What are the challenges?
Two Challenges:

1. Keep deviation under control (3d)

2. Focus Close (2d)

- To take a close-up or macro picture you need to get closer to your subject.

- As you get closer to your subject, the stereoscopic deviation increases. At some point it might become excessive, making the 3d picture hard to view/fuse. Keeping the stereoscopic deviation under control is a challenge in 3d.

- As you keep getting closer, at some point you will reach the close focusing point of the camera or lens so focusing can also become a challenge. This is a 2d issue.
**Magnification**

Magnification = Size of Image / Size of Object

![Magnification Formula](image)

Magnification = Focal Length / Distance

There are two ways to increase the magnification:

- **Increasing the focal length or enlarging the image.** The focal length acts as a scaling factor. Everything (foreground and background) becomes larger equally. Also, enlargement after taking the picture has the same effect as using a longer focal length lens in the first place.

- **Reducing the distance or getting closer.** The distance affects the closer objects more than the far objects. So it affects the perspective (ratio of size of near vs. far objects).
<table>
<thead>
<tr>
<th>Type of 3d</th>
<th>Think of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distant</td>
<td>![Distant Image]</td>
</tr>
<tr>
<td>Close-up</td>
<td>![Close-up Image]</td>
</tr>
<tr>
<td>Macro</td>
<td>![Macro Image]</td>
</tr>
<tr>
<td></td>
<td>Officially when $M &gt; 1$</td>
</tr>
</tbody>
</table>
Stereoscopic Deviation

Also known as “Parallax”. Small differences (horizontal displacements) between the right and left picture, which, when fused by the brain, provide a sense of depth.

\[ P = \frac{F \times B}{I} = M \times B \]

Stereoscopic Deviation (P) = Magnification (M) x Stereo Base (B)
The Need of smaller B

- Stereo Base (B) creates stereoscopic deviation (P)
- Since the stereoscopic deviation increases when the magnification increases, one would like to reduce the stereo base to keep the stereoscopic deviation under control

\[ P = M \times B \]

So to do close-up or macro 3d photography one has to reduce the stereo base (distance of the lenses)
# Close-Ups in 3D

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Stereo Base</th>
<th>Focal Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close-up camera or mirror attachment</td>
<td>Medium (30-40 mm)</td>
<td>Normal</td>
</tr>
<tr>
<td>Regular Stereo camera or twin cameras</td>
<td>Wide</td>
<td>Long</td>
</tr>
</tbody>
</table>
Close-ups w/ a close-up camera

Panasonic Lumix 3D1 at a Glance—Positives & Negatives

+ Good image quality
+ Well-aligned images
+ Image stabilization
+ Wide angle focal length
+ Well-suited for close-ups
+ Good battery performance
+ Compact & easy to use

- Limited exposure control
- No ISO adjustment
- No ability to turn flash on
- Flash between lenses
- Narrow base for general 3d
- No 3d display
**Close-ups w/ a close-up camera**

**Practical Question:** Given the distance of the lenses B, how close can you get to your subject for a good close-up?

**General Recommendation:** 10-30x B

**For Lumix 3D1:** 300mm-900mm, 12-36 inches

Perfect for self-portraits at 24 inches (which is approximately the distance of the extended hands)
Close-ups with wider stereo base

A regular 3D camera (B~55-75mm) or even twin cameras (B = 4 inches or more) can be used for close-ups if the background is blocked. It also helps to:

Move back and zoom-in

Examples of the background being “blocked”:
1. Physically blocked (by a wall, for example)
2. Darkened using flash
3. Totally out of focus so it does not distract from the main subject
Move back and zoom in?

\[ P = \frac{F \cdot B}{I} = 2 \cdot \frac{F \cdot B}{2 \cdot I} = \frac{F \cdot B}{I} \]

- **Move back**: \( I \rightarrow 2I \)
- **Zoom in**: \( F \rightarrow 2F \)

\[ P = \frac{F \cdot B}{I} = \frac{(2F) \cdot B}{(2I)} = \frac{F \cdot B}{I} \quad --- \quad \text{P did not change!} \]

This makes sense because the magnification does not change and \( P \sim M \)

So, how does that work?
The formula $P = FB/I$ is incomplete. It assumes that the background (far object) is at infinity and $I$ is the distance to the near object ($I_{\text{near}}$).

The more accurate formula (taking into account the near and far objects):

$$P = FB/I = FB \left( \frac{1}{I_{\text{near}}} - \frac{1}{I_{\text{far}}} \right)$$

This explains why blocking the background helps reduce $P$.

In the special case where the subject has limited depth (typical for macros):

$$P = F \cdot B \left( \frac{1}{I_{\text{near}}} - \frac{1}{I_{\text{far}}} \right) = F \cdot B \left( \frac{I_{\text{far}} - I_{\text{near}}}{I_{\text{near}} \cdot I_{\text{far}}} \right)$$

$$P = F \cdot B \cdot t / I^2 = (F/I)(B/I)t = M \cdot (B/I) \cdot t$$

Where $t$ is the thickness of the subject, assuming that it is quite a bit smaller than the distance to the subject (the background is blocked).

In this case stereoscopic deviation depends on the inverse square of the distance, so moving back (2I) and zooming in (2F) results in reducing $P$ to $P/2$. 

$$P = FB/I = FB \left( \frac{1}{I_{\text{near}}} - \frac{1}{I_{\text{far}}} \right)$$
Stereoscopic Deviation

\[ P = M \quad B \]

This formula applies for distant pictures with infinity. For close-ups, macro where there is no infinity, and the subject has limited depth (t), it is better to use this formula:

\[ P = M \quad (B/I) \quad t \]

This “close-up) formula still shows the need for reduced stereo base, but it also shows that stepping back and zooming in can work too.
The stereo base (B) by itself (without taking into account the distance) does not tell how much depth there will be in the picture. But the ratio of B/I is a better quantity to quantify depth. I like to use this ratio to compare different close-up/macro camera systems.

Note the similarity between the Magnification (F/I) a 2d quantity and the Convergence Ratio (B/I) a 3d quantity.

<table>
<thead>
<tr>
<th>Type of picture</th>
<th>Recommended C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Stereo</td>
<td>~ 1/30</td>
</tr>
<tr>
<td>Close-Up</td>
<td>~ 1/20</td>
</tr>
<tr>
<td>Macro</td>
<td>~1/20-1/10</td>
</tr>
</tbody>
</table>
So it is possible to take a picture (usually a close-up, including portraits) using either a short/normal lens and a hypostereo, or a long lens and a hyperstereo. The results will look similar. HC McKay (~1950s) called this the “PePax principle”. According to this principle, if you increase the focal length, you should increase the stereo base proportionally.

Even though the pictures looks similar, there is a difference in perspective. Short FL/distances result in exaggerated perspective, long FL/long distances result in a compressed perspective. It is not the focal length (F) but the distance (I) that causes this effect.
WILDLIFE Stereo Photography

Standard Stereo camera
F = 35 mm, B = 2.5 in
Near distance = 7 ft
Not a good idea!

Twin cameras
F = 135 mm
B = 10 in
Near distance = 28 ft
Better!
Close-Ups in 3D - Summary

• Use a **regular stereo camera** and get closer. This works well if the **background is blocked** and the **subject is not “sensitive”** (a portrait is a sensitive subject)

• To make things better, **step back and zoom in**. This works well if the background is blocked. You can even use twin cameras (hyperstereo) if you **increase the distance, focal length and stereo base proportionally**.

• If you enjoy close-ups, for the best results (in terms of convenience) **buy a close-up camera** (B = 25~50mm) like the Panasonic 3D1 (B = 30mm) or the Cycloptical3D close-up attachment for the Fuji.
Macros in 3D

1. Macro stereo camera
2. Mirror/Prism attachments
   ⇒ For 2D camera
   ⇒ For 3D camera
   ⇒ For two cameras
3. Single (2d) camera and shift
Macros in 3D

**Equipment**

- Macro camera or lens
- Mirror/Prism attachment
The simplest way to take macro 3d pictures

A simple compact (front surface) mirror is placed to the side of the camera lens and perpendicular, or at a small angle, to the lens. The camera sensor sees the subject and the reflection of the subject through the mirror. The common field of view is $S$ and it is equivalent to a stereo pair recorded from the real lens $L$ and its mirror image (virtual lens) $L'$. The stereo pair will need to be corrected digitally to remove keystone distortion and non-overlapping areas and flip the reflected image horizontally.

An extension of the single mirror concept is to use 2 mirrors making a small angle, or 3 or 4 mirrors and a single camera. Some of these designs have been produced commercially or by amateur stereo photographers.

Picture & description by Donald Simanek.
Mirror setup by **Albrecht Kloeckner**
http://www.fotocommunity.de/fotograf/albrecht-kloeckner/540065

Mirror setup by **Donald Simanek**
http://www.lhup.edu/~dsimanek/3d/stereo/3dgallery16.htm
Stereo Camera Attachments

- Attachments use **mirrors** or **prisms** to allow stereo cameras to take close-up or even macro pictures.
- These attachments redirect the light and effectively *reduce the spacing of the recording lenses*.
- Two examples include the **RBT macro attachment** for RBT cameras and the **Cyclopital3d attachment** for the Fuji 3d camera.
Two Cameras & Attachments

- Semi-transparent Mirror
- Binocular design
- Use of Prism
Prism Design by Dr. Imre Zsolnai-Nagy
LOREO LIAC Modification - Dr. Imre Zsolnai-Nagy
Macrobox for Canon SDM cameras—Features:

- Adjustable stereo base from 0mm to 50mm
- Comes with macro/close-up lens
- Lens cover is foldable and easy removable
- Filter threads in cover allows to use filters
- High-quality half mirror w/ anti reflex coating
- 2 * 1/4" tripod threads on the bottom
- Made out of lightweight but stable plastic
- Cost ~ 450 Euros

http://www.digi-dat.de/produkte/index_eng.html#SDM_MacroS90
Panasonic 3D Lumix G Lens

- Micro 4/3 mount lens for Panasonic / Olympus cameras
- Produces a 3d (MPO) file in certain (all recent micro 4/3) Panasonic cameras
- Two lenses, 10mm apart
- 12.5mm FL, f12 fixed aperture, fixed focus (Range: 0.6m-INF)
- Not good for general photography
- Very good for macros thanks to its lens spacing but it needs to be modified to focus closer
How to Focus Close

Focusing close is done by:

1. Moving the lens forward (away from the camera)
2. Using Close-Up Lenses
Close-Up Lenses

Used in today’s compact (non-removable lens) digital cameras

Strength of CU lens:
+1, +2, +4
Diopter = 1000mm/FL

Achromatic CU lenses
+3, +5, +10
Recommended for anything higher than +1
# Panasonic 3D Lens Modification

*Modifications to focus closer (increase magnification)*

<table>
<thead>
<tr>
<th>Extension</th>
<th>Close-up Lenses</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Extension Image" /></td>
<td><img src="image2.png" alt="Close-up Lenses Image" /></td>
</tr>
</tbody>
</table>

---

**Extension**

- Modifies the lens to focus closer, increasing magnification.

**Close-up Lenses**

- Demonstrates the enhanced focus capabilities after modification.
Step-by-step Modification

- **Tools Needed**: Screwdriver, tweezers, strong reading glasses, washers (no. 2)

- Remove the 3 screws in the back of the lens, push the back out a bit.

- Using the tweezers, insert the washer(s) in one slot, put the screw back, tighten just a bit. Repeat for the other two screws.

- Tighten screws when done.

- Total time (if all tools/space are available): 3 minutes
**Conv Ratio vs Extension**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Extension</th>
<th>Washers</th>
<th>Distance from Camera Back</th>
<th>Distance from Lens</th>
<th>Conv Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.5mm</td>
<td>0.8mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak</td>
<td>0 (as is)</td>
<td>0</td>
<td>0</td>
<td>~36 inches</td>
<td>~900mm</td>
</tr>
<tr>
<td></td>
<td>0.5mm</td>
<td>1</td>
<td>0</td>
<td>12 inches</td>
<td>10&quot; (250mm)</td>
</tr>
<tr>
<td>Good</td>
<td>0.8mm</td>
<td>0</td>
<td>1</td>
<td>10 inches</td>
<td>8&quot; (200mm)</td>
</tr>
<tr>
<td></td>
<td>1.0mm</td>
<td>2</td>
<td>0</td>
<td>8 inches</td>
<td>6&quot; (150mm)</td>
</tr>
<tr>
<td></td>
<td>1.3mm</td>
<td>1</td>
<td>1</td>
<td>6 inches</td>
<td>4&quot; (100mm)</td>
</tr>
<tr>
<td>Strong</td>
<td>1.6mm</td>
<td>0</td>
<td>2</td>
<td>5.5 inches</td>
<td>3.5&quot; (90mm)</td>
</tr>
<tr>
<td></td>
<td>2.4mm</td>
<td>0</td>
<td>3</td>
<td>4.3 inches</td>
<td>2.3&quot; (60mm)</td>
</tr>
</tbody>
</table>

**Personal recommendations:**

- Anything less than 0.5mm extension is not very useful, in my opinion. If you decide to use 0.5mm, consider a combination with close-up lenses.
- If you only going to have one lens, the 1.0mm is a good choice.
- If you can afford 3 lenses, consider: (0.5, 1.0, 1.6) or (0.8, 1.3, 2.4)
## Panasonic 3D Lens Resolution

<table>
<thead>
<tr>
<th>Camera Model</th>
<th>GF2, GX1, GX7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Image size at 4:3</strong></td>
<td>4592 x 3448</td>
</tr>
<tr>
<td>Stereo Image at 4:3</td>
<td>2x 1824 x 1368 (40%)</td>
</tr>
<tr>
<td>0.5mm ext</td>
<td>~1750 x 1368</td>
</tr>
<tr>
<td>1.0mm ext</td>
<td>~1650 x 1368</td>
</tr>
<tr>
<td>2.5mm ext</td>
<td>~1350 x 1368</td>
</tr>
<tr>
<td>4:3</td>
<td>1824 x 1368</td>
</tr>
<tr>
<td>3:2</td>
<td>1824 x 1216</td>
</tr>
<tr>
<td>16:9</td>
<td>1824 x 1024</td>
</tr>
<tr>
<td>1:1</td>
<td>1712 x 1712</td>
</tr>
</tbody>
</table>

Resolution (image size) depends on:
- Resolution of camera
- Aspect ratio selected
- Amount of cropping to fix the stereo window
How I use the Lumix 3D Lenses

• On a **Panasonic GX1 camera**.

• **4:3 aspect ratio** (1:1 occasionally) in M or P mode. I usually adjust the ISO to the lowest value (160) when using flash, or higher when hand-held, depending on the amount of light.

• I use a **6 inch focus bar** for lenses of 1.0mm extension or higher. The bar is graduated for higher than 1.3mm extension. With the 0.5mm extension I use a pointer marked for 12 inches.

• I use a **grip** to hold the camera and focus bar.

• I use the **camera flash** for most of my pictures. I adjust the flash strength to control flash exposure. Occasionally I use the Metz macro flash.

• I use **SPM** and only adjust the horizontal alignment for the stereo window, nothing else.

**Note:** Others use a variety of methods to adjust extension or aid in focusing. Some people **tape the contacts** to get the actual recorded image and adjust it manually. Taping the contacts will allow you to shoot movies and use all the camera functions, including raw files.
# 3D Lens vs. Macrobox

<table>
<thead>
<tr>
<th></th>
<th>3D Lens</th>
<th>Macrobox</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Convenience</strong></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td><strong>Portability</strong></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>
The Advantage of Digital

1. Lightweight cameras
2. Alignment via Software
3. Quick Preview

- Digital cameras are usually **smaller**, **lighter**, and **more compact**, because there is no need for film to run through them. The end result is a smaller and lighter macro 3d outfit, an advantage when working in the field.

- **Alignment** is not as critical and alignment or distortion errors can be corrected in post processing with **software**.

- It is possible to have a **quick preview** of the results and make any necessary adjustments. This is important since macro 3d photography is, in many cases, a **trial and error** method.
USE of FLASH

1. Freezes Motion
2. Allows using small f-stops
3. Darkens Background
4. Consistent Light

Metz 15 MS-1

For macro pictures flash works particularly well because the size of the flash head can be as large or larger than the subject, which avoids typical harsh shadows when the light source is small.

There are a variety of macro flash units, including ring flashes and units with LED lights. My personal favorite is the Metz M15 S-1.

One important variable when using flash is shutter speed synchronization. It is an advantage if the flash can be synchronized at high shutter speeds (not always possible). Using a high shutter speed will reduce ambient exposure and keep the background dark, while the main subject is illuminated by the flash.
Digital Post Processing

- Post-processing is an **important** part of digital macro 3D. That’s because the two pictures are often misaligned, deformed, reflected, rotated, etc.

- An extreme example is when using the single camera & single mirror method. This method would be impossible without access to post-processing.

- Even stereo pairs from the Macro box need to be aligned, one image (reflected) needs to be flipped, color balance might need to be adjusted (the image going through the mirror might pick up some color due to the mirror), etc.

- Most digital 3d photographers use **StereoPhoto Maker** (SPM), a free program that makes these operations relatively easy.
ONE camera & shift

A single 2D camera is perhaps the easiest and least expensive way to start, especially if you already have a camera than can focus close. All you need to do is take one picture, shift the camera, take another picture, and you are done!

**Advantage:** Flexible stereo base!

**Drawback:** For stationary objects only

Starting recommendation for Stereo Base: 
~ 1/20-1/10 x Distance Of Nearest Object
• Hand Held or Slide Bar?

• Converge or not?

With film the standard advice was not to converge. With digital, convergence errors (keystoning) can be corrected so convergence is widely used.

• High magnification: subject Tilt (Rotation)
CAUTION: Do NOT shift Flash !!!

Right Shadow  Left Shadow

Shadows = Pseudoscopic
3D Macros - Summary

- Macro 3D photography is a **fascinating** field to explore and, now, with digital photography, it is easier than ever to experiment. There are many **different methods** varying in expense and degree of difficulty.

- The least expensive methods are: using **one camera and shift** (for stationary objects), or a **single camera and a hand-held mirror** (for moving objects).

- If cost or bulk is not an issue, the **Macrobox**, based on two cameras and a half-silvered mirror, is one of the most versatile tools for macro 3D. For simplicity, I would go for the **Panasonic 3D lens**.

- A good amount of **experimentation** is required to get good results. The results however more than justify the effort.