# Bayer Filter and Demosaicing

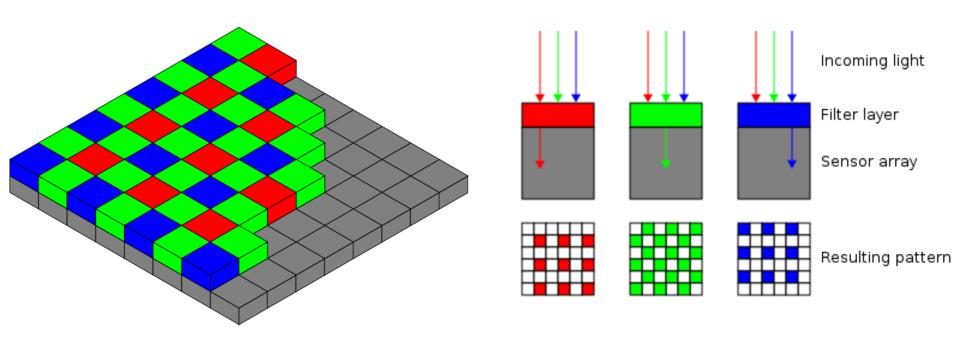
## Bayer Filter Mosaic

- Color filter array (CFA) for arranging RGB color filters on a square grid of photo sensors.
- Filter pattern is 50% green, 25% red and 25% blue,
  - hence also called RGBG, GRGB or RGGB
- Allows digital cameras to capture information for all 3 channels using a single 2D arrangement of sensors
  - Each sensor element captures either red, green or blue channel
  - Missing values are reconstructed using demosaicing

# Bayer Filter Mosaic (cont'd)

Bayer arrangement of color filters on the pixel array of an image sensor

**Profile/cross-section of sensor** 



Gray boxes indicate individual sensor elements and the overlaid RGB boxes indicate the channel whose information each sensor element captures.

Colored boxes in the resulting pattern indicate pixels where respective color information is captured; color information at white boxes needs to be reconstructed

# Demosaicing

- Reconstruct a full color image from the incomplete color samples ("Bayer Pattern") output from an image sensor overlaid with a CFA
- Many methods exist
  - Simple methods interpolate the color value of the pixels of the same color in the neighborhood

## Demosaicing Rules

- The channel masks are moved over the Bayer pattern image like a sliding window but with no overlap
- Locations where the mask is 1 (shaded)
  - value is directly copied from the Bayer image.
- Locations where the mask is 0 (unshaded)
  - value is the average of neighboring existing pixels
  - no. of neighboring pixels to average may be 2
     (above/below or right/left) or 4 (all diagonal corners)
  - if a row/column in the mask is entirely empty, values are copied from neighboring non empty row/column

## Demosaicing Example

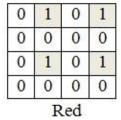
Let this be the 8x8 Bayer Pattern Image:

| 0   | 1  | 2  | 3  | 4  | 5   | 6  | 7   |
|-----|--|--|--|--|---|--|---|
| 102 | 230                                      | 199  | 147  | 166  | 175   | 124  | 164   |
| 19  | 241                                      | 99   | 15   | 187  | 47  | 111  | 97  |
| 61  | 125                                      | 62   | 60   | 165  | 94  | 114  | 207   |
| 31  | 125                                      | 103  | 90   | 115  | 160   | 78   | 136   |
| 47  | 86                                       | 25   | 209  | 139  | 199   | 130  | 89  |
| 61  | 230                                      | 34   | 4  | 76   | 21  | 130  | 239   |
| 106 | 94                                       | 240  | 11   | 190  | 237   | 208  | 223   |
| 13  | 28                                       | 244  | 43   | 48   | 198   | 203  | 140   |
|     | 102<br>19<br>61<br>31<br>47<br>61<br>106 | 102     230       19     241       61     125       31     125       47     86       61     230       106     94 | 102     230     199       19     241     99       61     125     62       31     125     103       47     86     25       61     230     34       106     94     240 | 102     230     199     147       19     241     99     15       61     125     62     60       31     125     103     90       47     86     25     209       61     230     34     4       106     94     240     11 | 102     230     199     147     166       19     241     99     15     187       61     125     62     60     165       31     125     103     90     115       47     86     25     209     139       61     230     34     4     76       106     94     240     11     190 | 102     230     199     147     166     175       19     241     99     15     187     47       61     125     62     60     165     94       31     125     103     90     115     160       47     86     25     209     139     199       61     230     34     4     76     21       106     94     240     11     190     237 | 102     230     199     147     166     175     124       19     241     99     15     187     47     111       61     125     62     60     165     94     114       31     125     103     90     115     160     78       47     86     25     209     139     199     130       61     230     34     4     76     21     130       106     94     240     11     190     237     208 |

Let these be the 4x4 channel masks:

| 1 | 0   | 1  | 0 |
|---|-----|----|---|
| 0 | 1   | 0  | 1 |
| 1 | 0   | 1  | 0 |
| 0 | 1   | 0  | 1 |
|   | Gre | en |   |

| 0    | 0  | 0  | 0 |
|------|----|----|---|
| 1    | 0  | 1  | 0 |
| 0    | 0  | 0  | 0 |
| 1    | 0  | 1  | 0 |
| 9 10 | Bl | ne |   |

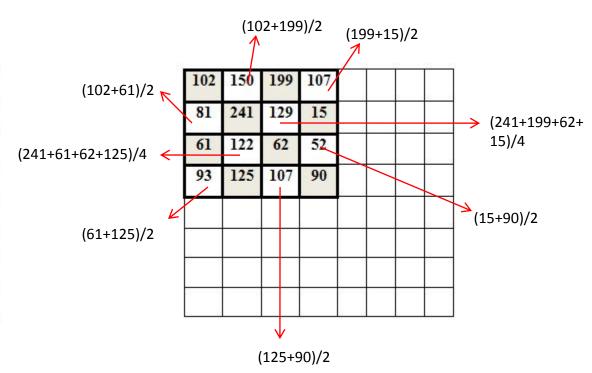


# Demosaicing Example: Reconstructing Green Channel

## Mask position within the image

### 175 124

### **Reconstructed Pixel Values**



# Demosaicing Example: Reconstructing Green Channel (cont'd)

## Mask positions within the image

| 102 | 230 | 199 | 147 | 166 | 175 | 124 | 164 |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 19  | 241 | 99  | 15  | 187 | 47  | 111 | 97  |
| 61  | 125 | 62  | 60  | 165 | 94  | 114 | 207 |
| 31  | 125 | 103 | 90  | 115 | 160 | 78  | 136 |
| 47  | 86  | 25  | 209 | 139 | 199 | 130 | 89  |
| 61  | 230 | 34  | 4   | 76  | 21  | 130 | 239 |
| 106 | 94  | 240 | 11  | 190 | 237 | 208 | 223 |
| 13  | 28  | 244 | 43  | 48  | 198 | 203 | 140 |

| 102 | 230 | 199 | 147 | 166 | 175 | 124 | 164 |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 19  | 241 | 99  | 15  | 187 | 47  | 111 | 97  |
| 61  | 125 | 62  | 60  | 165 | 94  | 114 | 207 |
| 31  | 125 | 103 | 90  | 115 | 160 | 78  | 136 |
| 47  | 86  | 25  | 209 | 139 | 199 | 130 | 89  |
| 61  | 230 | 34  | 4   | 76  | 21  | 130 | 239 |
| 106 | 94  | 240 | 11  | 190 | 237 | 208 | 223 |
| 13  | 28  | 244 | 43  | 48  | 198 | 203 | 140 |

| 102 | 230 | 199 | 147 | 166 | 175 | 124 | 164 |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 19  | 241 | 99  | 15  | 187 | 47  | 111 | 97  |
| 61  | 125 | 62  | 60  | 165 | 94  | 114 | 207 |
| 31  | 125 | 103 | 90  | 115 | 160 | 78  | 136 |
| 47  | 86  | 25  | 209 | 139 | 199 | 130 | 89  |
| 61  | 230 | 34  | 4   | 76  | 21  | 130 | 239 |
| 106 | 94  | 240 | 11  | 190 | 237 | 208 | 223 |
| 13  | 28  | 244 | 43  | 48  | 198 | 203 | 140 |

### **Reconstructed Pixel Values**

| 102 | 150 | 199 | 107 | 166 |       |     | 110 |
|-----|-----|-----|-----|-----|-------|-----|-----|
| 81  | 241 | 129 | 15  | 165 | 47    | 95  | 97  |
| 61  | 122 | 62  | 52  | 165 |       | 114 | 116 |
| 93  | 125 | 107 | 90  | 115 | 160   | 148 | 136 |
|     |     |     |     |     | 6-7   |     |     |
|     |     |     |     |     |       |     |     |
|     |     |     |     | X   | s — x |     |     |
|     |     |     |     |     |       |     |     |

| 102 | 150 | 199 | 107 | 166      | 145 | 124 | 110 |
|-----|-----|-----|-----|----------|-----|-----|-----|
| 81  | 241 | 129 | 15  | 165      | 47  | 95  | 97  |
| 61  | 122 | 62  | 52  | 165      | 121 | 114 | 116 |
| 93  | 125 | 107 | 90  | 115      | 160 | 148 | 136 |
| 47  | 36  | 25  | 14  |          |     |     |     |
| 76  | 230 | 124 | 4   | 2        |     |     |     |
| 106 | 151 | 240 | 23  | či<br>Ci |     |     |     |
| 67  | 28  | 35  | 43  |          |     |     |     |

| 102 | 150 | 199 | 107 | 166 | 145 | 124 | 110 |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 81  | 241 | 129 | 15  | 165 | 47  | 95  | 97  |
| 61  | 122 | 62  | 52  | 165 | 121 | 114 | 116 |
| 93  | 125 | 107 | 90  | 115 | 160 | 148 | 136 |
| 47  | 36  | 25  | 14  | 139 | 134 | 130 | 184 |
| 76  | 230 | 124 | 4   | 164 | 21  | 149 | 239 |
| 106 | 151 | 240 | 23  | 190 | 154 | 208 | 189 |
| 67  | 28  | 35  | 43  | 194 | 198 | 169 | 140 |

# Demosaicing Example: Reconstructing Red Channel

## Mask position within the image

| 102 | 230 | 199 | 147 | 166 | 175 | 124 | 164 |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 19  | 241 | 99  | 15  | 187 | 47  | 111 | 97  |
| 61  | 125 | 62  | 60  | 165 | 94  | 114 | 207 |
| 31  | 125 | 103 | 90  | 115 | 160 | 78  | 136 |
| 47  | 86  | 25  | 209 | 139 | 199 | 130 | 89  |
| 61  | 230 | 34  | 4   | 76  | 21  | 130 | 239 |
| 106 | 94  | 240 | 11  | 190 | 237 | 208 | 223 |
| 13  | 28  | 244 | 43  | 48  | 198 | 203 | 140 |

### **Reconstructed Pixel Values**

