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# Improving self-supervised 3D face reconstruction with few-shot transfer learning

Martin Dornier, Philippe-Henri Gosselin, Yann Ricquebourg, Christian Raymond, Bertrand B. Coüasnon

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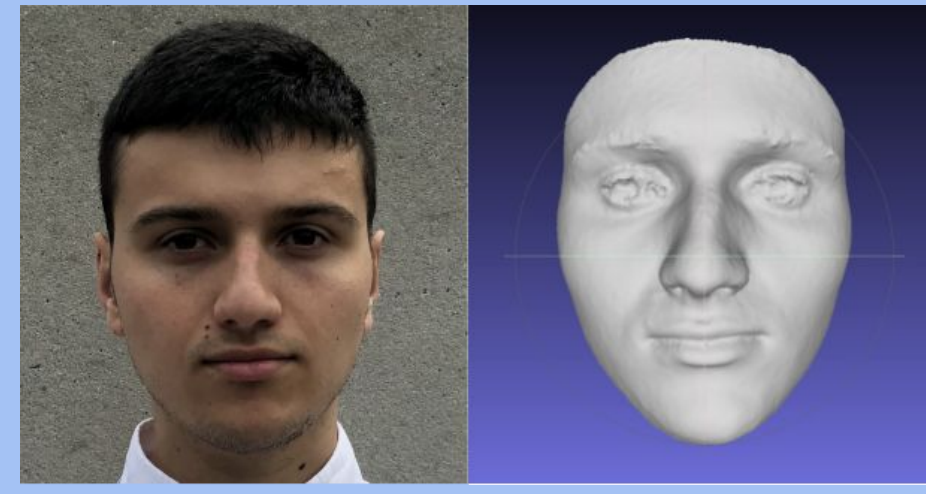
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## 1. INTRODUCTION

### 1.1 3D face reconstruction

**Principle:** Get a face 3D mesh from a monocular face image



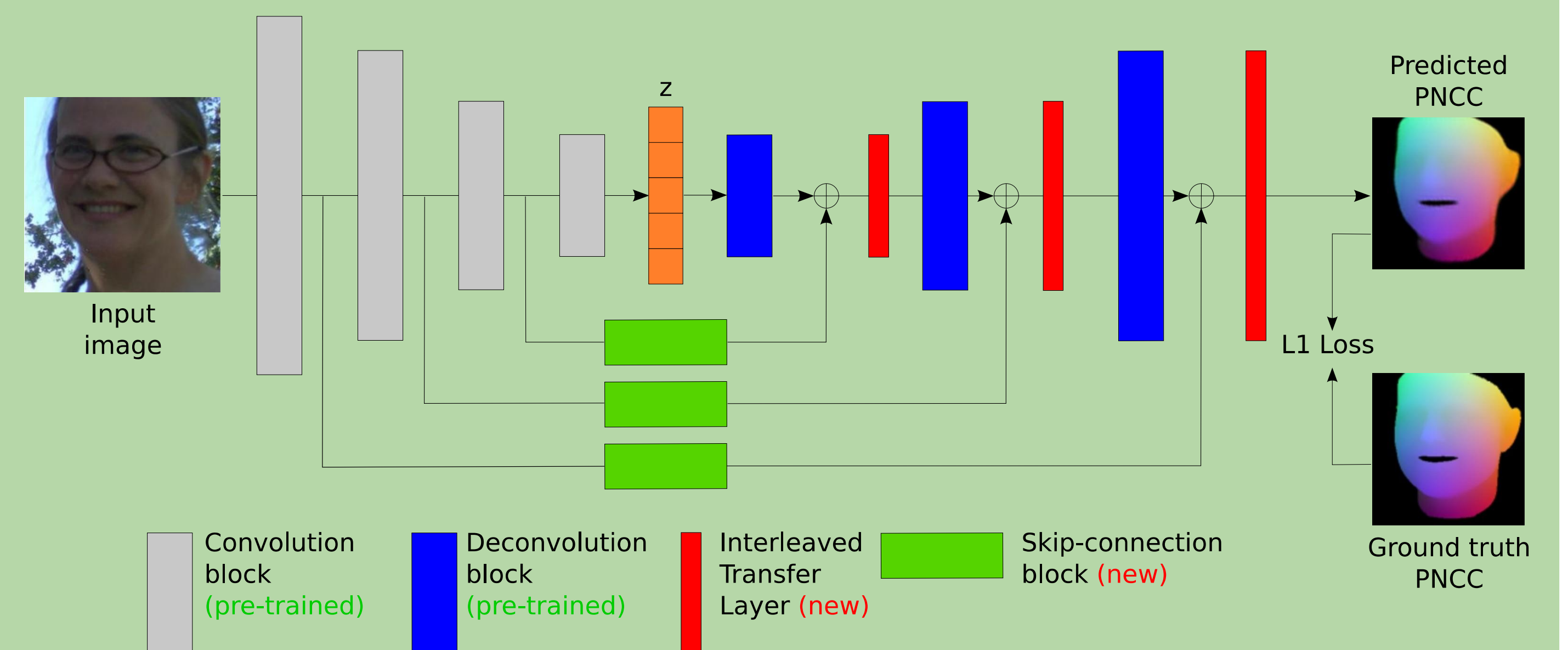
### 1.2 Problem: lack of annotated data

- **Supervised methods:**
  - Need annotated data to train
  - **3D annotations are hard to obtain**
- **Self-supervised methods:**
  - Do not need annotated data
  - **But tend to predict wrong head pose and scale**

### 1.3 Goal: Improve self-supervised methods predicted head pose and scale

- Add **supervised 3D** information
- But use **as few as possible** annotated 3D samples

### 2.2 PNCC predictor

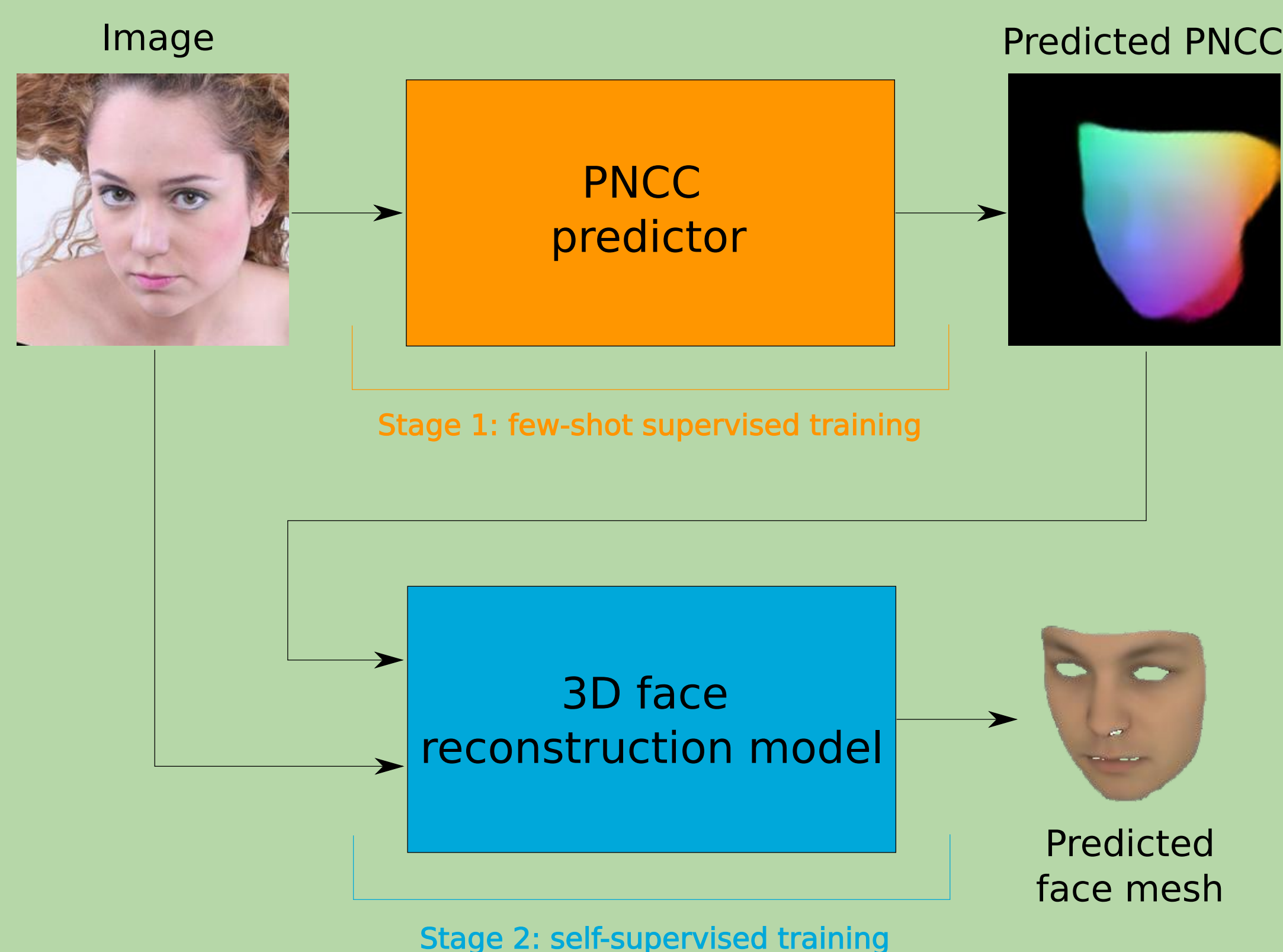


- Architecture based on SCAF [4]
  - **Pre-trained face autoencoder** adapted to the PNCC prediction task
  - **Interleaved Transfer Layers (ITLs)** [3] and **skip-connections** are added for the supervised PNCC prediction task
  - ITLs adapt the decoder flow to the PNCC prediction task
  - Skip-connections improve the quality of the generated PNCCs
  - Can be trained with **limited annotated data**

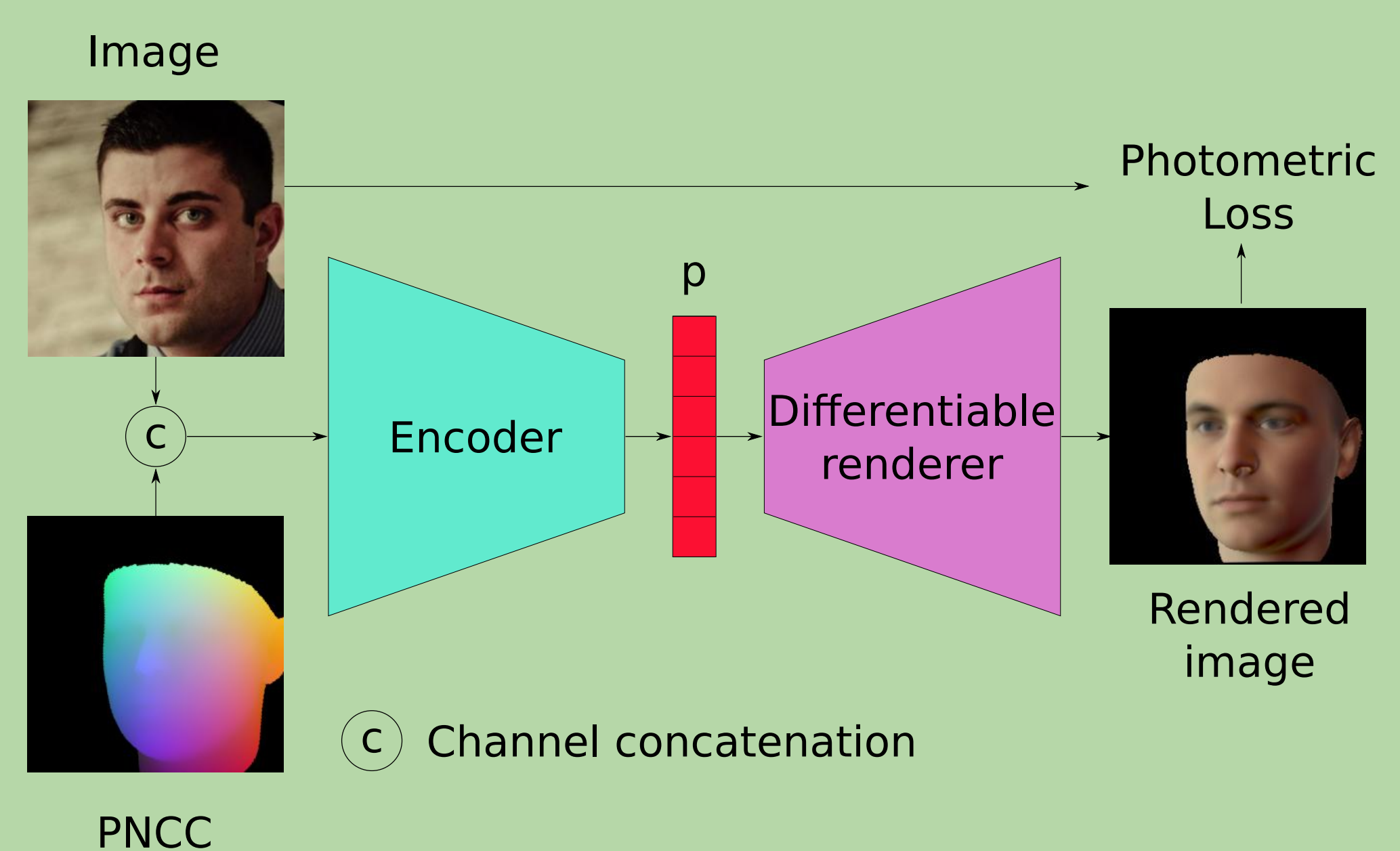
## 2. Method

### 2.1 Principle

- Use the **Projected Normalized Coordinate Code (PNCC)** [1] as supervised information
- **2-stage** pipeline
  - **Stage 1:** Train a PNCC predictor with **a few annotated 3D samples**
  - **Stage 2:** Add the **PNCC as additional input** to a self-supervised 3D face reconstruction model



### 2.3 Enhanced 3D face reconstruction model



- 3D face reconstruction model based on the **self-supervised model MoFa** [2]
- The encoder predicts the 3D face parameter vector (3D face reconstruction goal)
- The decoder renders the face from the parameter vector
  - Only used for training
- We enhance MoFa [2] with an **additional PNCC input** to help it **predict better head pose and scale**
- The **face image is concatenated** with the **PNCC** predicted with our PNCC predictor

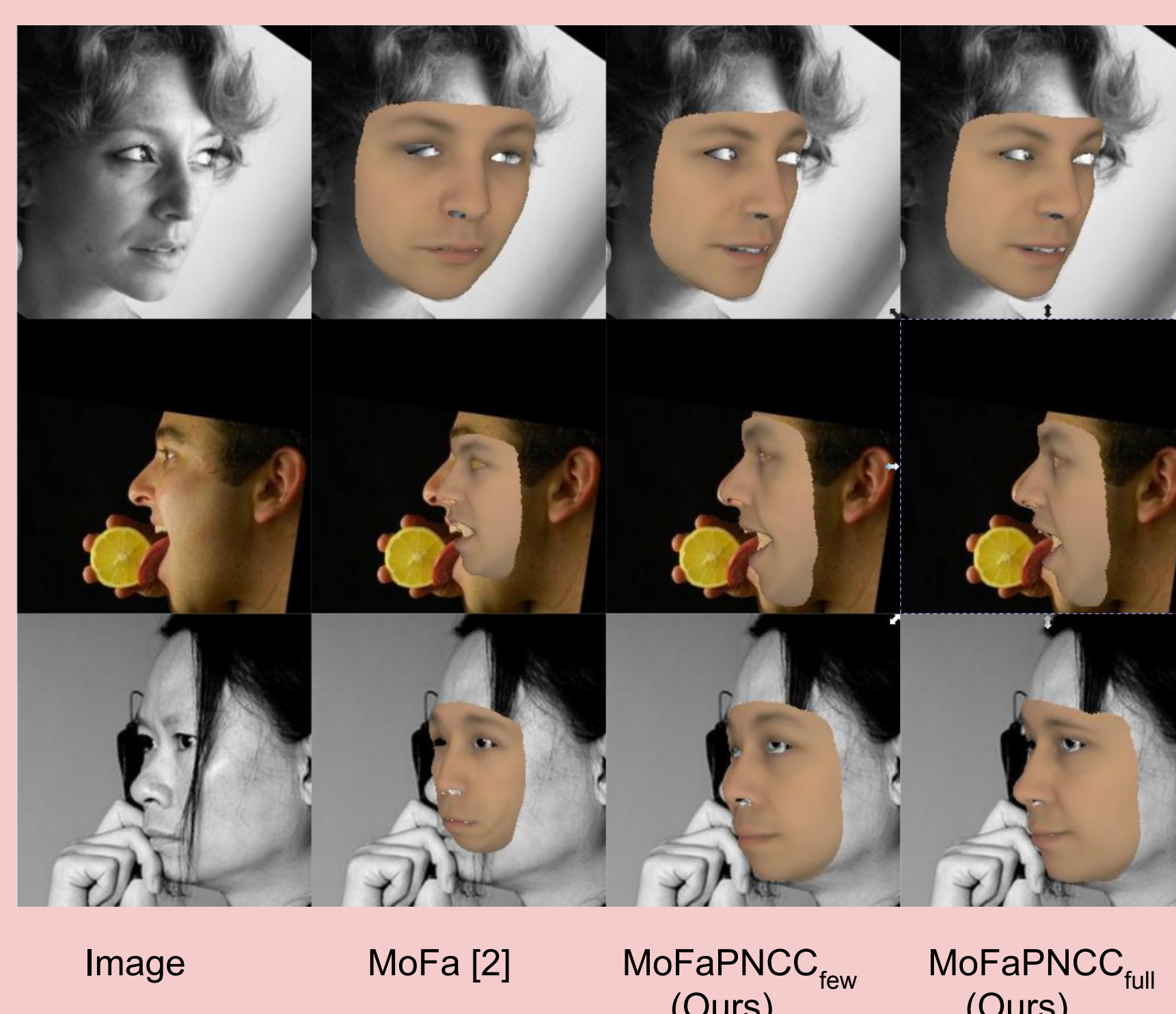
## 3. Results

### 3.1 Quantitative results

Method	Dense 2D ↓	Dense 3D ↓	Yaw MAE ↓
MoFa [2]	4.31	5.85	4.97
MoFaPNCC <sub>few</sub> (Ours)	4.20	5.66	4.95
MoFaPNCC <sub>full</sub> (Ours)	4.12	5.48	4.66

- MoFaPNCC<sub>few</sub> uses PNCC predictions from our PNCC predictor trained with **only 50 annotated samples** of 300W-LP [1] dataset
- MoFaPNCC<sub>full</sub> uses PNCC predictions from our PNCC predictor trained on the whole 300W-LP
- Both models **improve over MoFa** [2] for the **dense alignment** (Dense 2D and 3D) and **head pose** (Yaw MAE) error metrics

### 3.1 Qualitative results



- Our models predict better head pose and face scale

## 4. Conclusion

- Proposed method for 3D face reconstruction
  - **Goal:** improve the predicted **head pose** and **face scale** of self-supervised methods
  - **Context:** use **limited annotated data** (50 examples)
  - **Principle:** use the **PNCC** [1] to help the 3D face reconstruction model
- **Implementation: 2-stage pipeline**
  - **Stage 1: PNCC predictor training**
    - Based on a **pre-trained generative model**
    - Adapted to the PNCC task via the addition of **ITLs and skip-connections**.
    - Trained with **limited annotated data**
  - **Stage 2: Self-supervised 3D face reconstruction model training**
    - Predicted **PNCCs** as **additional input**
    - **Results: improved predicted head pose and face scale** compared to baseline

Martin Dornier<sup>1,2</sup>  
Philippe-Henri Gosselin<sup>1</sup>  
Yann Ricquebourg<sup>2</sup>  
Christian Raymond<sup>2</sup>  
Bertrand Couasnon<sup>2</sup>

**Contact**  
martin.dornier@irisa.fr

### References

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- [2] Ayush Tewari, Michael Zollhofer, Hyeonwoo Kim, Pablo Garrido, Florian Bernard, Patrick Perez, and Christian Theobalt. 2017. MoFa: Model-based deep convolutional face autoencoder for unsupervised monocular reconstruction. In Proceedings of the IEEE International Conference on Computer Vision Workshops. 1274–1283
- [3] Bjorn Browatzki and Christian Wallraven. « 3fabrec: Fast few-shot face alignment by reconstruction ». In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, 2020, pp. 6110–6120
- [4] Martin Dornier, Philippe-Henri Gosselin, Christian Raymond, Yann Ricquebourg, and Bertrand Couasnon. « SCAF: Skip-Connections in Auto-encoder for Face Alignment with Few Annotated Data ». In International Conference on Image Analysis and Processing, Springer, 2022, pp. 425–437.

<sup>1</sup>InterDigital

<sup>2</sup>Univ Rennes, CNRS, IRISA, France