

## Supplemental Material

### **Behind the Scene of “The Holy Family with St. Anne and the Young St. John” by Bernardino Luini: A Computer Assisted Method to Unveil the Underdrawings**

Michele Caccia,<sup>1</sup> Letizia Bonizzoni,<sup>2</sup> Marco Martini,<sup>1</sup> Raffaella Fontana,<sup>3</sup> Valeria Villa,<sup>4</sup> Anna Galli<sup>5,1</sup>

<sup>1</sup>Dipartimento di Scienza dei Materiali, Università degli Studi di Milano-Bicocca, via R. Cozzi 55, 20125 Milano and INFN, Sezione Milano-Bicocca, Italy

<sup>2</sup>Dipartimento di Fisica Aldo Pontremoli, Università degli Studi di Milano, via Celoria 16, 20161 Milano, Italy

<sup>3</sup>CNR-INO Istituto Nazionale di Ottica, Largo Fermi 6, 50125, Firenze, (IT)

<sup>4</sup>Cultura Valore, Piazza Rizzi 10, 21100, Varese, Italy

<sup>5</sup>CNR-IBFM Istituto di Bioimmagini e Fisiologia Molecolare, via F.lli Cervi 93, 20090 Segrate, Italy

\*Corresponding author email: michele.caccia@unimib.it

The extraction of the underdrawings has been performed also on three paintings by Luini that do not have a handcrafted counterpart: “The Blessing Christ” (Figures S1a and S1b), “The Holy Mary that breastfeeds the Holy Baby” (Figures S1c and S1d), and “The Noli Me Tangere” (Figures S1e and S1f). The absence of references complicates the critical review of the results; however, it is also based on the discussion about the panels described in the main text and it is possible to underline some interesting features. The extracted underdrawings (UDs) show the detailed drawing Luini designed for the characters of his paintings; the anatomical features (faces, hands, and feet) and the dresses are carefully designed (green arrows in Figure S1b, S1d, and S1f) even if the painting is not a portrait as in the case of “The Noli Me Tangere”. On the other hand the background surrounding the main subject is just sketched; this is evident for “The Noli Me Tangere”, but can be observed also in the panel, “The Holy Mary that breastfeeds the Holy Baby” in which the scenario framed by the window is composed by few sparse traits (pink arrows in Figures S1d and S1f). Moreover, these case studies confirm that the algorithm cannot be asked for exact recovery of the UD designed by the artist. Some areas of the extracted underdrawings appear over-segmented (red arrows in Figure S1b, S1d and S1e) while others are characterized by fewer details with respect to what one would expect (orange arrows Figure S1b, S1d and S1e). Because the paintings all come from the same workshop, i.e., the same Master, fewer details are not surprising and the reasons that determine the performance of the algorithm are the same as those discussed in the main text while describing the

results obtained on “The Holy Family with St. Anne and the Young St. John” and “The Child with the Lamb”.

Since it requires the direct involvement of the user, the removal of the compromised images keeps a certain degree of arbitrariness and can be recognized as, computationally, the most critical step of the algorithm. The panels of Figure S2 report all the masks obtained by the none SHSs used for the analysis of “The Holy Family”. The green v and the red x indicate the masks used for recovering the UD and those that have been discarded, respectively.

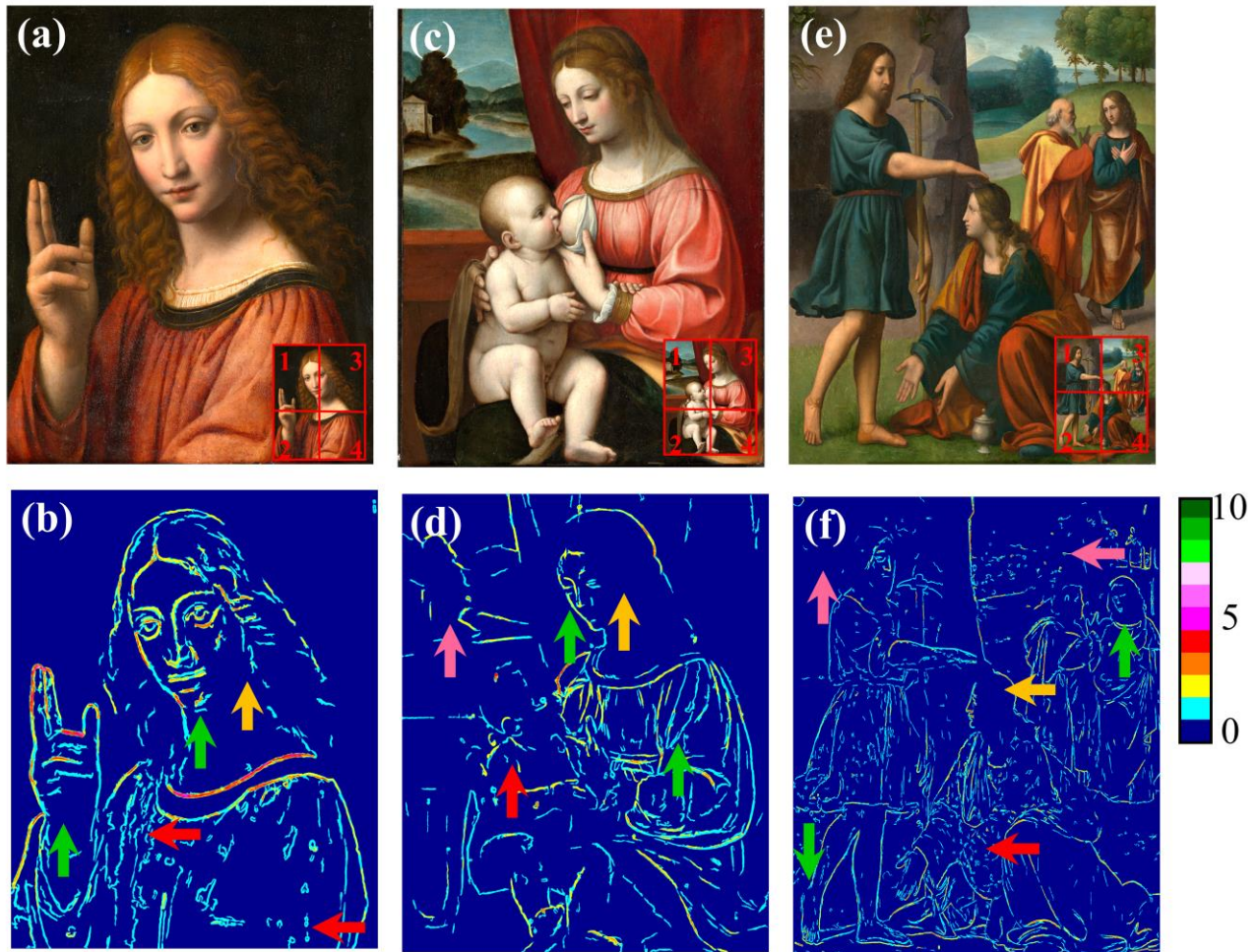


Figure S1. Three paintings by Bernardino Luini searched for the UD. (a–b) Show respectively an RGB image and the extracted underdrawing of “The Blessing Christ”. (cd) Show respectively an RGB image and the extracted underdrawing of “The Holy Mary that breastfeeds the Holy Baby”. (e–f) Show respectively an RGB image and the extracted underdrawing of “The Noli Me Tangere”. In (a), (c) and (e) the contrast of the images has been deliberately enhanced for display purpose. The Insets shows the organization of the sub-hyper-spaces used for extracting the UDs. The multi-colour bars refer to (b), (d), and (f) and indicate how many times a pixel has been detected as belonging to the traits of the UD. The colored arrows point out the main details of the UDs discussed in the supplementary materials’ short discussion.

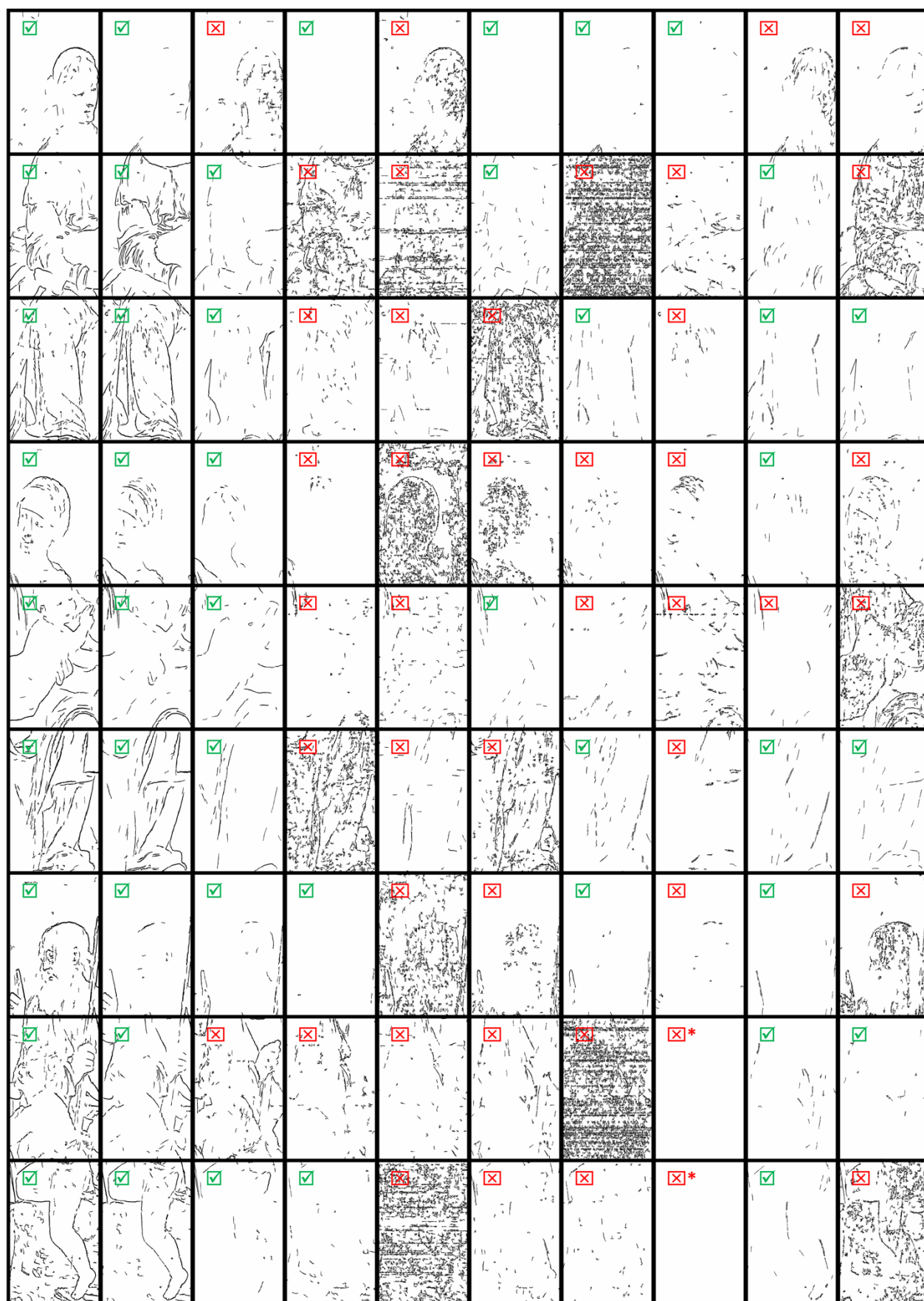


Figure S2. The binarized images that the user has been asked to check in the case of the painting “The Holy Family with St. Anne and the Young St. John”. The nine stripes refer to the nine sub-

hyper-spaces in which the stack of the original reflectograms has been divided. The red x highlights the discarded components while the green checkmarks indicate the images used for recovering the UD. The masks indicated by the symbol \* have been discarded because they do not contain information at all.