Appendix A. Value Function and Policy Construction

Algorithm 1 The algorithm used to generate the value function for a chart without water current.

Require: $\mathcal{A}$ contains only movement actions.
Ensure: $V(x,y) = V(x + kx_{\max}, y + ly_{\max})\ \forall\ k,l \in \mathbb{Z}$ and $\forall\ (x,y)$.

$V_0(x,y) \leftarrow 0\ \forall\ (x,y)$
$V_1(x,y) \leftarrow \min_{a\in\mathcal{A}} c(x,y,a)\ \forall\ (x,y)$
$n \leftarrow 1$
while $\|V_n - V_{n-1}\|_\infty > 0$ **do**
  $n \leftarrow n+1$
  $V_n(\cdot) \leftarrow \min_{a\in\mathcal{A}} c(\cdot,a) + \gamma V_{n-1}(a_M(\cdot,W))$
end while
$V(x,y) \leftarrow V_n(x,y)$

Algorithm 2 Algorithm used to generate a policy with uncertainty incorporated.

Initialize position estimate $(\hat{x},\hat{y}) \leftarrow (x,y)$.
Initialize water current estimate $\hat{W} \leftarrow W(x,y)$.
Initial uncertainty in position and water current as zero.
while $-1 < V(x,y) < 100$ **do**
  Predict minimal value $V_{\min}$ over all movement actions using state estimate and uncertainties.
  if $V_{\min}$ is greater than the cost to measure both position and water current **then**
    $(\hat{x},\hat{y}) \leftarrow (x,y)$.
    Positional uncertainty $\leftarrow 0$.
    $\hat{W} \leftarrow W(x,y)$.
    Water current uncertainty $\leftarrow 0$.
  else if $V_{\min}$ is greater than the cost to measure position or $V(\hat{x},\hat{y}) = -1$ **then**
    $(\hat{x},\hat{y}) \leftarrow (x,y)$.
    Positional uncertainty $\leftarrow 0$.
    Update $\hat{W}$ using positions.
    Water current uncertainty decreases.
  else if $V_{\min}$ is greater than the cost to measure water current **then**
    $\hat{W} \leftarrow W(x,y)$.
    Water current uncertainty $\leftarrow 0$.
  end if
  Predict value for each movement action using estimates and uncertainties.
  Choose movement action with minimal value.
  Increase water current uncertainty by one unit.
  Increase positional uncertainty relative to water current uncertainty.
  Update $(\hat{x},\hat{y})$ using movement action and $\hat{W}$.
  Update (x,y) using movement action and $W(x,y)$.
end while

Appendix B. Chart Generation Method

The system the agent is navigating in is contained inside a rectangular area with periodic boundary conditions and dimensions $x_{\max}$ and $y_{\max}$. Each these island obstacles is represented by a 2-dimensional Gaussian function, defined as

$$g(x,y) = Ae^{-\left(a(x-x_0)^2+2b(x-x_0)(y-y_0)+c(y-y_0)^2\right)}, \tag{B.1}$$

where $x_0 \in [0, x_{\max})$, $y_0 \in [0, y_{\max})$, $A \in [1,2]$, $a, c \in [1,\infty)$ are independently sampled uniformly from their respective ranges and $b \in (-\sqrt{ac}, \sqrt{ac})$ is also sampled uniformly, (however it is dependent on a and c). We then define the land function as

$$f(x,y) = \sum_{i=1}^{N} \sum_{j=-\infty}^{\infty} \sum_{k=-\infty}^{\infty} g_i(x + jx_{\max}, y + ky_{\max}), \tag{B.2}$$

where N is the number of islands and the parameters for each g_i are sampled as described above and independently from each other island. While true periodic boundary conditions require the infinite sums, the bounds $-1 \le j, k \le 1$ are sufficient for our purposes.

Appendix C. Water Current Generation Method

For each island $g_i(x,y)$, the water current $W(x,y)$ vector at position (x,y) has direction given by

$$\begin{aligned} w(x,y) = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \sum_{i=1}^{N} \sum_{j=-\infty}^{\infty} \sum_{k=-\infty}^{\infty} \Bigg(&(-1)^{m_i(x,y)} \times \\ &\nabla g_i(x + jx_{\max}, y + ky_{\max}) \Bigg), \end{aligned} \tag{C.1}$$

where each m_i only returns the discrete values 0 and 1 and is chosen to maximize $\|w(x,y)\|_2$. The water current $W(x,y)$ function is then defined as

$$W(x,y) = \frac{w_{\max} - \|w(x,y)\|_2}{2w_{\max}\|w(x,y)\|_2} w(x,y) \tag{C.2}$$

if $f(x,y) < 0.9$ and $0 < \|w(x,y)\|_2 \le w_{\max}$, $W(x,y) = 0$ if $f(x,y) \ge 0.9$ or $\|w(x,y)\|_2 > w_{\max}$, and

$$W(x,y) = \frac{w_{\max}}{\|w(x,y)\|_2} w(x,y) \tag{C.3}$$

if $f(x,y) < 0.9$ and $w(x,y) = 0$, where $w_{\max} \ge 0$. In other words, the water current vector at (x,y) is perpendicular to $\nabla f(x,y)$ with magnitude bounded and related to $-\|\nabla f(x,y)\|_2$.