Bioinspired Visual Guidance in Turbid Underwater Environment
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ABSTRACT
• An obstacle avoidance strategy using monocular gray-scale robotic vision for turbid wa-
ter environments is presented;
• This method was biologically inspired by the unique vision system of the cubozoan, or box jellyfish;
• It is computationally inexpensive for a compact autonomous underwater vehicle with
limited on-board, real-time processing capabilities;
• The sharp contrast reduction in turbid waters between obstacles and the surrounding en-
vironment is leveraged as a semi-reliable measure of relative distance between obstacles
to form an evasion response based on obstacle priority;
• It is shown that using contrast as a sole depth cue in turbid underwater environments is
suitable for the detection of large, stationary obstacles.

VISION SYSTEM OF BOX JELLYFISH
• Box Jellyfish is known to be able to navigate among complex
• mangrove roots and in murky lagoon water in days and nights using
24 specialized eyes;
• 8 of these eyes are complex, lensed eyes, and cubozoans are rel-
• atively primitive animals without a definite, centralized brain;
• Each lens eye possesses all of the components of a typical cam-
era-like eye, including a cornea, lens, retina, pigment layer and
iris, and can provide spatial vision within a 10-20 degree span;
• It is believed that the cubozoan uses the LLEs for obstacle avoid-
ance and the ULE for navigational guidance;
• Cubozoan vision is also believed to be nearly colorblind;
• Geometric modeling has shown that the cubozoan lens eyes are extremely
under-focused.

RELATIVE DEPTH FROM CONTRAST ATTENUATION
• It has been shown that the lower lens eyes control the obstacle avoidance response in cubo-
zoans, avoiding the underwater roots of mangrove trees;
• It has been shown that a sharper contrast between a specified obstacle and the surrounding environ-
ment provoked a stronger obstacle avoidance response from the cubozoan.

PRELIMINARY TESTING RESULTS

Fig. 8. A compact, monocular vision module designed for depth estimation from con-
trast reduction.

Fig. 9. Turbid water image captured by the vision-module in the pre-vehicle testing environ-
ment. Local contrast changes are placed at the same depth, the contrast between the obstacles and the environment is
the same (left). Contrast differences increase when the objects are placed at different depths (middle). Gray-scale images (right) of the same scene
(right).

Table 1. Resonance times (in seconds) based on image resolution:

\[
\begin{array}{|c|c|c|}
\hline
\text{Image Capture} & 80 \times 80 \text{ pixels} & 120 \times 120 \text{ pixels} \\
\hline
\text{Primary Scan} & 0.021 & 0.031 \\
\hline
\text{Secondary Scan} & 0.005 & 0.008 \\
\hline
\text{Actuation Delay} & 0.002 & 0.002 \\
\hline
\text{Total Execution Time} & 0.02 & 0.05 \\
\hline
\end{array}
\]

Fig. 10. Cubozoan applies asym-
metric bell contractions in reac-
tion to changes in ambient light. 
This figure shows the behavior 
the same animal during four swim 
pulses, using four different lighting 
conditions. The dark panel is in-
duced by a black circle and 18 pan-
els by green circles. The outline of 
the ventral opening is indicated by 
the broken line. Figure adapted from [8].

Fig. 11. A conceptual illus-
tration of a distributed sen-
somotor system by com-
limenting each jet thruster on Cephalopod AUV with a dedicated bioinspired visual module.

FUTURE WORK
Emulate cubozoans’ feeding behavior where they active 
their bell muscle asymmetrically in reaction to local visual 
frequencies in order to stay within light shafts.

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