

# FUJIFILM X10 white orbs and DeOrbit

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# FUJIFILM X10

- **Retro-styled enthusiast compact camera;** it *feels* like a 25-year-old rangefinder
- **Full manual controls,** promise of **high IQ**
- **f/2.0-f/2.8** lens with **28-112mm** view



# FUJIFILM X10

- Retro-styled enthusiast compact camera; it *feels* like a 25-year-old rangefinder
- Full manual controls, promise of high IQ
- f/2.0-f/2.8 lens with 28-112mm view
- **Nasty “white orbs” (WOs) wrecking shots...**





# An X10 WO





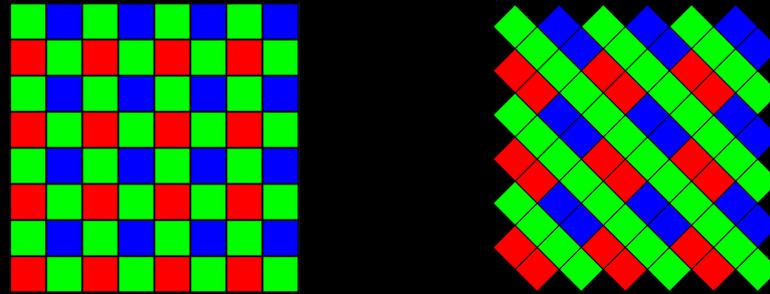
# WO Repaired



# What Are WOs?

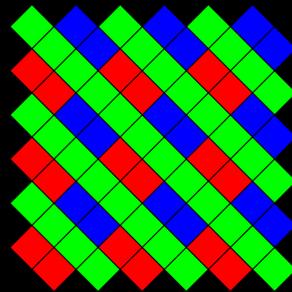
- Images of ghosts or angels?
- Light reflecting off airborne dust?
- Out-of-focus point spread function (OOF PSF) from point light sources?
- **Huge, disc-shaped, blooming artifacts due to sensor design and processing...**

# The X10 “EXR” Sensor



- 12MP CMOS 2/3” (8.8x6.6um sensels)
- Diagonal layout of sensels
- Unusual color filter array (CFA) design
- Unusual interpolation & processing modes

# X10 Sensor Modes



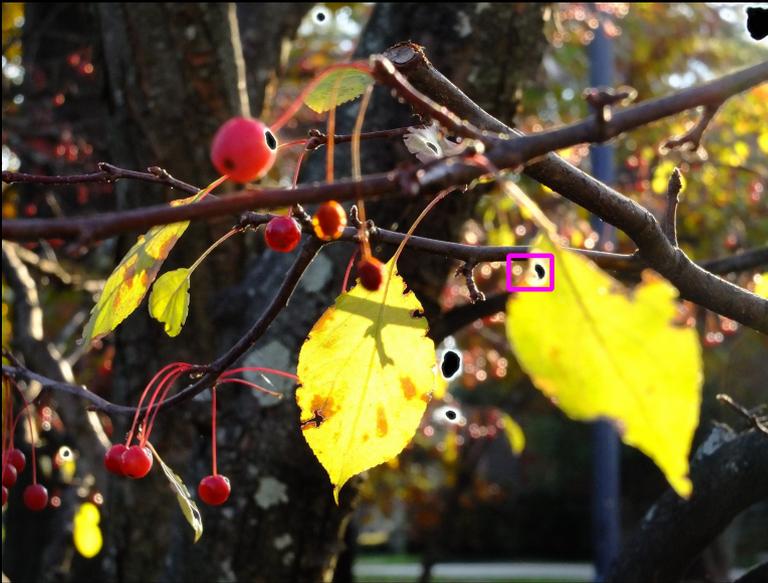
- **HR Mode**: each sensel is a pixel, 12MP
- **DR Mode**: pair of sensels is a pixel, 6MP; avoids saturation by sampling one early
- **SN Mode**: pair of sensels is a pixel, 6MP; averages to improve signal/noise ratio

# A Short History Of WO

4	/2011	X10 announced
10	/2011	many reports of “white orbs”
2/25/2012		ineffective firmware update
3/ 7/2012		DeOrblt released
3/12/2012		sensor replacement announced
4	/2012	new sensors start appearing

- Problem unique to FUJIFILM X10 and X-S1
- New sensor still blooms, but no WOs

# X10 “Black Holes” (BH)



- Another unique saturation artifact
- Only happens in Velvia mode + high contrast
- Fixed in Ver. 1.03 firmware, 12/2011

# 21 Stops Of WOs



- Blooms 3 ► 86-pixel diameter (800x area)
- Always white, typically with thin dark outline
- Effect is less at higher ISOs

# Manual Repair Algorithm

- Any saturated area, including WOs, has lost data for the saturated region
- Key to repair is **texture synthesis**
- Initial test using **gimp**:
  1. Select WOs by selecting by color white and then manually enlarging/cropping
  2. Synthesize credible background by “Heal Selection” – using “Resynthesizer” plug-in per Harrison's 2005 PhD dissertation

# Automatic Repair?

- Algorithm should be *implementable as firmware in the camera*:
  - Must automate WO detection
  - Must run fast enough (e.g., fast synthesis at an acceptable quality level)
- Synthesized texture often continues flare pattern to centers, but doesn't get brighter; a re-lighting step should be added

# A Fishy Image



- A *test scene* that is well repaired by DeOrbit
- Out-of-camera JPEG & reprocessed

# A Fishy Image



- Left: the synthesized textures
- Right: the relighting

# DeOrbit (`deorbit.c`)

- Only 2,133 lines of pure C code
- Either command line or CGI interface – CGI logs images from users for testing
- Initially used PPM files (raw via `dcraw`); later switched to JPEG using `jpeglib`
- Entire repair executes faster than the `gimp` “Heal Selection” plug-in alone
- Fully automatic, with adjustable parameters

## Processing Parameters

The `deorbit` processing parameters can be changed below. They are initialized to the values used to produce the image above. Note that it may be desirable to let `deorbit` be overly aggressive about processing regions and then selectively combine this output with the original by overlaying it in `gimp`, `photoshop`, etc., and manually erasing the portions that were too aggressively processed. The selection below facilitates even more aggressive tuning in your favorite image editor by giving access to the synthesized fill and relighting as separate images.

Display fully processed de-orbed image ▾

Enlarge region by  1 pixels beyond threshold edge.  
*Increase this to remove sharpening artifacts that were around saturated regions.  
Decrease this if the processing seems to have blurred too much around saturated areas.*

Feather orb edges by  2 pixels beyond region edge.  
*This determines how many pixels past a region edge are used for blending.*

Smooth within regions using up to  2 passes.  
*This determines how many smoothing passes are made over regions.*

The maximum orb diameter to be processed is  128 pixels.  
*Sets the largest diameter that will be considered an orb; larger are not processed.*

The exponent (power) for the region shading is  1.  
*Used to change sharpness of tonal transition to saturation: higher is sharper.  
The default 1.0 produces spherical shading, but some scenes look better around 2.0.*

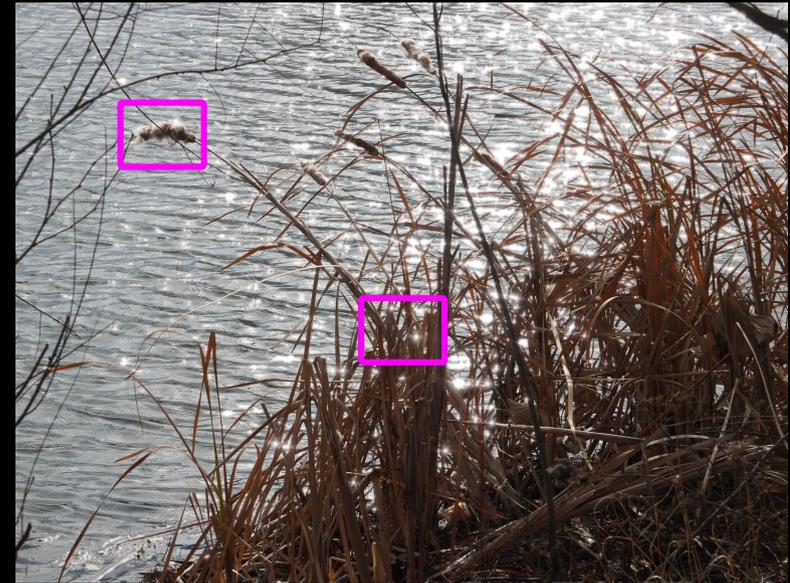
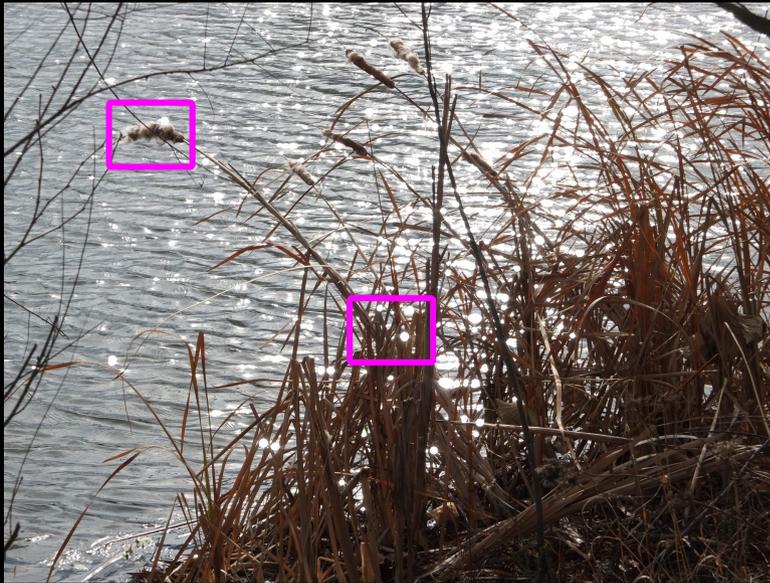
The window radius for smoothing and texturing of regions is  3 pixels.  
*A larger window radius yields smoother shading transitions.*

The threshold for treatment as saturated pixels is  97%.  
*Adjusts the threshold for the minimum brightness to be considered part of an orb.*

# DeOrbit Algorithm Overview

- Works on linear gamma, float, RGB images
- Most work done only on WO areas, using cache-aware non-recursive algorithms
- WO recognition by saturation, edge distance, group size, and roughly circular shape
- Synthesis randomly “smears” into WOs
- Lighting based on distance from WO edge
- Blending and smoothing construct the final image, which is saved as a JPEG

# Pond Reeds



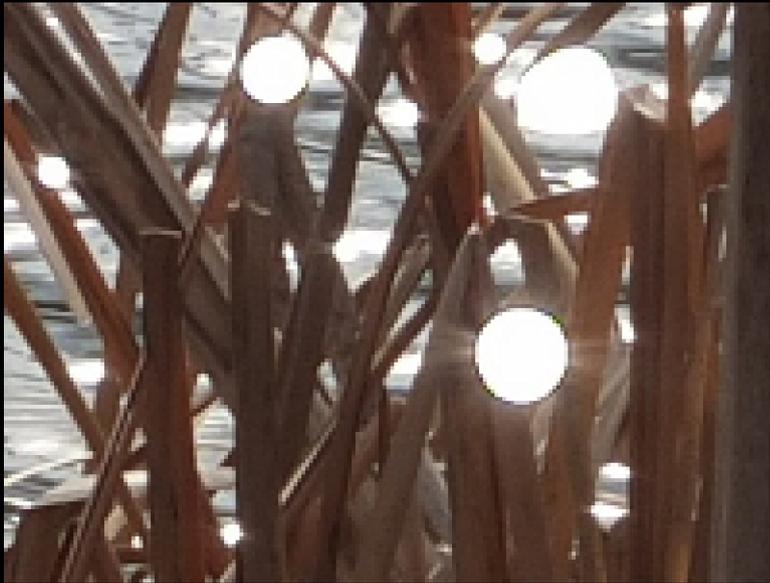
- A *test scene* over troubled waters
- Out-of-camera JPEG & reprocessed
- **Magenta** boxes show close-up regions...

# Pond Reeds (Crop)



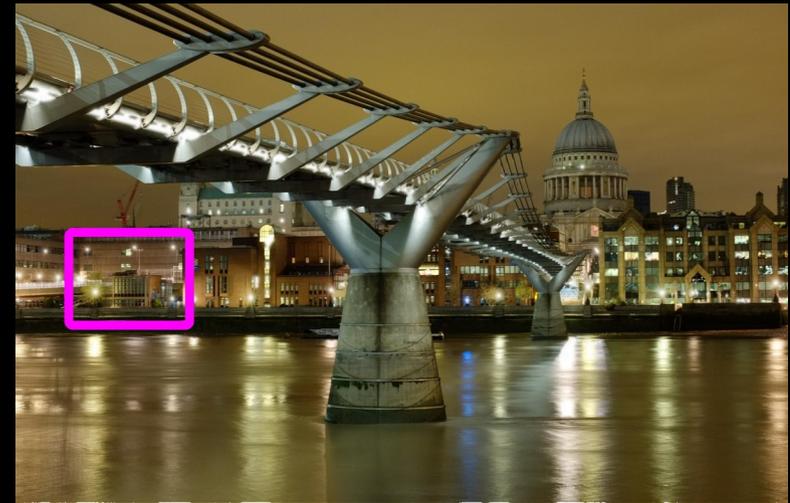
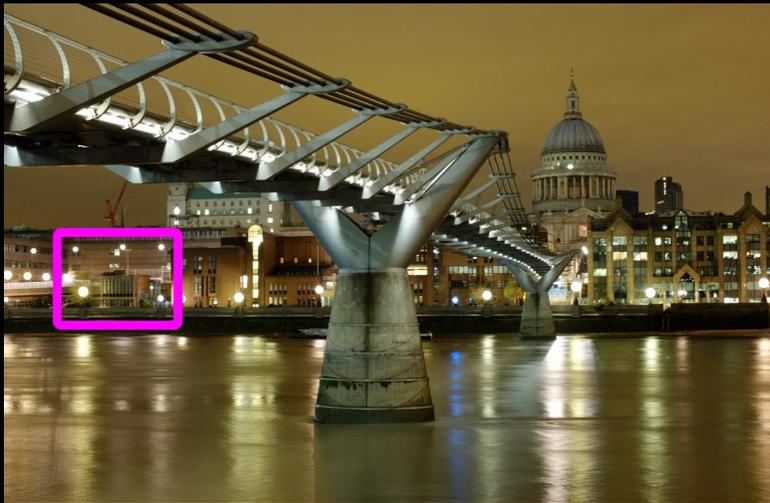
- Out-of-camera JPEG & reprocessed crop
- A slightly overly aggressive repair...?

# Pond Reeds (Crop)



- Out-of-camera JPEG & reprocessed crop
- Texture synthesis errors not too obvious...?

# Millennium Bridge



- A *user image* (by Paul Till) repaired well
- Out-of-camera JPEG & reprocessed
- **Magenta** box shows close-up region...

# Millennium Bridge (Crop)



- Out-of-camera JPEG & reprocessed crop
- **Excellent repair**, a little too smooth?

# Millennium Bridge (Crop)



- Left: the synthesized textures
- Right: the relighting

# High-Contrast Scene (Crop)



- A *user image* (by M. Djebbari)
- High contrast shows texture synthesis flaws

# Loss Of Highlight Shape (Crop)



- A *user image* (by Victor Zaveduk)
- Repair either leaves too-sharp edges or (as here) window reflection shape is lost

# Huge Saturated Areas (Crop)



- A *user image* (by [wymjym@wymjym.com](mailto:wymjym@wymjym.com))
- Overlap of WOs with non-blooming saturated areas results in mix of under/over processing

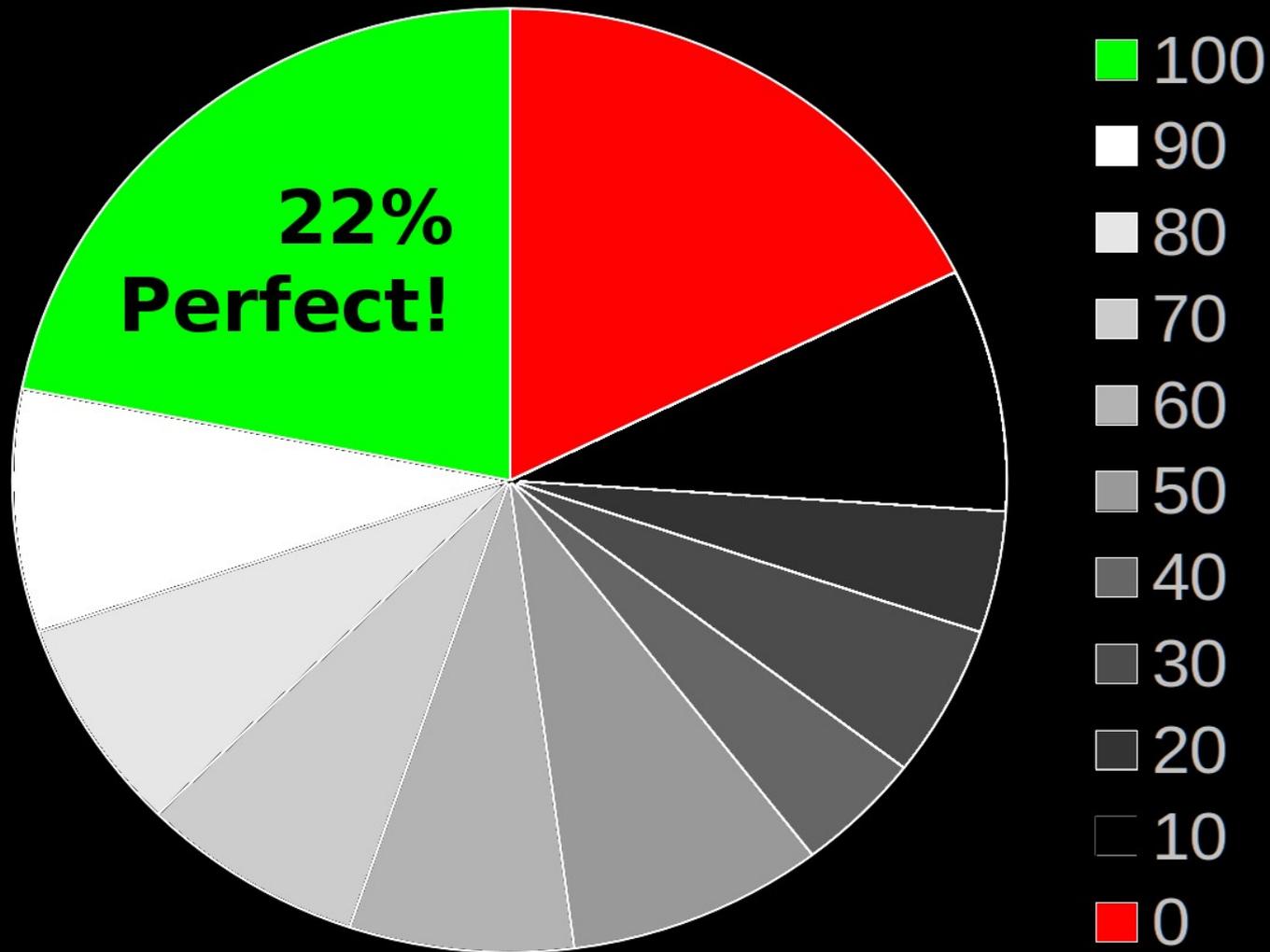
# Where Do WOs Come From?

- 41% *user* images were specular reflections off motor vehicles (cars and motorcycles)
- 32% *user* images were outdoors at night using streetlights as the primary lighting
- 8% *user* WO images **did not contain WOs!**
- Reflections off bodies of water were rare, but among the worst-repaired *user* images
- 20% of *our random X10 shots* had WOs; 10% were bad enough to require repair

# Repair Quality Analysis

- DeOrbit gave the option of 0%-100% score per *image + set of parameters* to the tool
- 22% gave 100% quality rating for repair
- 40% of scores were below 50% quality
- Lowest scores largely came from *images that did not have WOs* being left untouched...

# Repair Quality Scores



# Conclusions

- DeOrbit proves computational photography methods can *hide* serious camera flaws
- The new sensor is a *better fix*, but DeOrbit can repair existing images that have WOs
- Users are not great at recognizing WOs
- FUJIFILM's handling of the WO problem was the real issue; the new sensor seems to have worse bloom than competitors, but is praised

# Want To Know More?

Watch our research WWW site:



And see our live demos tomorrow...