计算机图形学第二次作业实验报告

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实验描述

本实验要求：

- 必做部分：使用 Eigen 库，实现至少两种图像变形（Warping）算法
  - Inverse distance-weighted interpolation method (IDW)
  - Radial basis functions interpolation method (RBF)
- 选做部分：
  - 使用 Annoy 库求最近邻点，对变形后的图像实现白缝填充
  - 使用 ANN 库，训练神经网络进行拟合，实现图像变形算法

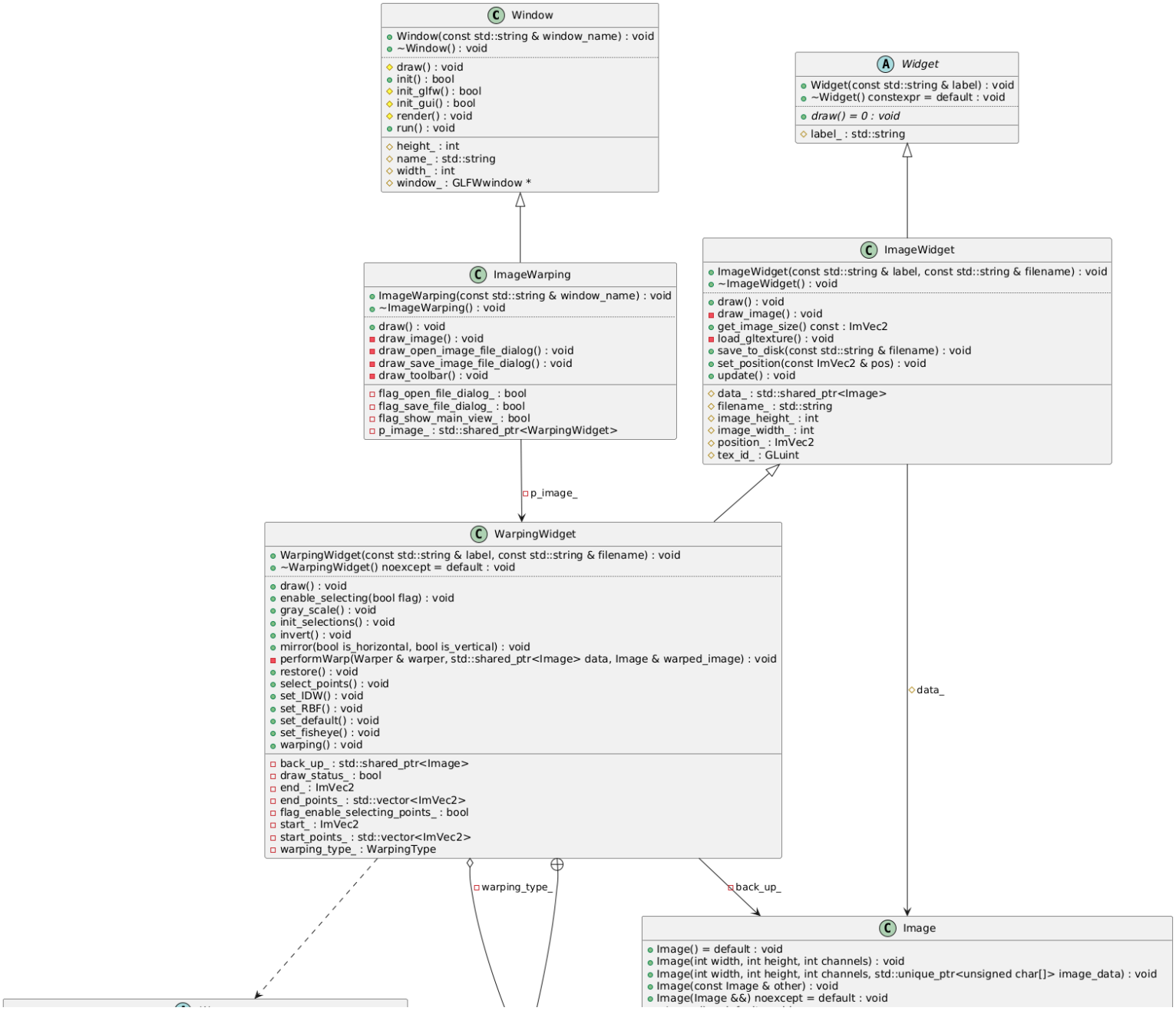
~~由于这周被突发状况淹没~~，我仅完成了必做部分和白缝填充算法，未完成神经网络拟合的部分，比较遗憾。

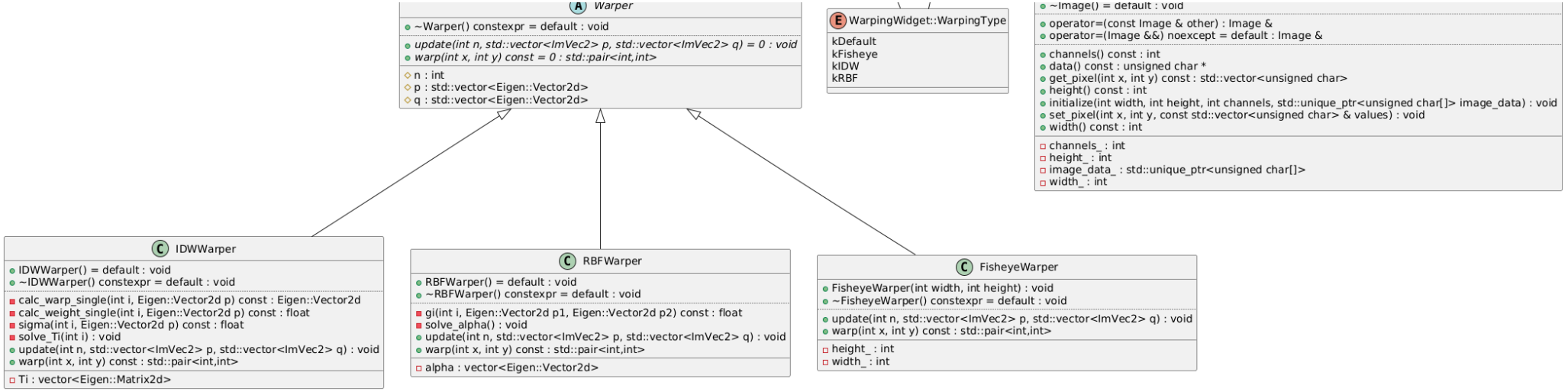
实验过程

整体设计

类图　下所示，`IDWWarper`、`RBFWarper`、`FisheyeWarper` 均为 `Warper` 的派生类，提供相同的接口。`update` 接口用于更新对象的状态，这

些状态用于存储预处理好的数据，从而加速计算。





注意到 `FisheyeWarper` 也被抽象出来，用于减少 `WarpingWidget::warping` 方法的重复代码，简化后的代码　下：

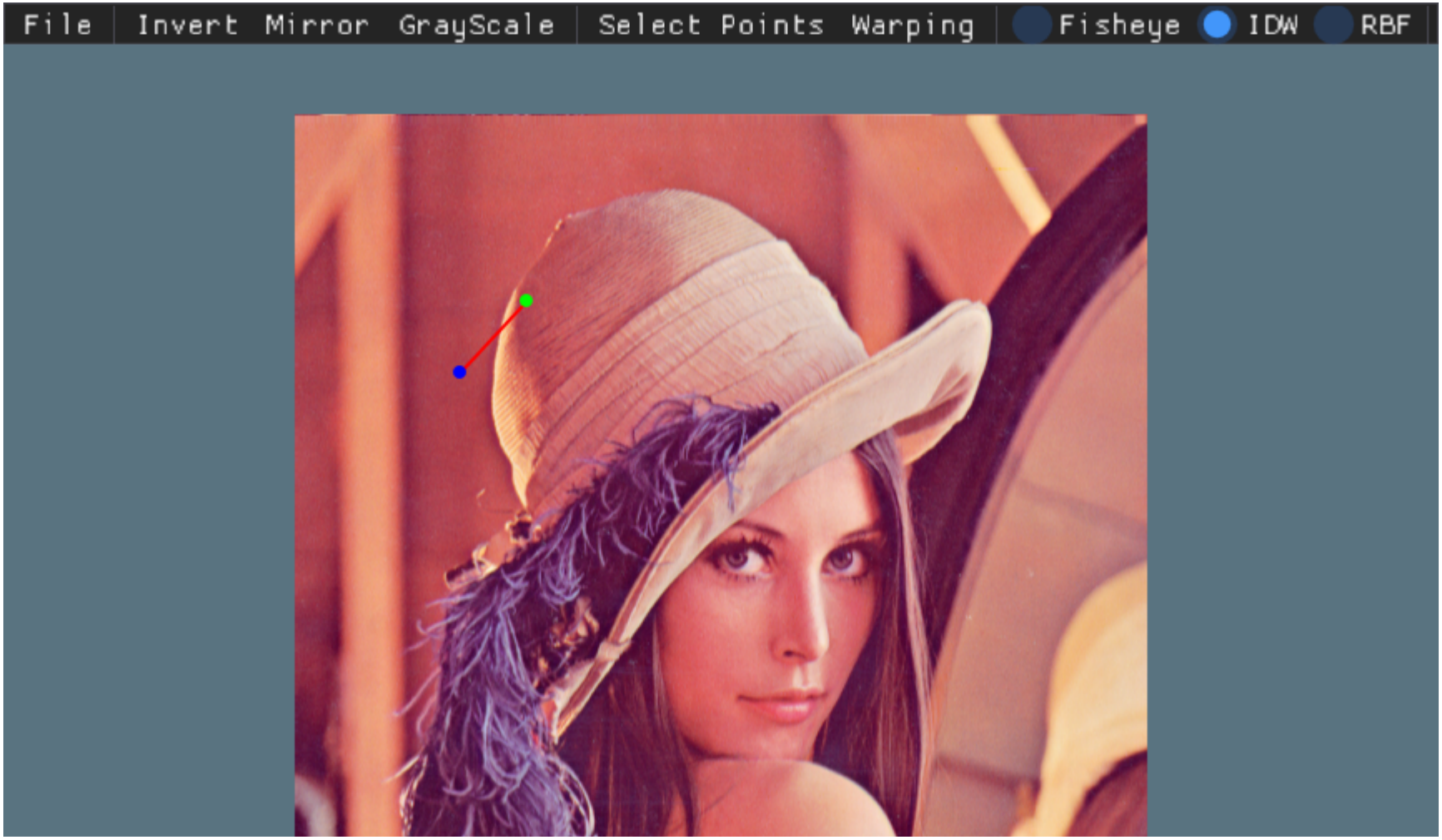
```
std::unique_ptr<Warper> warper;
switch (warping_type_)
{
    case kDefault: break;
    case kFisheye:
        warper = std::make_unique<FisheyeWarper>(data_->width(), data_->height());
        break;
    case kIDW:
    {
        auto idw = std::make_unique<IDWWarper>();
        idw->update(start_points_.size(), start_points_, end_points_);
        warper = std::move(idw);
        break;
    }
    case kRBF:
    {
        auto rbf = std::make_unique<RBFWarper>();
        rbf->update(start_points_.size(), start_points_, end_points_);
        warper = std::move(rbf);
        break;
    }
    default: break;
}

if (warper) {
    performWarp(*warper, data_, warped_image);
    *data_ = std::move(warped_image);
    update();
}
```

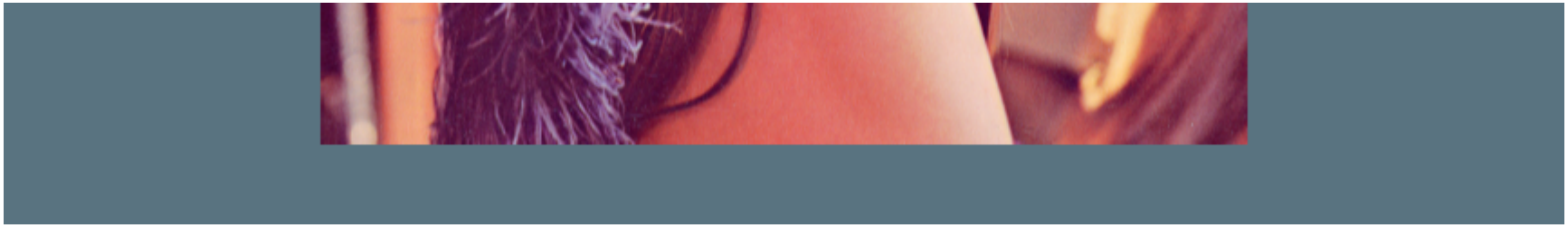
IDW 算法

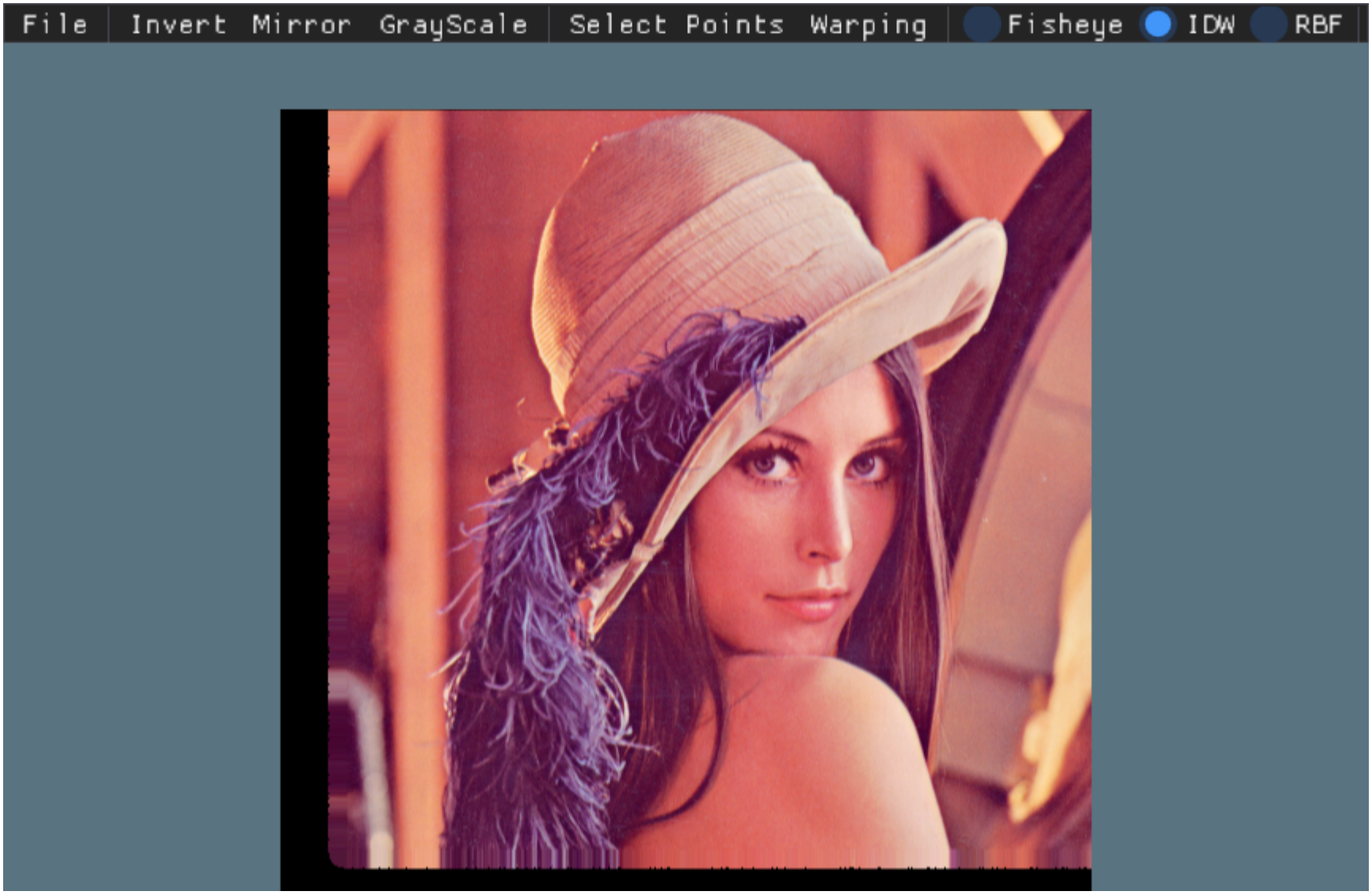
根据给出的公式，需要注意边界条件：

- 当给出的点对小于 3 个时，需要特判处理，我这里直接将 `T_i` 置为单位矩阵了
- 当给出的点对大于等于 3 个时，按公式实现算法即可

实验结果　下：



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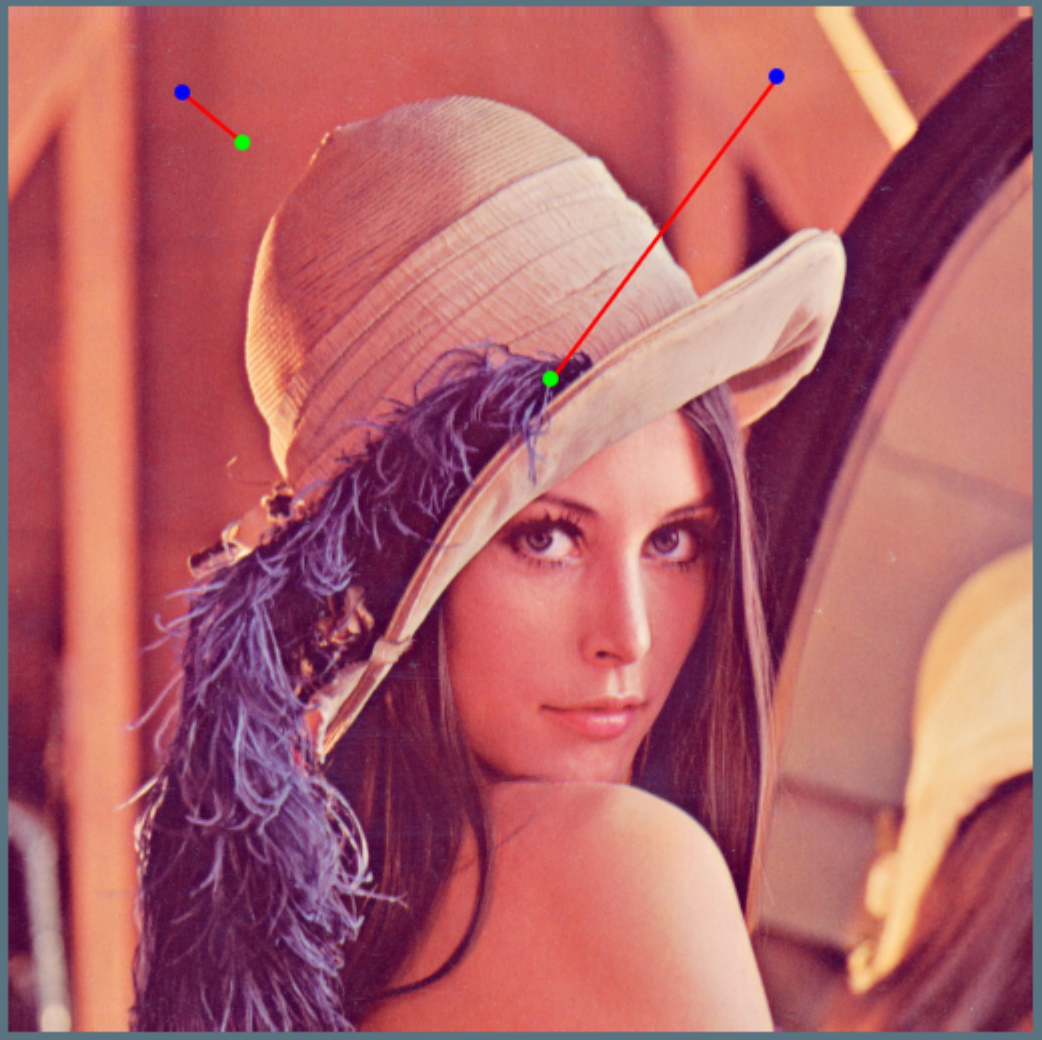
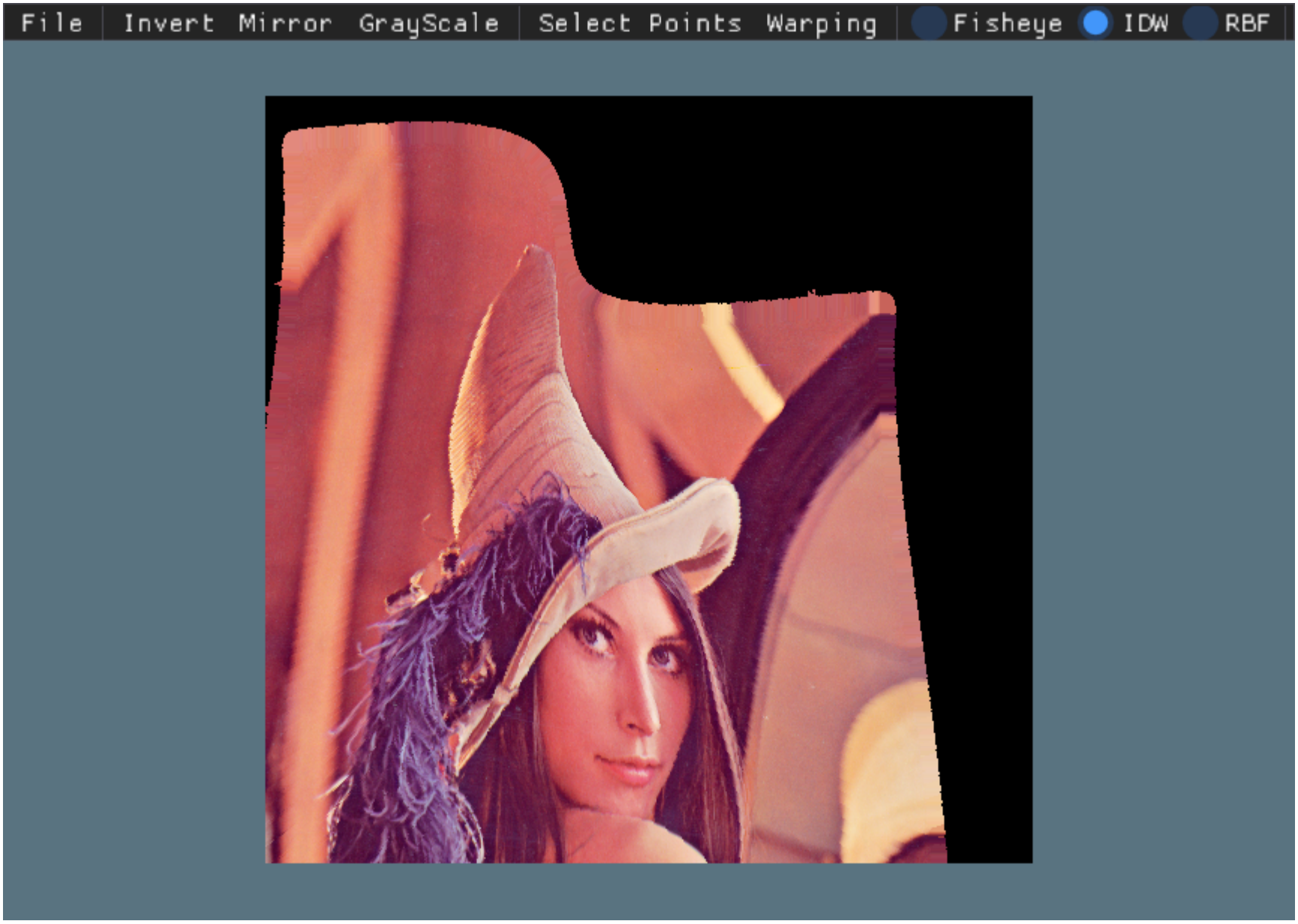
Mirror
GrayScale
Select Points
Warping
Fisheye
IDW
RBF

File Invert Mirror GrayScale Select Points Warping Fisheye IDW RBF

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File
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Warping
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IDW
RBF
Restore


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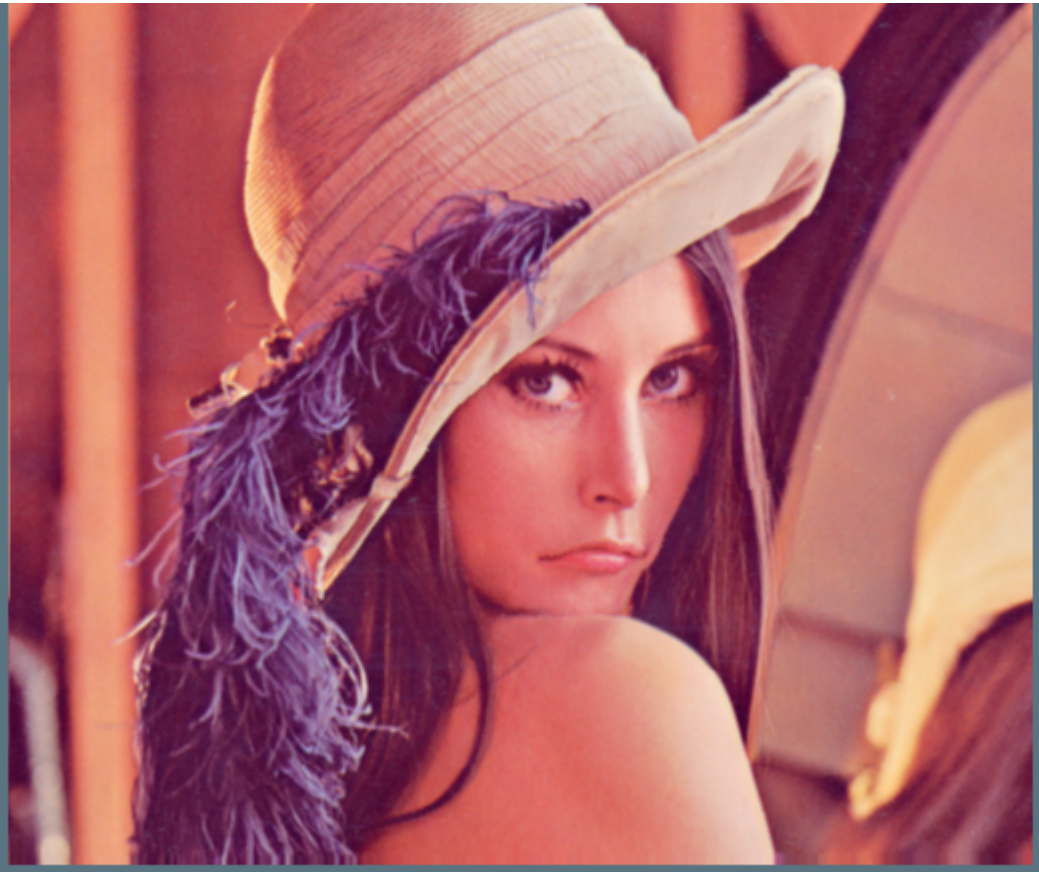
IDW
RBF
Restore



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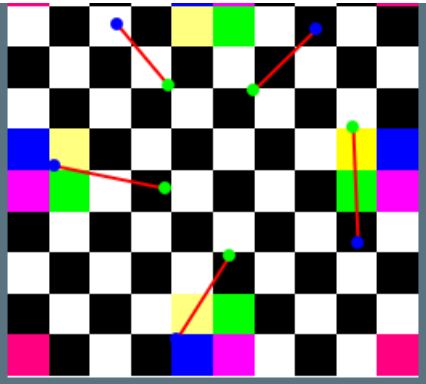

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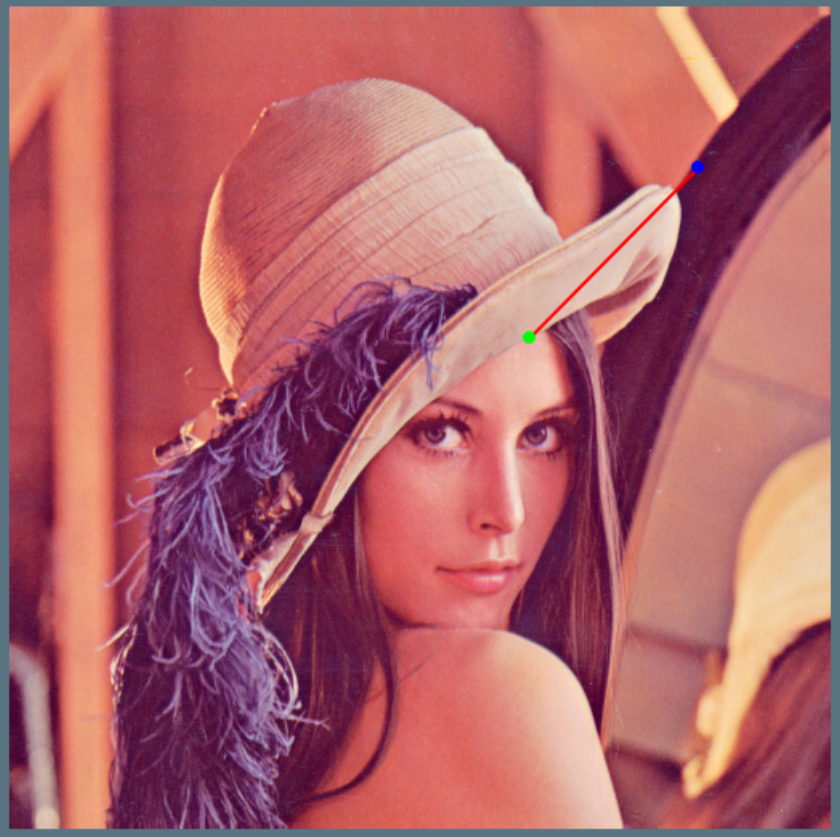
RBF 算法

同样需要注意边界条件：

```
    // 当只有一个控制点时，直接采用平移变换
    if (n == 1)
    {
        alpha.resize(1);
        alpha[0] = this->q[0] - this->p[0];
    }
    else if (n > 1)
    {
        solve_alpha();
    }
```

实验结果　下：



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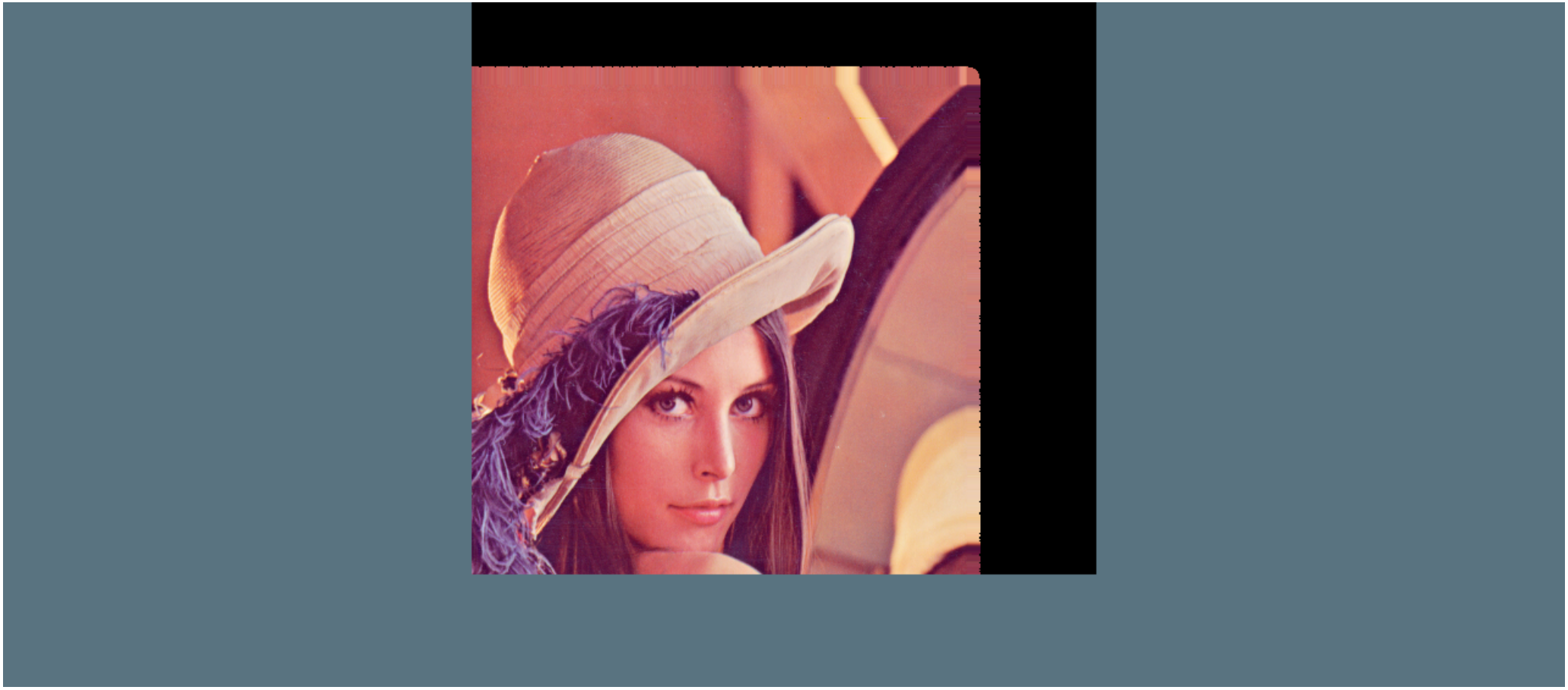

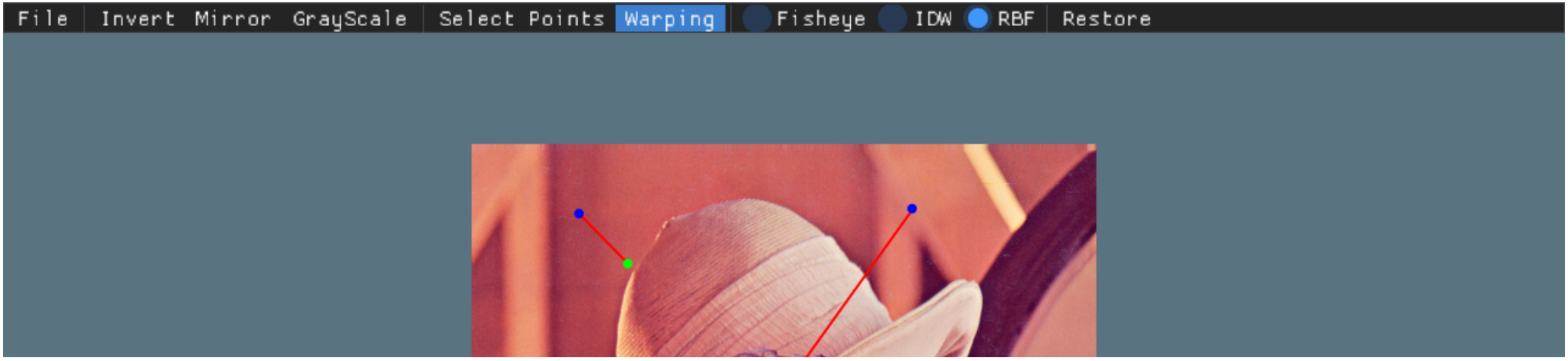
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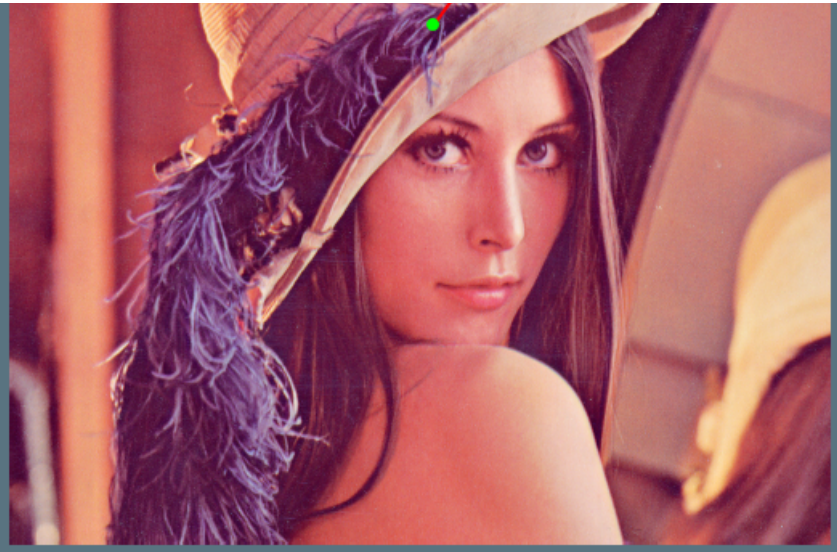

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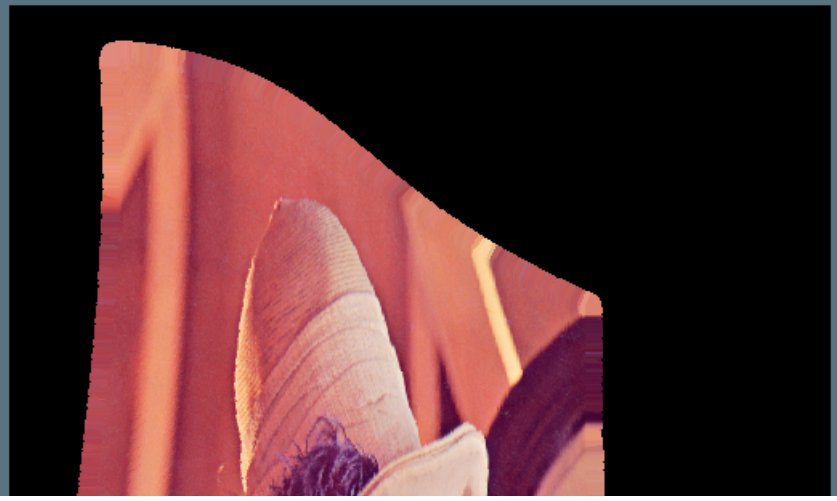

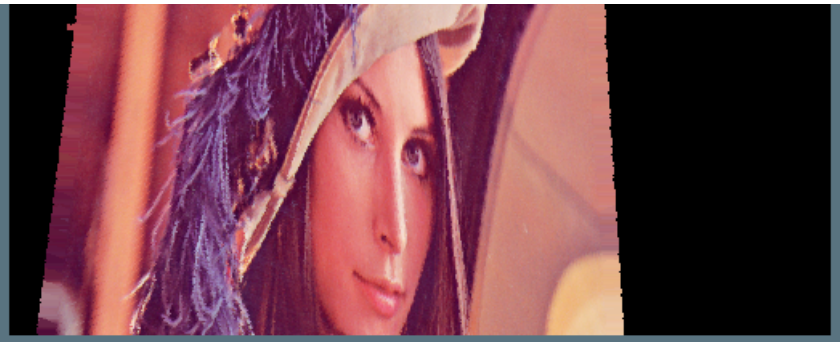

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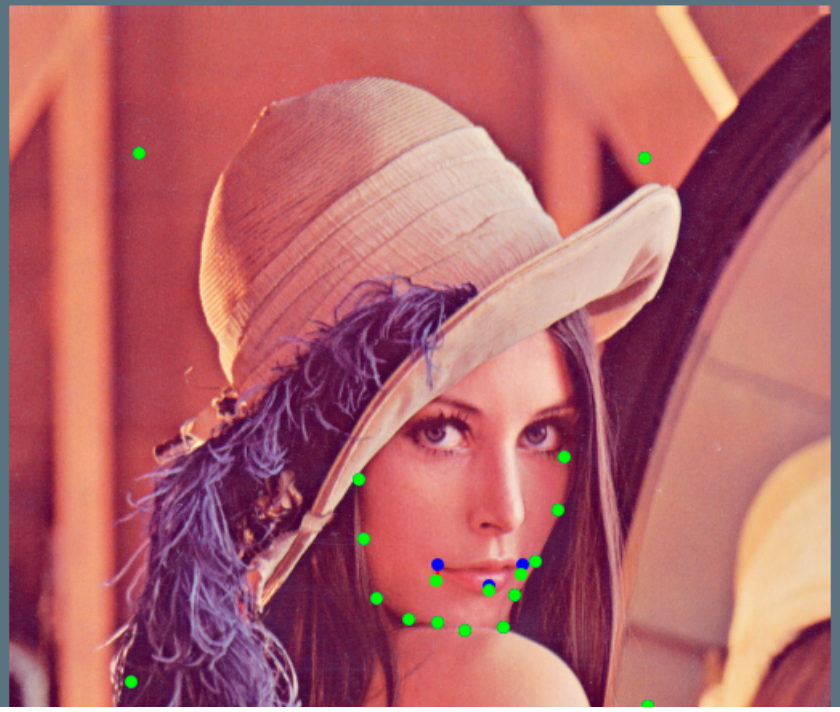

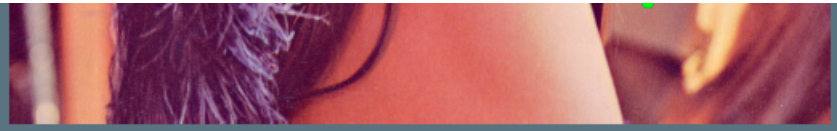

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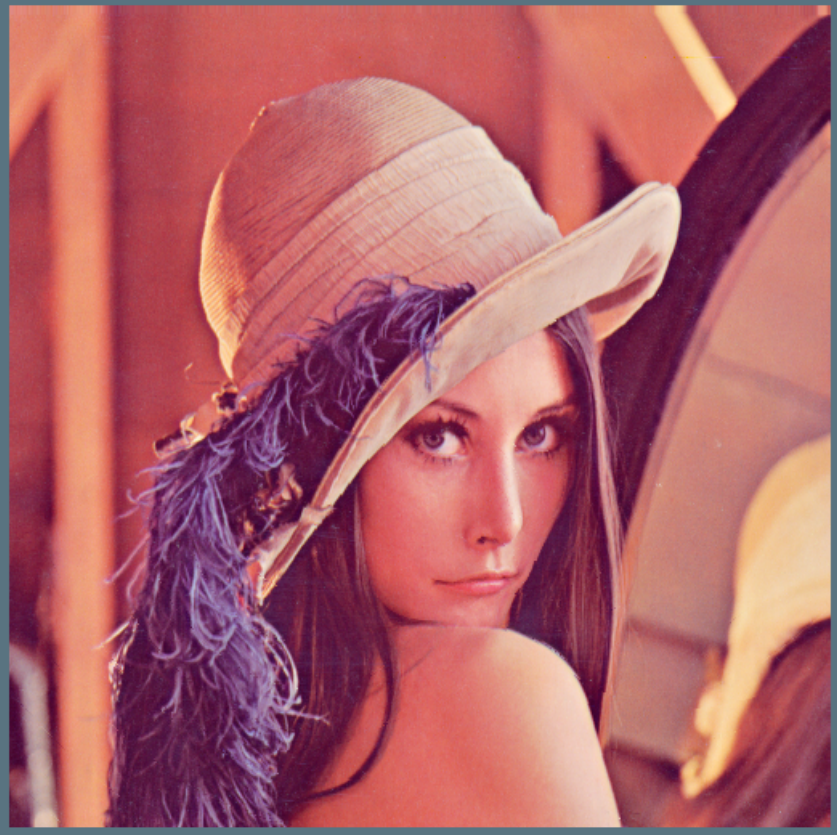

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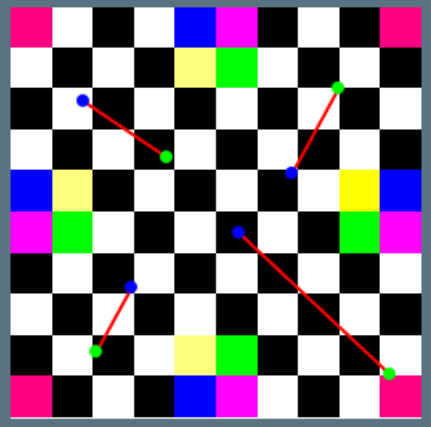

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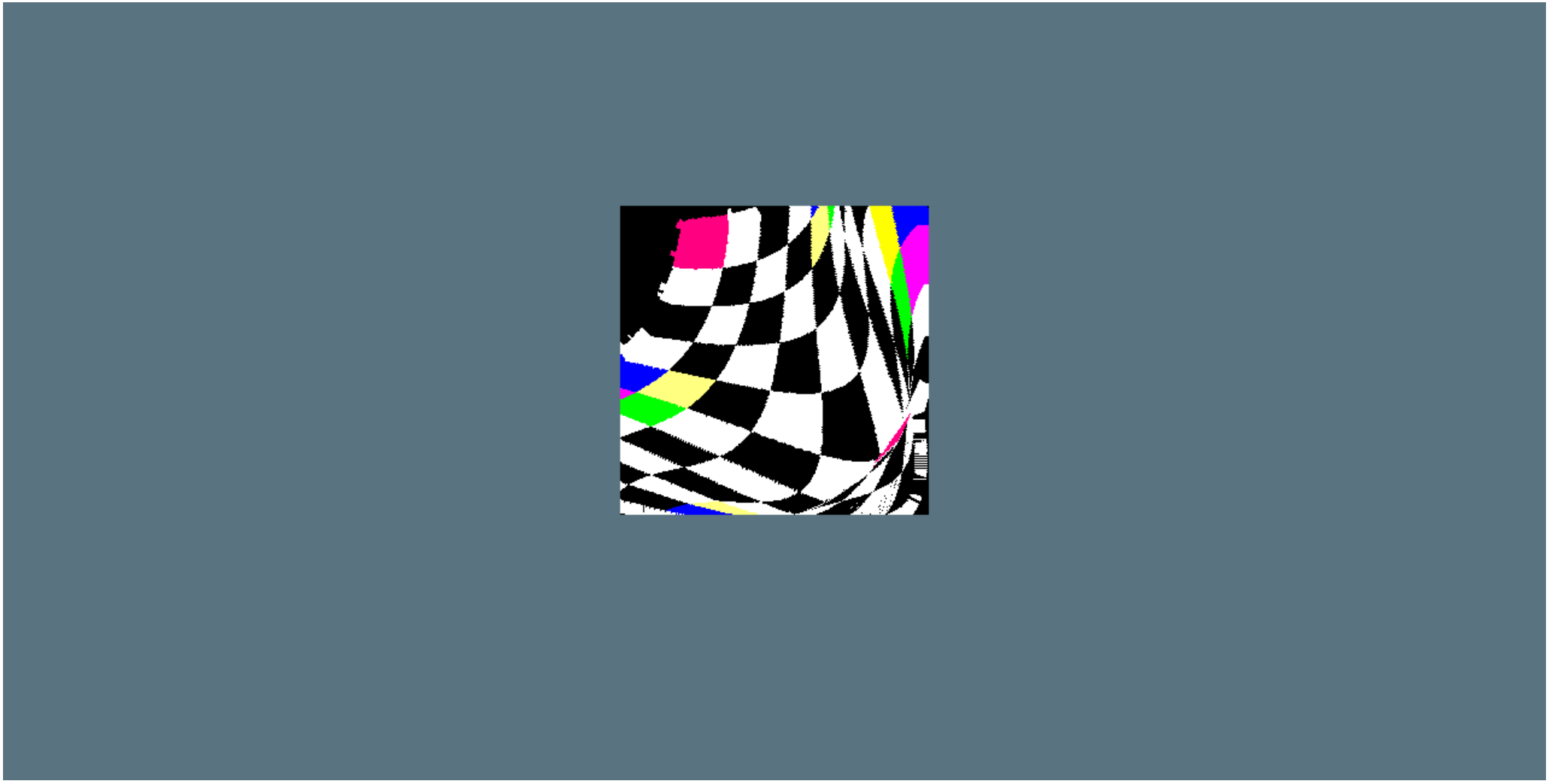

白缝填充（Optional）

作为 `WarpingWidget::performWarp` 的一部分实现，主要函数是 `fillHolesWithNearestNeighbor`。由于时间紧迫，仅实现了最近邻点插值算法，好处是实现简单，坏处是得到的图像锯齿较为明显，效果上不　双线性插值、双三次插值等方法。

这里实现的白缝填充算法不填充变换后图像外的无色区域，而我们只有变换后的像素集合。为了区分一个点是在这些像素之内还是之外，一个可能

的想法是使用计算几何方法，先画出这些像素对应的凸包，再判断这个点是在凸包之外还是之内。然而，计算几何算法手动实现存在难度，相关库也暂时没有时间来研究使用方法。

因此，这里我考虑了一个实现简单的方法，但需要牺牲填充后图像的质量。对于画布上的任意一点 `(x, y)`，寻找其最近邻像素 `(x1, y1)`，两者距离记作 `dis1`；同时寻找 `(x1, y1)` 的最近邻像素 `(x2, y2)`，两者距离记作 `dis2`。 果满足条件 `dis1 <= μ * dis2`，则认为点 `(x, y)` 在变换后的图像之内，使用最近邻像素来填充颜色；否则，不填充颜色。

上面的 `μ >= 1`，是一个可以按照需求取值的正常数。容易看出，`μ` 取得越大，对于变换后图像像素稀疏程度的接受程度越强，但填充后图像的边缘也更有可能也会出现奇怪的变化。正常 `μ` 取 5 左右就可以得到较为满意的效果。

实现代码 下：

```cpp
// 辅助函数：对结果图像中的空洞（背景色为黑）进行最近邻重采样填充
void fillHolesWithNearestNeighbor(const std::vector<pair<int, int>>& new_pixels, Image &warped_image) {
    const int dim = 2;
    int n_points = new_pixels.size();

    Annoy::AnnoyIndex<int, float, Annoy::Euclidean, Annoy::Kiss32Random, Annoy::AnnoyIndexSingleThreadedBuildPolicy> index(d
    for (int i = 0; i < n_points; i++) {
        float vec[dim] = { static_cast<float>(new_pixels[i].first), static_cast<float>(new_pixels[i].second) };
        index.add_item(i, vec);
    }
    index.build(10);

    int width = warped_image.width();
    int height = warped_image.height();
    for (int y = 0; y < height; ++y) {
        for (int x = 0; x < width; ++x) {
            // 对于 (x, y)，找其最近邻点 (x1, y1)
            float query[dim] = { static_cast<float>(x), static_cast<float>(y) };
            std::vector<int> result;
            std::vector<float> distances;
            index.get_nns_by_vector(query, 1, -1, &result, &distances);
            if(result.empty()) continue;
            auto [x1, y1] = new_pixels[result[0]];
            float dis1 = distances[0];

            // 对于 (x1, y1)，找其最近邻（要求返回 2 个，第二个为真正的邻居）
            float query2[dim] = { static_cast<float>(x1), static_cast<float>(y1) };
            std::vector<int> result2;
            std::vector<float> distances2;
            index.get_nns_by_vector(query2, 2, -1, &result2, &distances2);
```

```
            if(distances2.size() < 2) continue;
            float dis2 = distances2[1];

            // 如果 dis1 <= dis2 * sigma，则认为 (x, y) 为图片内部产生的空洞，需要填充
            // 实际测试下取 8 还是比较合适的（
            if (dis1 <= dis2 * 8) {
                if (x1 >= 0 && x1 < width && y1 >= 0 && y1 < height) {
                    auto fill_color = warped_image.get_pixel(x1, y1);
                    warped_image.set_pixel(x, y, fill_color);
                }
            }
        }
    }
}
```