Guidelines for handheld image acquisition

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This is a minimal guide designed to help you get some underwater images suitable for mosaicking. Think of it as a "getting started" guide – there are more details to get into later, but it is best to get something, see how it turns out, then modify and learn from experience. So start here, but refine based on how the results turn out.

Basic Idea

The basic goal is to swim over the survey area with the camera pointing nearly vertically down as possible. Cover the area using a double "lawn mower" pattern. Typically the survey areas are on the order of 10x10 to 20 x20 m. These are sizes that can be accomplished in one dive (usually 30-40 min). The pattern should consist of a set of parallel transects followed by a second set of "tie lines". The parallel transects in the primary direction should have substantial side-to-side overlap (60-80%), the tie lines in the other direction do not necessarily need as much side to side overlap, but it is best to do so if you have time (Fig 1).

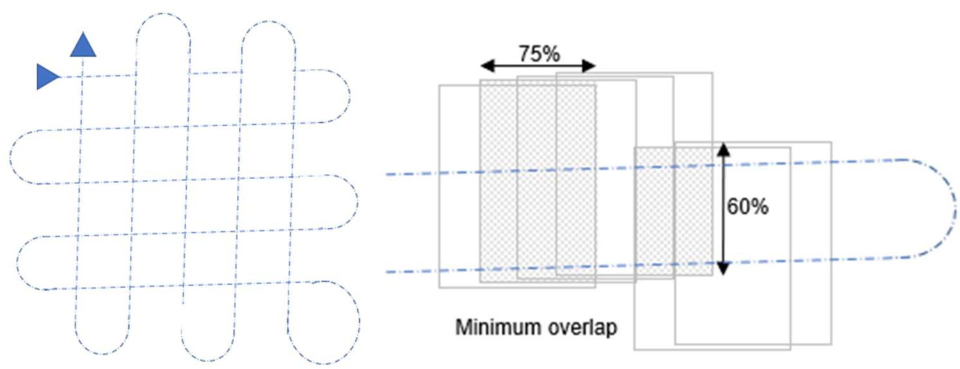

Figure 1: Ideal "double lawnmower" survey pattern. Left: camera path to ensure complete double coverage of the area. Right: overlap along-track should be >= 75% and across-track >=60%, ideally.

After doing the full set of double passes, it is also a good idea to do one circular pass around the area pointing the camera towards the middle of the plot at an angle, somewhere between 20-45 degrees (Fig. 2). Try not to tip the camera so much that you get views of the water column in the images. Better to have too little tip with seabed fully filling the frame than have too much tip with water column taking up a portion of the frame.

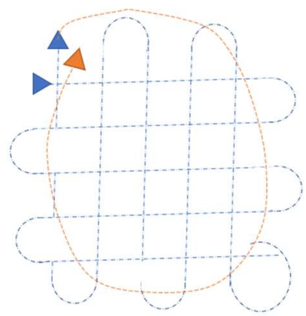

Figure 2: Ideal way to finish the survey. After doing the full double set of passes with the camera pointed vertically down at the seabed (blue path), then do a single circle around the plot with the camera tipped at an angle, pointed at the middle, (orange path).

Make sure you have noticeable overlap between strips in the primary direction. Do not forget to do the tie lines, otherwise the sequence is unusable for mosaicking. See the following example for what happens if you don't have any tie lines:
http://web2.physics.miami.edu/~agleason/mosaic_results/puerto_rico_acropora/thicket41.html

How high above the seabed? The height of the camera above the seabed affects 1) the resolution of the images (and therefore the final mosaic), 2) the time it takes to survey a single plot, and 3) the ease with which matches can be found between frames. You want to swim low to get good resolution and high to reduce time and ensure the mosaicing works. The rule of thumb is to swim 1.5 to 2 times the height of the largest object in the survey area. So if there is a 1 m high coral in the plot, swim 1.5-2 m above the top of that, or 2.5-3 m above the bottom. If time is available, it is a good idea to try the same practice plot at multiple altitudes to get a feeling for the right height.

Put a few scale bars (e.g. quadrats, meter sticks, tiles etc…) in the area to be mapped. These serve two purposes: a) to help guide the diver so the entire area is covered, and b) to allow the scale of the final mosaic to be computed. You must have some sort of scale in the plot. Ideally it is "self documenting" i.e. someone who looks at the picture can tell how big the scale bar is (write the size on it, for example). Finally, before clearing up the site, make a note of the depth of some (ideally 4-6) prominent objects. What works best is to have the scale bars numbered or color-coded, then as you are setting down or picking up the scale bars, record their depths with your dive gauge. Strictly speaking depths are not 100% necessary to make the models, but they help to orient the model to local vertical, which is especially important on sloping sites.

Rules of thumb

- *Blur is the enemy! Images must be in focus.* Avoid fast rotation motion at the end of each swath because turning the camera can lead to motion blur, especially at the edges of the images, even when it does not seem that you are turning the camera quickly. A good strategy is to rotate the diver around the camera at the end of each transect, so that the camera is always oriented in the same direction, rather than rotating the camera to swim the other direction. Figure 1 is a bit misleading in this regard. It appears that there are big curving loops at the end of each transect, but that is just to give the idea. In reality, you do not want to swim big loops or turns at the end of each transect. Your pattern will look more like a sawtooth than strictly parallel lines (Fig. 3).

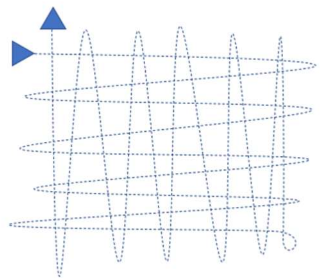

Figure 3. A more realistic swimming pattern. Note, there are not big looping turns at the end of each transect. Rather, the diver flips at the end of each pass so the camera stays oriented the same way regardless which way you are swimming. This minimizes the chances of motion blur.

- If your camera can zoom, set the camera to maximum zoom out (widest field of view). You can try different settings, but make complete datasets at each setting. Do not change the zoom during data acquisition.
- Cameras should be set to high shutter speed. Some cameras allow for manually defining the shutter speed, while the aperture (camera iris) and/or ISO setting (gain) is automatically controlled to adjust to the light conditions. In such case, this mode should be used at a high shutter speed (1/640 or higher), as long as there is enough light. By using high shutter speed, the motion blur on each frame is reduced, resulting in more precise motion estimation.
- Camera motion should be slow. This way, the effects of motion blur are reduced and high overlap is more likely. Use combination of speed and altitude so that an object is captured on at least 3 consecutive frames as you swim over it.
- Use an automated timer (intervalometer) if your camera has one. Set to take 1 image per second.
- For GoPro cameras use the medium field of view setting (not the ultra-wide) or, preferably, use the “linear” setting if your GoPro has one (the newer ones do).
- It is not a bad idea if you have two cameras to get redundant data. For example attach a GoPro to a DSLR and get both sets of data at once. This can help image matching in complicated sites and also serves as a back up in case of disaster (card failure, camera flooding etc..).
- Usually moving over about 1 m per pass works well for most cameras / altitudes above the bottom. So a 10 x 10 m plot would have about 10 transects in each direction. Doing more is always OK (it just takes longer). If you find you are doing much fewer, however, that is probably a warning sign that you do not have enough side-to-side overlap.
- Turn OFF auto rotate of images, if your camera has that option. We want all the images on disk to be oriented the same way (landscape).
- 10x10 m plot will require ~30-40 minutes of images, which will be 1800 to 2300 images per camera at 1 / sec.
- It is necessary to cover the eyepiece for DSLR cameras as you would for a long exposure (most cameras come with a cover for this or just use electrical tape). If your images have wacky over and under exposure problems it is because you did not cover the eyepiece.

Complications

The above instructions cover the basics. Current, extreme depths (both shallow and deep), visibility, shadows, caustics, high relief, and low light all require special care. Also, sites with "low texture" like bare sand, high seagrass cover, or monotype thickets (*e.g.* large stands of single *Acropora* sp.) require special techniques sometimes.

One of the ideal uses of mosaics is for repeat monitoring of a site. To do this, however you will need to mark your site somehow. Most people use rebar or stainless steel pins driven into or cemented into the seabed. One pin in the center of a site is a minimum. More pins takes longer the first time but helps set up the site faster in subsequent surveys and provides some redundancy in case a pin is lost (does happen).

Alternate survey patterns

The "double lawnmower" pattern shown above is the best option, usually (Figs 1,2). The exact pattern used is somewhat arbitrary, however. What is important is getting (a) complete coverage (b) lots (75%) overlap between overlapping images (c) some non-sequential tie-lines. For example, three other patterns that have been used successfully are the "not quite full double lawnmower" (when time is short), the "spiral" (for circular plots) and the "nearly parallel double pass" (for steep slopes where repeated depth changes are undesirable.

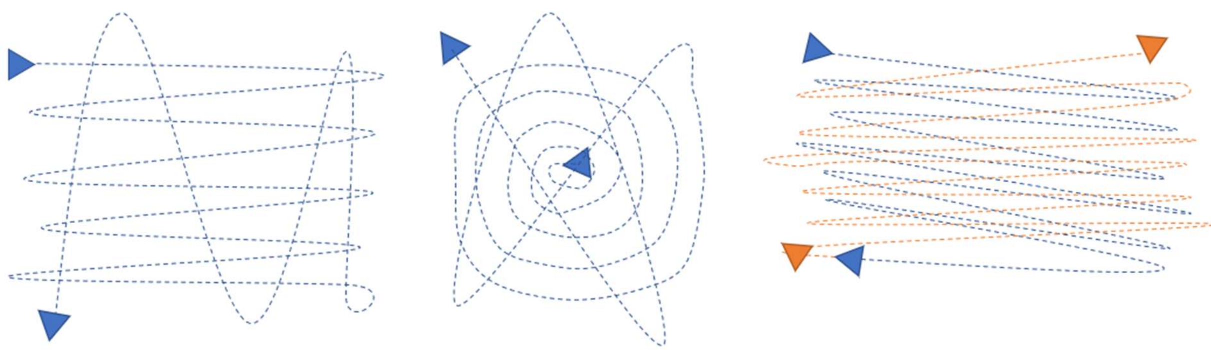

Figure 4: Alternative survey patterns that could be used in place of the ideal "double lawnmower." Left: an abbreviated double lawnmower, in which the first set of passes is the same but the second set does not get full coverage. Center: the spiral, for circular plots. Make sure to get overlap on successive spirals and also to do a few criss-crosses over the site at the end. Right: two nearly parallel sets of passes. This is like the double lawnmower but instead of having the second set (in orange) perpendicular to the first set (in blue), they are almost, but not quite parallel. Just rotate the orange set of passes by 10-20 degrees rather than by 90 degrees normally. This is good for example on steep slopes or anywhere else that transects in a particular direction will require a yo-yo depth profile.

Data organization

Most SLR cameras will let you define which folder to store images. It does make organizing your photos easier to put each site or survey in its own folder. GoPros typically start a new image series number each time shutter is presses in time lapse mode, but they do not always start a new folder.

When you download, use an organized file structure. I use YEAR/SITENAME/CAMERA/<images>

I usually have multiple cameras so it might look like:

2016/MolassesSIte1/Nikon/<images...>
2016/MolassesSIte1/GoProStills/<images...>
2016/MolassesSIte2/Nikon/<images...>
2016/MolassesSIte2/GoProStills/<images...>

Etc...

Do NOT rename the images. Do not rotate, color balance, or do anything else to the raw images. If you want to adjust them make a second copy.

It is most convenient to NOT use spaces or strange characters such as parenthesis, commas, etc. in the file or directory names. Underscores are OK.