Test Plan:
STEM Moiré GPA

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1 Revision History

Date	Version	Notes
Date 1	1.0	Notes

2 Symbols, Abbreviations and Acronyms

symbol	description
T	Test

Contents

List of Tables

List of Figures

3 General Information

3.1 Purpose

The purpose of the document is to provide the plan for testing STEM Moiré GPA software.

3.2 Scope

3.3 Overview of Document

4 Plan

4.1 Software Description

STEM Moiré GPA software is converting STEM Moiré hologram into deformation maps. Details on the goal and the requirements of STEM Moiré GPA are provided in the Problem Statement and the SRS documents. Acronyms, symbols and terminologies used in the following document are the same as the ones in the SRS document.

4.2 Test Team

The author is the only member of the test team.

4.3 Automated Testing Approach

blbabla

4.4 Verification Tools

4.5 Non-Testing Based Verification

5 System Test Description

5.1 Tests for Functional Requirements

5.1.1 Output error characterization

Test R 3 in IM 1: Correctness of the sampling theory application when undersampling g

Test 1 Test-aliasing-frequency

- ⋆ Type: Functional, Dynamical
- ⋆ Initial State:
- ⋆ Input: $I_{C_{\text{ref}}} = e^{2i\pi gx}$, p such that $\overrightarrow{q} = \frac{1}{p}\vec{u_x}$
- ⋆ Expected output : $\widetilde{I}_{SHM_{\text{sim}}} = \delta(\vec{\nu} - \vec{q})$
- ⋆ Output: $\widetilde{I}^t_{SHM_{\text{sim}}}$ to be tested as a Dirac delta function at $\overrightarrow{q}$

Test R 7 in IM 2: Correctness of the GPA method application

Test 2 Test-Phase-Extraction-No-Strain

- ⋆ Type: Functional, Dynamical
- ⋆ Initial State: ?
- ⋆ Input: $I_{SMH_{exp}} = e^{2i\pi gx}$, Mask M of one pixel at $g\overrightarrow{u_x}$ in $\widetilde{I}_{SMH_{exp}}$
- ⋆ Expected output $P_{\Delta\overrightarrow{g_j}^{M_{exp}}} = 0$, $\Delta\overrightarrow{g_j}^{M_{exp}} = \overrightarrow{0}$,
- ⋆ Test output:$P_{\Delta\overrightarrow{g_j}^{M_{exp}}}{}^t$, $\Delta\overrightarrow{g_j}^{M_{exp}}{}^t$
  - $\forall \vec{r} \in \mathbb{I},\ E_{P_{\Delta\overrightarrow{g_j}^{M_{exp}}}}(\vec{r}) = |P_{\Delta\overrightarrow{g_j}^{M_{exp}}}{}^t(\vec{r})|$
  - $\forall \vec{r} \in \mathbb{I},\ E_{\Delta\overrightarrow{g_j}^{M_{exp}}}(\vec{r}) = |\Delta\overrightarrow{g_j}^{M_{exp}}{}^t(\vec{r})|$

Test 3 Test-Phase-Extraction-Known-Strain

- ⋆ Type: Functional, Dynamical
- ⋆ Initial State:
- ⋆ Input: $I_{SMH_{exp}} = e^{2i\pi(g+K(x))x}$, Mask M centred on $g\overrightarrow{u_x}$ in $\widetilde{I}_{SMH_{exp}}$ and with the minimum radius to include $K(x)$.
- ⋆ Expected output $P_{\Delta\overrightarrow{g_j}^{M_{exp}}} = K(x)x$, $\Delta\overrightarrow{g_j}^{M_{exp}} = K(x)\overrightarrow{u_x}$,
- ⋆ Test output:$P_{\Delta\overrightarrow{g_j}^{M_{exp}}}{}^t$, $\Delta\overrightarrow{g_j}^{M_{exp}\,t}$
  - $\forall \vec{r} \in \mathbb{I},\ E_{P_{\Delta\overrightarrow{g_j}^{M_{exp}}}}(\vec{r}) = |P_{\Delta\overrightarrow{g_j}^{M_{exp}}}{}^t(\vec{r}) - P_{\Delta\overrightarrow{g_j}^{M_{exp}}}(\vec{r})|$
  - $\forall \vec{r} \in \mathbb{I},\ E_{\Delta\overrightarrow{g_j}^{M_{exp}}}(\vec{r}) = |\Delta\overrightarrow{g_j}^{M_{exp}\,t}(\vec{r}) - \Delta\overrightarrow{g_j}^{M_{exp}}(\vec{r})|$

Test 4 Test-Phase-Extraction-Mask

- ⋆ Type: Functional, Dynamical
- ⋆ Initial State:
- ⋆ Input: $I_{SMH_{exp}} = e^{2i\pi(g+K(x))x}$, Mask M centred on $g\overrightarrow{u_x}$ in $\widetilde{I}_{SMH_{exp}}$ with different radius ϵ.
- ⋆ Expected output $P_{\Delta\overrightarrow{g_j}^{M_{exp}}} = K(x)x$, $\Delta\overrightarrow{g_j}^{M_{exp}} = K(x)\overrightarrow{u_x}$,
- ⋆ Test output:$P_{\Delta\overrightarrow{g_j}^{M_{exp}}}{}^t$, $\Delta\overrightarrow{g_j}^{M_{exp}\,t}$
  - $\forall \vec{r} \in \mathbb{I},\ E_{P_{\Delta\overrightarrow{g_j}^{M_{exp}}}}(\vec{r},\epsilon) = |P_{\Delta\overrightarrow{g_j}^{M_{exp}}}{}^t(\vec{r},\epsilon) - P_{\Delta\overrightarrow{g_j}^{M_{exp}}}(\vec{r})|$
  - $\forall \vec{r} \in \mathbb{I},\ E_{\Delta\overrightarrow{g_j}^{M_{exp}}}(\vec{r},\epsilon) = |\Delta\overrightarrow{g_j}^{M_{exp}\,t}(\vec{r},\epsilon) - \Delta\overrightarrow{g_j}^{M_{exp}}(\vec{r})|$

Because the GPA method is itself based on a approximation (see IM 2 in SRS document), errors from the algorithm are added to the errors from the code. Both are probed at the same time in the tests and cannot be fully separated. Therefore, to interpret the various 2D array errors generated from the test functions Test 3, Test 4, the error will be characterized as a function of the mask properties (such as radius) and the deformation magnitude. This characterization will allow the GPA algorithm of STEM Moiré GPA to be compared with other software using the same GPA algorithm.

Test R 10 in IM 3: Correctness of the unstrained reference calculation

Test 5 Test-constant-delta-g

- Type: Functional, Dynamical
- Initial State:
- Input:
  - $\forall \vec{r} \in \mathbb{I},\ \Delta \overrightarrow{g}^{M_{\text{exp}}}(\vec{r}) = \overrightarrow{C}$
  - U array of 1 pixel wherever on $\Delta \overrightarrow{g}^{M_{\text{exp}}}(\vec{r})$
  - $\overrightarrow{g}^{M_{\text{exp}}} = {g_x}^{M_{\text{exp}}}\overrightarrow{u_x} + {g_y}^{M_{\text{exp}}}\overrightarrow{u_y}$
- Expected output: $\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}} = \overrightarrow{g}^{M_{\text{exp}}} - \overrightarrow{C},\ \Delta \overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}} = \overrightarrow{0}$
- Output: ${\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}}^{t},\ \Delta {\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}}^{t}$
  - $E_{\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}} = ||{\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}}^{t} - \overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}||$
  - $\forall \vec{r} \in \mathbb{I},\ E_{\Delta \overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}} = ||\Delta {\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}}^{t}||$

Test 6 Test-constant-delta-g-with-noise

- Type: Functional, Dynamical
- Initial State:
- Input:
  - $\overrightarrow{N}$, 2D random noise
  - $\forall \vec{r} \in \mathbb{I},\ \Delta \overrightarrow{g}^{M_{\text{exp}}}(\vec{r}) = \overrightarrow{C} + \overrightarrow{N}$
  - U array of $n \times m$ pixels wherever on $\Delta \overrightarrow{g}^{M_{\text{exp}}}(\vec{r})$
  - $\overrightarrow{g}^{M_{\text{exp}}} = {g_x}^{M_{\text{exp}}}\overrightarrow{u_x} + {g_y}^{M_{\text{exp}}}\overrightarrow{u_y}$
- Expected output: $\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}} = \overrightarrow{g}^{M_{\text{exp}}} - \overrightarrow{C},\ \Delta \overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}} = \overrightarrow{0}$
- Output: ${\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}}^{t}, \Delta {\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}}^{t}$

- $E_{\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}} = ||\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}{}^{t} - \overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}||$
- $\forall \vec{r} \in \mathbb{I},\ E_{\Delta\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}} = ||\Delta\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}{}^{t}||$

Test 6 is more representative of a real case than Test 5 and will be use to characterize the evolution of the error with respect to the level of noise and the size of U. The evaluation of $\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}$ is critical on the quantitative estimation of strain and rotation.

Test 7 Test-varying-delta-g

- ⋆ Type: Functional, Dynamical
- ⋆ Initial State:
- ⋆ Input:
  - $\forall \vec{r} \in \mathbb{I},\ \overrightarrow{g}^{M_{\text{exp}}}(\vec{r}) = \overrightarrow{C}(\vec{r})$
  - U array of $n \times m$ pixels wherever on $\Delta\overrightarrow{g}^{M_{\text{exp}}}(\vec{r})$
  - $\overrightarrow{g}^{M_{\text{exp}}} = g_x{}^{M_{\text{exp}}}\overrightarrow{u_x} + g_y{}^{M_{\text{exp}}}\overrightarrow{u_y}$
- ⋆ Expected output: $\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}} = \overrightarrow{g}^{M_{\text{exp}}} - F(\overrightarrow{C}(\vec{r}))$, $\Delta\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}} = \overrightarrow{C}(\vec{r}) - F(\overrightarrow{C}(\vec{r}))$ where $F(\overrightarrow{C}(\vec{r}))$ is the best possible linear fit of $\overrightarrow{C}(\vec{r})$ in U.
- ⋆ Output: $\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}{}^{t}, \Delta\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}{}^{t}$
  - $E_{\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}} = ||\overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}{}^{t} - \overrightarrow{g}^{M_{\text{exp}}}_{\text{uns}}||$
  - $\forall \vec{r} \in \mathbb{I},\ E_{\Delta\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}} = ||\Delta\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}{}^{t} - \Delta\overrightarrow{g_j}^{M_{\text{exp}}}_{\text{cor}}||$

5.2 Tests for Nonfunctional Requirements

5.2.1 Evolution of accuracy with noise of STEM Moiré GPA

Test NR 8 and NR 9

Test 8 bla

- ⋆ Type: Functional, Dynimical, Black box

- ⋆ Initial State: All parameters are predefined except the STEM Moiré holograms
- ⋆ Input: STEM Moiré holograms with different level of noise:
  - $I^1_{SMH_{\text{exp}}} = I(\vec{r})^1 + N(\vec{r})$ with I^1 a perfect SMH and N a random noise
  - $I^2_{SMH_{\text{exp}}} = I(\vec{r})^2 + N(\vec{r})$ with I^2 another perfect SMH and N the same random noise
- ⋆ Expected output
- ⋆ Output:

5.3 Traceability Between Test Cases and Requirements

6 Unit Testing Plan

6.0.1 Input Verification test

Test R 2 in IM 1

Test 9 Test-Existence-SMH

- ⋆ Type: Dynamical
- ⋆ Initial State: Waiting for $I_{SMH_{exp}}$ user input
- ⋆ Input: $I_{SMH_{exp}} = \emptyset$
- ⋆ Output: Error message $Err_{I_{SMH_{exp}}}$ should match: "No STEM Moiré hologram, please load a proper image"

Test 10 Test-Format-SMH

- ⋆ Type: Dynamical
- ⋆ Initial State: Waiting for $I_{SMH_{exp}}$ user input
- ⋆ Input: Various $I_{SMH_{exp}}$ improper format

- ⋆ Output: Error message $Err_{I_{SMH_{exp}}}$ should match: "Invalid STEM Moiré hologram format"

Test 11 Test-Existence-pixel

- ⋆ Type: Dynamical
- ⋆ Initial State: After importing $I_{SMH_{exp}}$ and format validated
- ⋆ Input: p=$\emptyset$
- ⋆ Output: Error message Err_p should match: "No pixel size found"

Test 12 Test-Format-pixel

- ⋆ Type: Dynamical
- ⋆ Initial State: After importing $I_{SMH_{exp}}$ and format validated
- ⋆ Input: Improper format of p
- ⋆ Output: Error message Err_p should match: "Invalid pixel size"

Test 13 Test-Format-Reference

- ⋆ Type: Dynamical
- ⋆ Initial State: Waiting for $I_{C_{ref}}$ user input
- ⋆ Input: Various $I_{C_{ref}}$ improper format
- ⋆ Output: Error message $Err_{I_{C_{ref}}}$ should match: "Invalid Reference image format"

Test R 6 in IM 2

Test 14 Test-Existence-Mask

- ⋆ Type: Dynamical
- ⋆ Initial State: Waiting for M user input on $\widetilde{I}_{SMH_{exp}}$
- ⋆ Input: M=$\emptyset$

- ⋆ Output: Error message Err_M should match: “No Mask found”

Test 15 Test-Format-Mask

- ⋆ Type: Dynamical
- ⋆ Initial State: Waiting for M user input on $\widetilde{I}_{SMH_{exp}}$
- ⋆ Input: M improper format
- ⋆ Output: Error message Err_M should match: “Improper mask format”

Test R 9 in IM 3

Test 16 Test-Existence-U

- ⋆ Type: Dynamical
- ⋆ Initial State: Waiting for U user input on $P_{\Delta\overrightarrow{g_j}^{Mexp}}$
- ⋆ Input: U=∅
- ⋆ Output: Error message Err_U should match: “No reference in phase image found”

Test 17 Test-Format-U

- ⋆ Type: Dynamical
- ⋆ Initial State: Waiting for U user input on $P_{\Delta\overrightarrow{g_j}^{Mexp}}$
- ⋆ Input: U improper format
- ⋆ Output: Error message Err_U should match: “Improper reference in phase image format”

6.0.2 Output results test

Test R 11 in IM 4

Test 18 bla

- Type: Functional
- Initial State:
- Input:
- Expected output
- Output:

TestR 12 in IM 5: Strain and rotation calculation correctness

Test 19 Test-No-2D-strain

- Type: Functional, Dynamical
- Initial State:
- Input:
  - $G_{\text{uns}}^{\text{exp}} = \begin{bmatrix} g_{1_{\text{uns}_x}}^{C_{\text{exp}}} & g_{2_{\text{uns}_x}}^{C_{\text{exp}}} \\ g_{2_{\text{uns}_x}}^{C_{\text{exp}}} & g_{2_{\text{uns}_y}}^{C_{\text{exp}}} \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$
  - $\Delta G^{\text{exp}}(\vec{r}) = \begin{bmatrix} \Delta g_{1_x}^{C_{\text{exp}}}(\vec{r}) & \Delta g_{1_y}^{C_{\text{exp}}}(\vec{r}) \\ \Delta g_{2_x}^{C_{\text{exp}}}(\vec{r}) & \Delta g_{2_y}^{C_{\text{exp}}}(\vec{r}) \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$
- Expected output:
  - $\forall \vec{r} \in \mathbb{I},\ \varepsilon^{\text{exp}}(\vec{r}) = \begin{bmatrix} \varepsilon_{xx^{\text{exp}}}(\vec{r}) & \varepsilon_{xy^{\text{exp}}}(\vec{r}) \\ \varepsilon_{xy^{\text{exp}}}(\vec{r}) & \varepsilon_{yy^{\text{exp}}}(\vec{r}) \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$
  - $\forall \vec{r} \in \mathbb{I},\ \omega^{\text{exp}}(\vec{r}) = \begin{bmatrix} 0 & \omega_{xy^{\text{exp}}}(\vec{r}) \\ -\omega_{xy^{\text{exp}}}(\vec{r}) & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$

Test 20 Test-known-constant-2D-strain

- ⋆ Type: Functional, Dynamical
- ⋆ Initial State:
- ⋆ Input:
  - $G^{\text{exp}}_{\text{uns}} = \begin{bmatrix} g^{C_{\text{exp}}}_{1_{\text{uns}_x}} & g^{C_{\text{exp}}}_{2_{\text{uns}_x}} \\ g^{C_{\text{exp}}}_{2_{\text{uns}_x}} & g^{C_{\text{exp}}}_{2_{\text{uns}_y}} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$
  - Various $\Delta G^{\text{exp}}(\vec{r}) = \begin{bmatrix} \Delta g^{C_{\text{exp}}}_{1_x}(\vec{r}) & \Delta g^{C_{\text{exp}}}_{1_y}(\vec{r}) \\ \Delta g^{C_{\text{exp}}}_{2_x}(\vec{r}) & \Delta g^{C_{\text{exp}}}_{2_y}(\vec{r}) \end{bmatrix}$
    - ∗ Uniaxial strain along $\vec{u_x}$, $\Delta G^{\text{exp}}(\vec{r}) = \begin{bmatrix} 0.1 & 0 \\ 0 & 0 \end{bmatrix}$
    - ∗ Uniaxial strain along $\vec{u_y}$, $\Delta G^{\text{exp}}(\vec{r}) = \begin{bmatrix} 0 & 0 \\ 0 & 0.1 \end{bmatrix}$
    - ∗ Pure shear strain, $\Delta G^{\text{exp}}(\vec{r}) = \begin{bmatrix} 0 & 0.1 \\ 0.1 & 0 \end{bmatrix}$
    - ∗ Pure rotation, $\Delta G^{\text{exp}}(\vec{r}) = \begin{bmatrix} 0 & 0.1 \\ -0.1 & 0 \end{bmatrix}$
- ⋆ Expected output:
  - Uniaxial strain along $\vec{u_x}$,

$$\begin{cases} \forall \vec{r} \in \mathbb{I},\ \varepsilon^{\text{exp}}(\vec{r}) = \begin{bmatrix} -\frac{1}{11} & 0 \\ 0 & 0 \end{bmatrix} \\ \forall \vec{r} \in \mathbb{I},\ \omega^{\text{exp}}(\vec{r}) = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \end{cases}$$

  - Uniaxial strain along $\vec{u_y}$,

$$\begin{cases} \forall \vec{r} \in \mathbb{I},\ \varepsilon^{\text{exp}}(\vec{r}) = \begin{bmatrix} 0 & 0 \\ 0 & -\frac{1}{11} \end{bmatrix} \\ \forall \vec{r} \in \mathbb{I},\ \omega^{\text{exp}}(\vec{r}) = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \end{cases}$$

– Pure shear strain,

$$\begin{cases} \forall \vec{r} \in \mathbb{I},\ \varepsilon^{\exp}(\vec{r}) = \begin{bmatrix} 0 & -\frac{1}{11} \\ -\frac{1}{11} & 0 \end{bmatrix} \\ \forall \vec{r} \in \mathbb{I},\ \omega^{\exp}(\vec{r}) = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \end{cases}$$

– Pure rotation,

$$\begin{cases} \forall \vec{r} \in \mathbb{I},\ \varepsilon^{\exp}(\vec{r}) = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \\ \forall \vec{r} \in \mathbb{I},\ \omega^{\exp}(\vec{r}) = \begin{bmatrix} 0 & \frac{1}{11} \\ -\frac{1}{11} & 0 \end{bmatrix} \end{cases}$$

⋆ Output: $\varepsilon^{\exp}(\vec{r})^t - \varepsilon^{\exp}(\vec{r}), \omega^{\exp}(\vec{r})^t - \omega^{\exp}(\vec{r})$ and test them to be 0

The special case with $det(G^{\exp}_{\text{uns}} + \Delta G^{\exp}) = 0$ should be also tested.

7 Appendix

This is where you can place additional information.

7.1 Symbolic Parameters

The definition of the test cases will call for SYMBOLIC_CONSTANTS. Their values are defined in this section for easy maintenance.

7.2 Usability Survey Questions?

This is a section that would be appropriate for some teams.