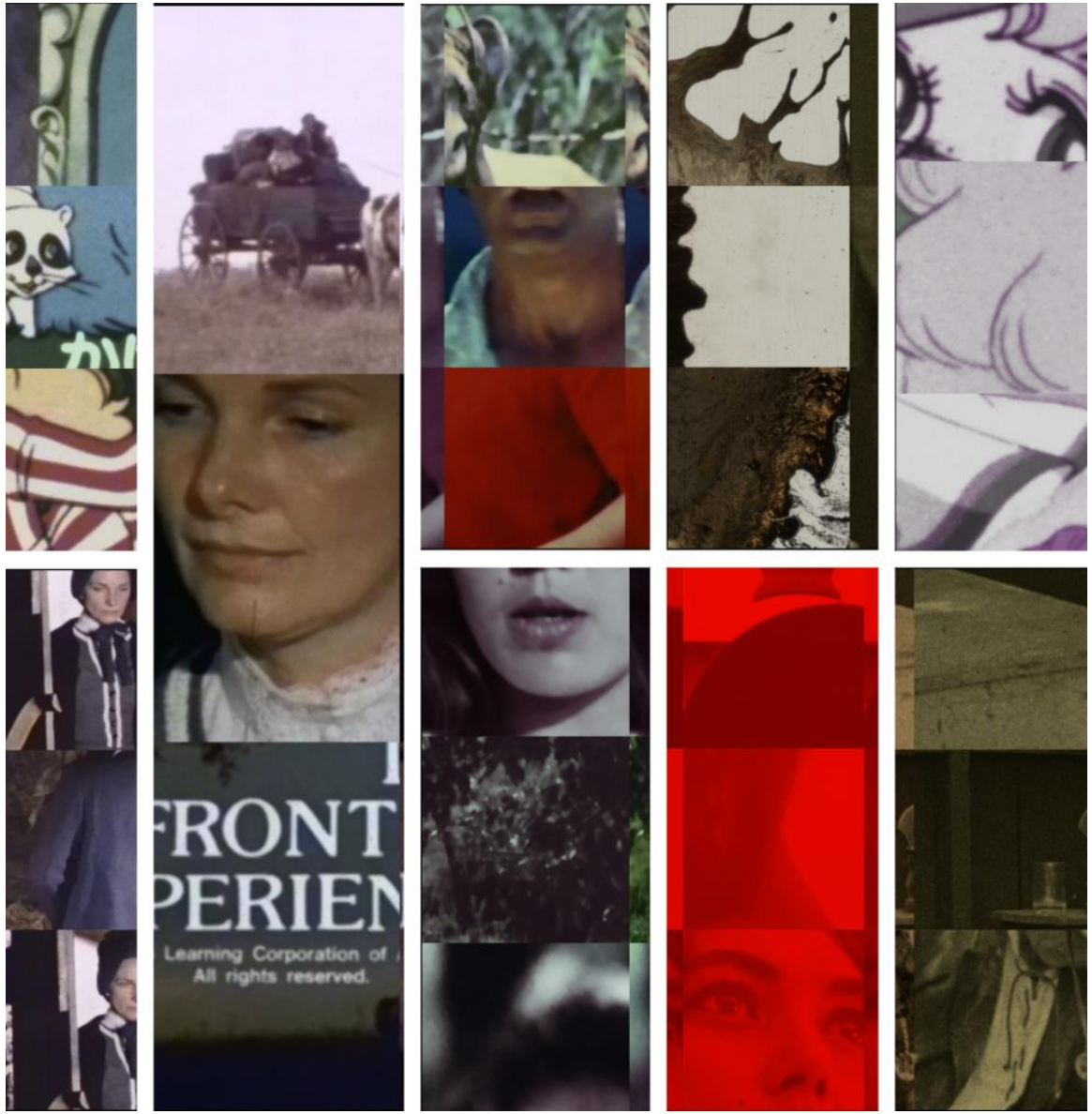

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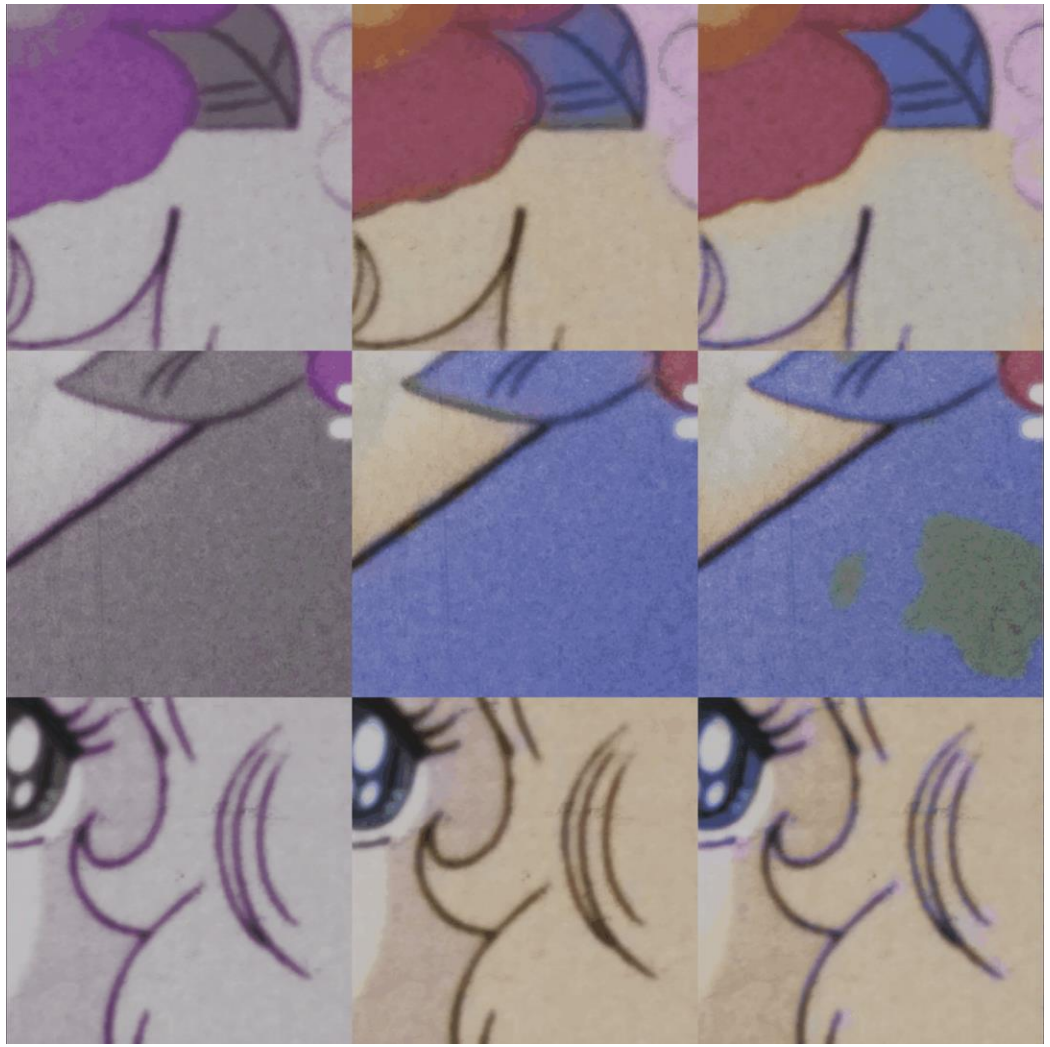
Content vs. Container: Why AI Restoration Needs Context

- Digitization separates content (image/sound) from container (film/tape)
- Digital restoration aims to reduce the visual impact of the container's degradation on the content
- General AI models treat all content as digitally born, often erasing analog traits like grain, weave, or flicker
- Custom-trained models preserve analog traits by learning from the material's specific characteristics

Original analog scan (top) vs. generalized AI enhancement (bottom)

Method Overview & Philosophy

- All models are trained locally in Nuke's CopyCat
- Inference is performed frame by frame, as current hardware and tools do not make temporal models feasible at the personal or consumer level
- References may include telecines, alternate gauges, DVDs, photographs, or paintings, based on availability and restoration goals (chroma or luma)
- We aim to recover what was originally there, not to reimagine or stylize

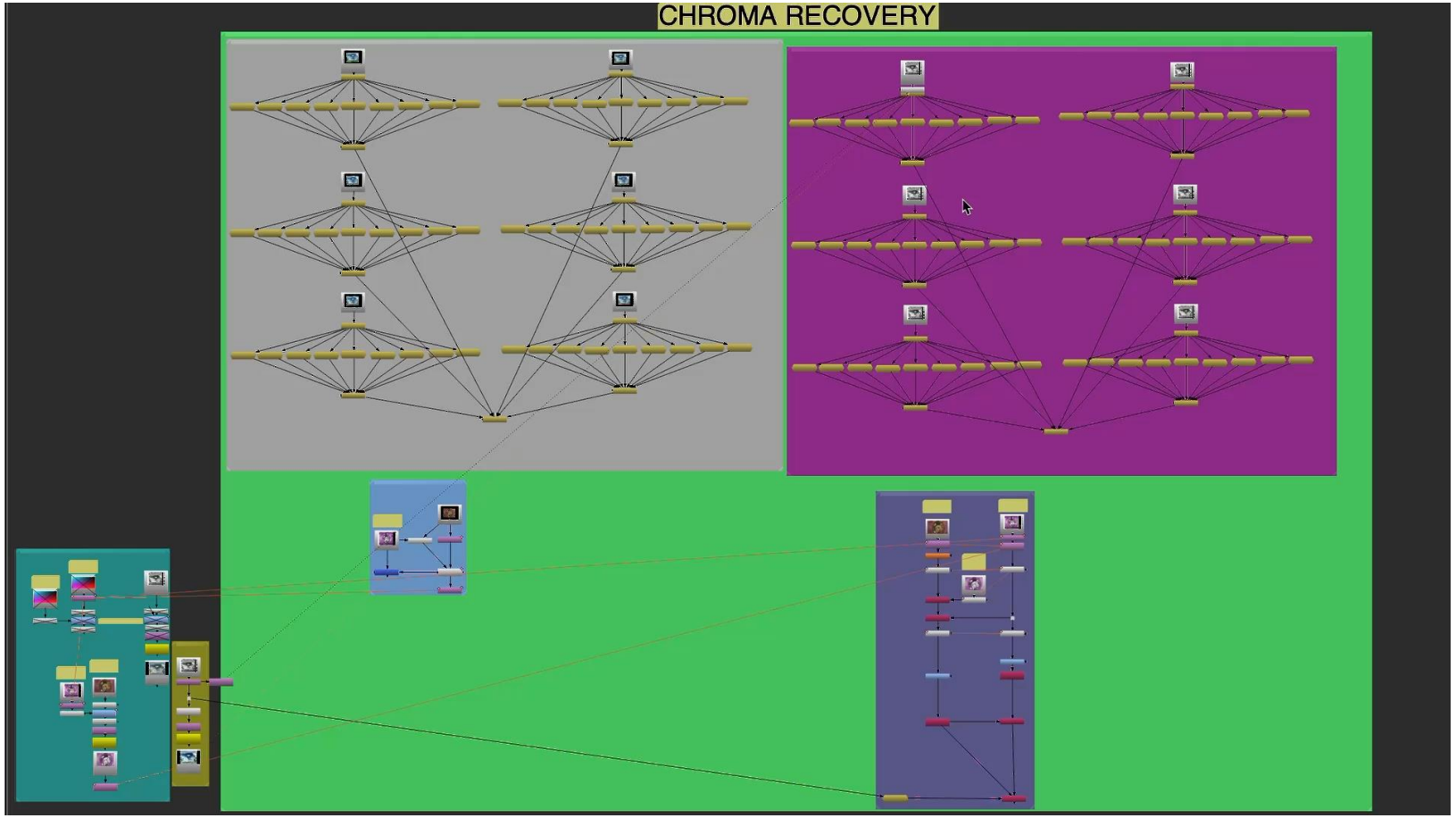


CopyCat's training layout: input (left), ground truth (center), and inference (right) shown as tiled patches

What is Chroma Recovery?

- Chroma is the color component of the image
- In chromogenic film stocks, chroma degrades over time due to dye fading (e.g. magenta shift in Eastman, Fuji, Agfa)
- Chroma carries less detail than luma and is lower in resolution and frequency, This makes chroma a natural starting point for machine learning–based restoration.

Chroma is inferred from context and reference, rather than fabricated.

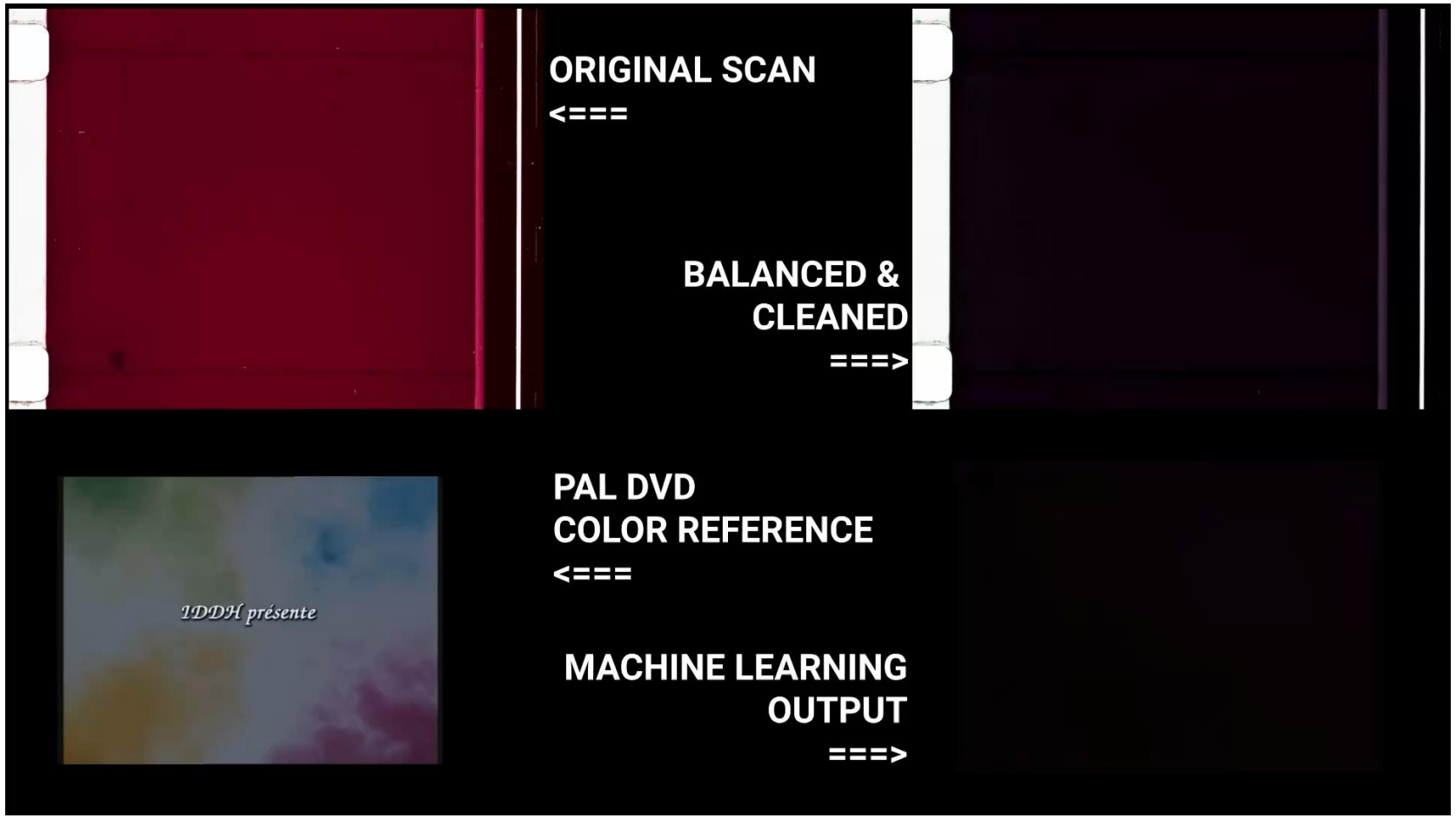


Chroma Recovery Demo: Candy Candy

DVD-guided chroma recovery of a faded 16mm print, trained and inferred in CopyCat.

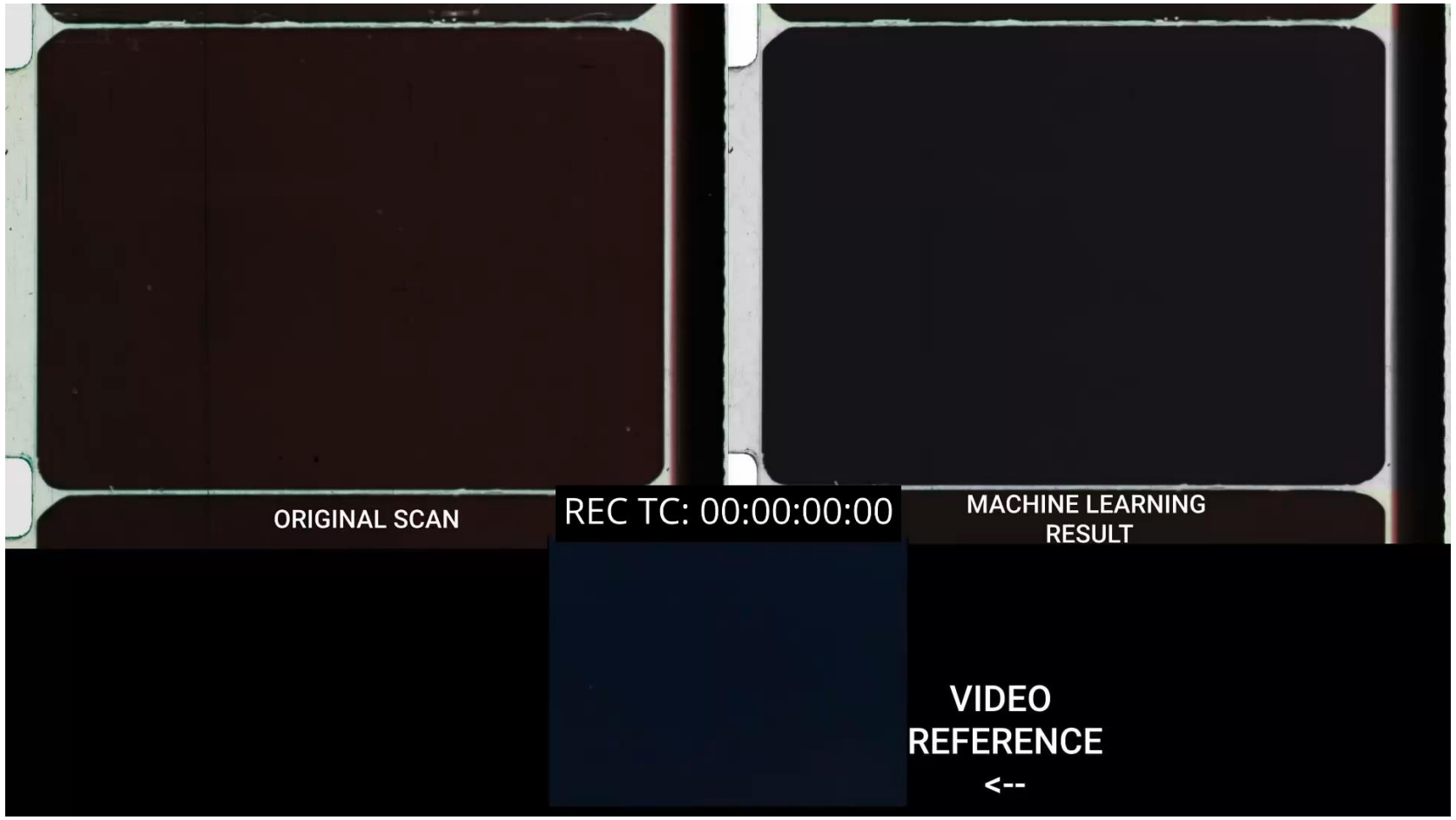
Top: Source, reference, and final model output. Bottom: progression from first to last training step, showing chroma refinement.

Model progression in chroma recovery



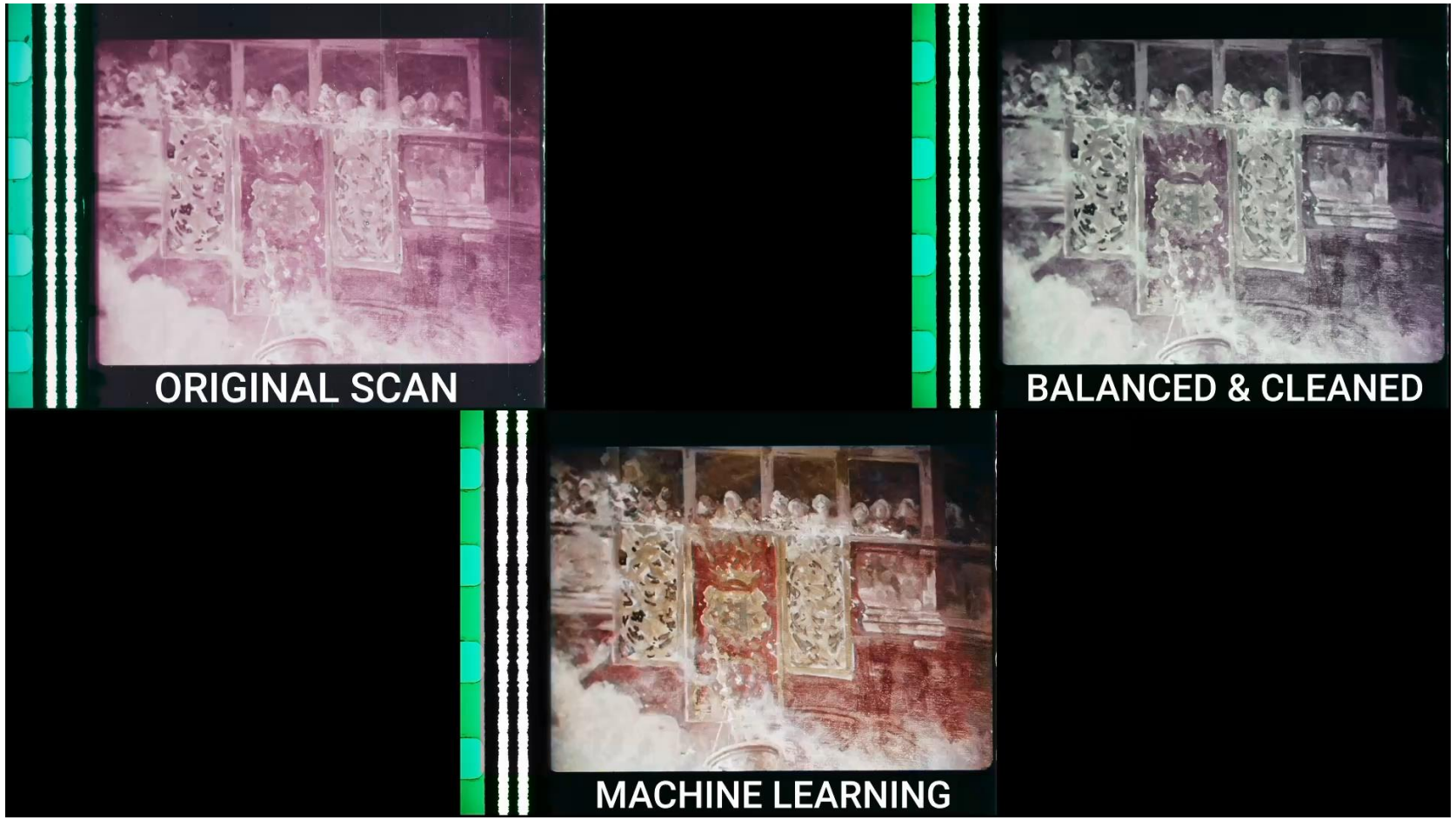
Original scan, aligned DVD reference, and ML output shown in full sequence – frame-by-frame inference using CopyCat

Candy Candy Chroma Recovery – Full Pipeline Video



Original scan, telecine reference, and machine learning output shown in sequence. Inference performed frame by frame using CopyCat.

Frontier Experience Chroma Recovery – Full Pipeline Video



Rebelión de las Tapadas – Chroma Recovery from Artwork

No video or telecine reference available, model trained using curated historical artwork

Historical Artwork Used for Chroma Recovery

Paintings from the Viceroyalty of Lima by artists such as Pancho Fierro and Johann Moritz Rugendas were used to guide chroma recovery for Rebelión de las Tapadas

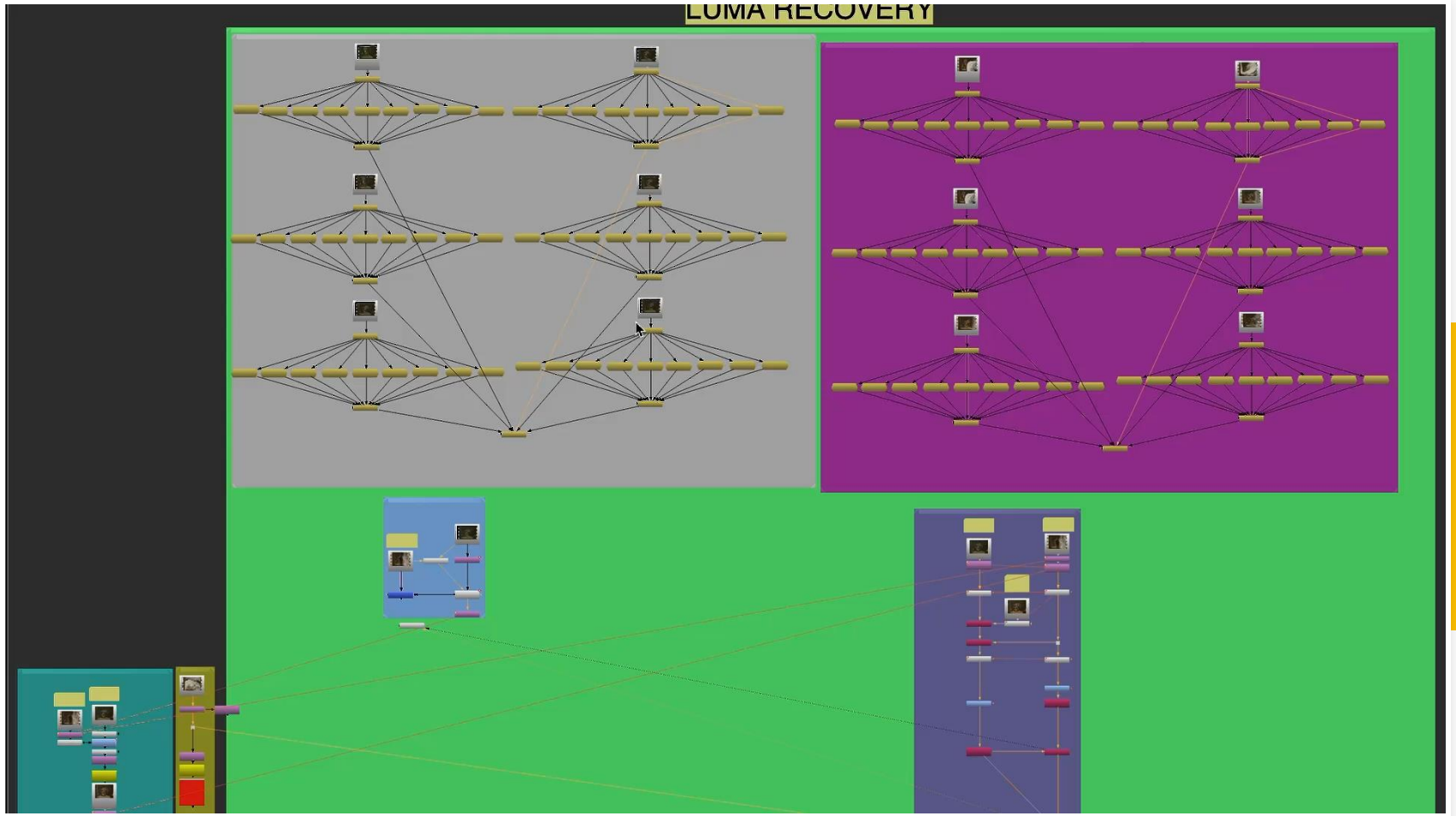
What is Luma Recovery?

- Luma is the spatial or detail component of the image
- In duplicated or aged film, it degrades due to physical damage, generation loss, or nitrate decay
- Luma carries high-frequency data, making training more complex and time-intensive, often requiring shot-by-shot segmentation
- Aligned references (telecines, prints, or negatives) help models recover lost structure
- Unlike enhancement, this process uses verifiable sources to reconstruct detail that existed in the film at some point

Luma recovery of a vinegar syndrome–damaged negative, using a mostly luma-preserved positive print as reference.

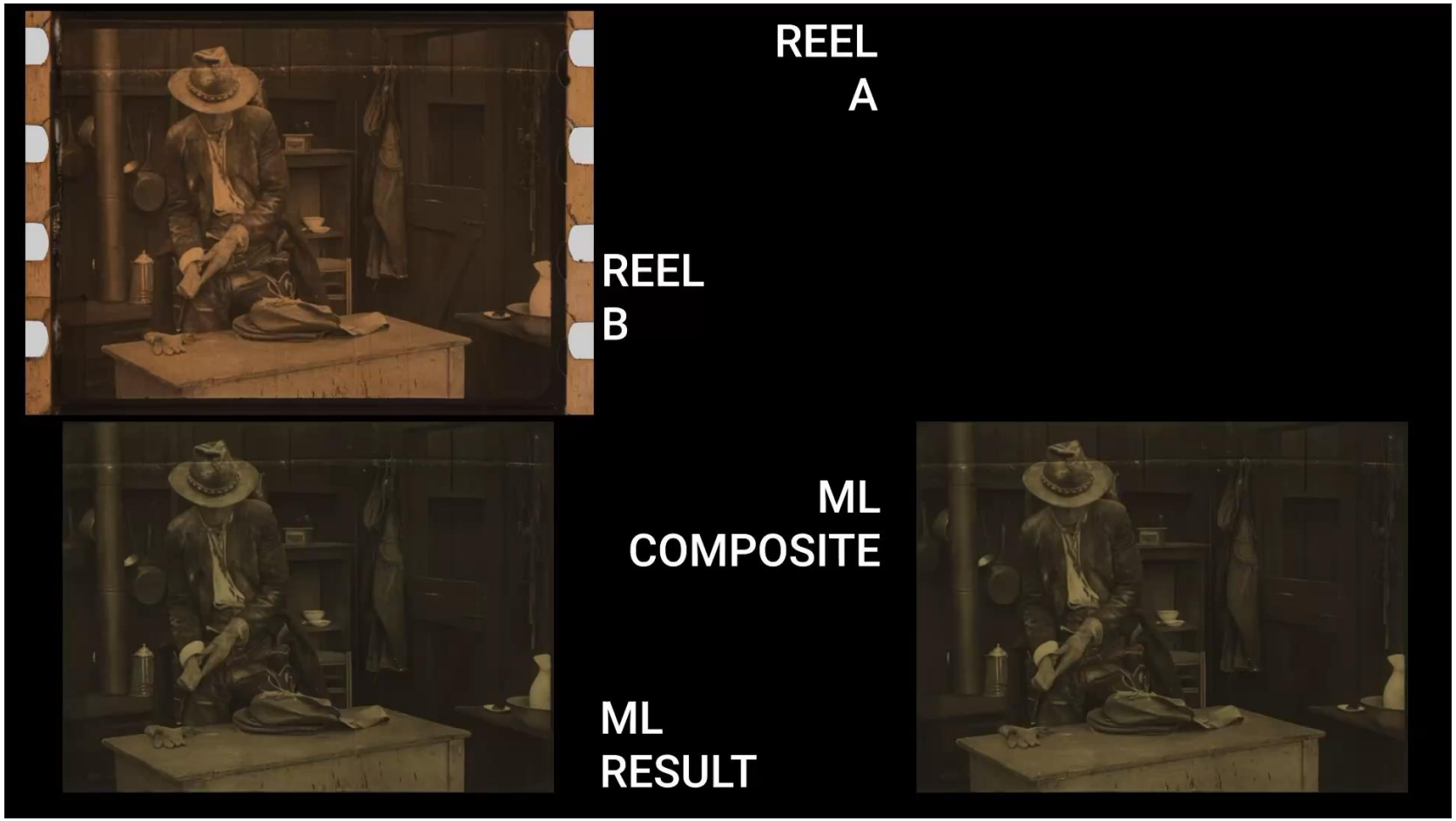
Original 16mm scan, aligned with 35mm faded reference, and ML output shown in full sequence – frame-by-frame inference using CopyCat

Mission Kill Luma Recovery – Full Pipeline Video



2 nitrate prints, are aligned to composite full shot, where some parts where inferred and other composited form the machine learning model

Luma Recovery Demo: Knight of the Trail



Monochromatic nitrate sources (Reels A and B) combined into a single composite for training. Machine learning result inferred from this composite to recover spatial detail in damaged areas.

Knight of the Trail Luma Recovery – Full Pipeline Video

Conclusions & Acknowledgements

- All models presented here were trained locally and inferred frame by frame, using references specific to each film element
- These workflows rely on curated sources such as telecines, alternate prints, and historical artwork, rather than generalized or generative inference
- Machine learning provides a practical and ethical justification for preserving multiple copies of the same film, as each can contribute distinct information for model training
- The aim is not to reinterpret the material but to recover what can be demonstrated and supported through visual context

Special thanks to:

- **Ross Lipman** for providing footage from *The Frontier Experience* (1975) by Barbara Loden
- **The film preservation services of the George Eastman Museum** for access to *Knight of the Trail* (1915), reconstructed from elements held by La Cinémathèque française, Fondazione Cineteca Italiana, and the George Eastman Museum, with support from the **Louis B. Mayer Foundation**