FAF'05 Mission A1 Report Draft

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Objective & Principle:

The objective in FAF'05 Mission A1 is to test the Adaptive Rapid Environmental Assessment (AREA) mechanisms. In this mission, AUV will follow an adaptively up-and-down yoyo track to capture sound speed uncertainties as much as possible in water column in regard to minimizing acoustic uncertainties. The experiment site is around Pianosa, Italy. In this area, existence of thermocline usually leads to main sound speed uncertainties. So, in mission A1, AUV will focus on capturing the thermocline.

By comparing local vertical gradient of sound speed (LVGSS) with a threshold, AUV can estimate whether it is above, inside of or below the thermocline. It assumes that at the beginning of the mission AUV is always on the surface. Then, while AUV is diving with the maximum pitch angle, CTD will collect sound speed data every 1 second. The LVGSS will be computed every 20 or more sampling points through *Linear Least Squares Fitting* method. As AUV diving, if LVGSS becomes greater than the threshold and then gets lower, it means that AUV just crossed the thermocline and is below it. Then, AUV will turn around upwards. If thereafter LVGSS becomes greater than the threshold and then lower again, that means AUV gets back above the thermocline. See Figure 1 for the control flow chart. Moreover, in this mission we set an upper bound and a lower bound for AUV. No matter has AUV crossed the thermocline or not, once the lower bound or upper bound is reached, AUV will have to turn around back to up or down respectively. In most range of FAF'05 area, the lower bound is set even lower than seabed and we assumes that AUV will be forced to turn around at 5 m above seabed by collision avoidance device.

In AUV yoyo control, there are two parameters needed to be optimized: 'points' and 'threshold'. 'points' is the number of sampling points used to compute LVGSS; 'threshold' is the value used to be compared with LVGSS to determine the relative position between AUV and thermocline, as mentioned before. It is supposed that before the experiment a priori sound velocity profile (SVP) error field σ, horizontal and vertical correlation length Lr, Lz are known. Also it is supposed that the correlation coefficient function of SVP between two locations $\mathbf{x}_1$, $\mathbf{x}_2$ is:

$$\rho_{x_1,x_2} = e^{-\frac{(\frac{r_1-r_2}{Lr})^2+(\frac{z_1-z_2}{Lz})^2}{2}}$$

Where r_1, r_2 are horizontal coordinates of $\mathbf{x}_1$ and $\mathbf{x}_2$ respectively; z_1, z_2 are vertical coordinates of $\mathbf{x}_1$ and $\mathbf{x}_2$ respectively. Thus, covariance between $\mathbf{x}_1$, $\mathbf{x}_2$ is:

$$Cov(\mathbf{x}_1, \mathbf{x}_2) = \sigma(\mathbf{x}_1)\sigma(\mathbf{x}_2)\rho_{x_1,x_2}$$

In addition, the principal ocean estimate ψ_0 and n different realizations $\psi_1, \cdots, \psi_n$ for the FAF'05 area on the next day will be given. By randomly taking one scenario ψ_i from $(\psi_0, \psi_1, \cdots, \psi_n)$ and implementing yoyo control with parameter pairs (points, threshold) and white measurement noise in ψ_i, a sequence of in-situ measurements $\mathbf{d}$ can be obtained at locations $\mathbf{X}$. By doing z-direction-oriented interpolation and extrapolation with respect to $\mathbf{d}$ and $\mathbf{X}$ on the vector of model grid point locations $\mathbf{x}$, the SVP background $\bar{\psi}$ can be obtained. Thus, Objective Analysis (OA) can be implemented through the following formula:

$$\hat{\psi}^{OA} = \bar{\psi} + Cov(x, X)[Cov(X, X) + R]^{-1}[d - \bar{d}]$$

$$P^{OA} = Cov(x,x) - Cov(x,X)[Cov(X,X) + R]^{-1}Cov(X,x)$$

$$\sigma^{OA} = diag(P^{OA})$$

where $\bar{d}$ is the background field at in-situ measurements locations $\mathbf{X}$, $\hat{\psi}^{OA}$ is the new principal ocean estimate from OA, P^{OA} is the OA estimate error covariance matrix, σ^{OA} is the diagonal items in P^{OA}. R is the error covariance matrix of $\mathbf{d}$. By the white noise assumption,

$$R = \begin{bmatrix} \sigma_n & & & \\ & \sigma_n & & \\ & & \ddots & \\ & & & \sigma_n \end{bmatrix}$$

where, σ_n is the CTD measurement error.

So, it can be seen that by doing in-situ measurements and data assimilation, a priori principal ocean estimate and error field $\{\psi_0, \sigma\}$ has been improved to be $\{\hat{\psi}^{OA}, \sigma^{OA}\}$, i.e. at the beginning, SVP in FAF'05 area was viewed as a Gaussian random vector $C \sim N(\psi_0, \sigma, Lr, Lz)$; after OA, the Gaussian random vector becomes as $C^{OA} \sim N(\hat{\psi}^{OA}, \sigma^{OA}, Lr, Lz)$. Usually, $\sigma^{OA} < \sigma$.

Since acoustic field is a function of SVP, transmission loss (TL) can be written as

$$TL = f(C)$$

and

$$TL^{OA} = f(C^{OA})$$

Usually function f is highly non-linear. To compute standard deviation or variance of TL, Monte Carlo simulations are necessary. Simply speaking, in project AREA the objective is to minimize $std(TL^{OA})$ by optimally choosing in-situ measurements locations. However, we have a lot of possible scenarios: $\psi_0, \psi_1, \cdots, \psi_n$. By taking each of them but implementing the same yoyo control pattern, a certain $std(TL^{OA})$ will be obtained, i.e. for ψ_i and the kth yoyo control pattern, $std(TL^{OA}_{i,k})$ will be obtained. So, to judge how good it is for the kth yoyo control parameters pair, we select:

$$\underset{i=0,1,\cdots,n}{E} \{std(TL^{OA}_{i,k})\}$$

as the cost function.

The optimal $(points, threshold) = arg \underset{k=1,2,\cdots}{min} \{E_{i=0,1,\cdots,n}\{std(TL^{OA}_{i,k})\}\}$

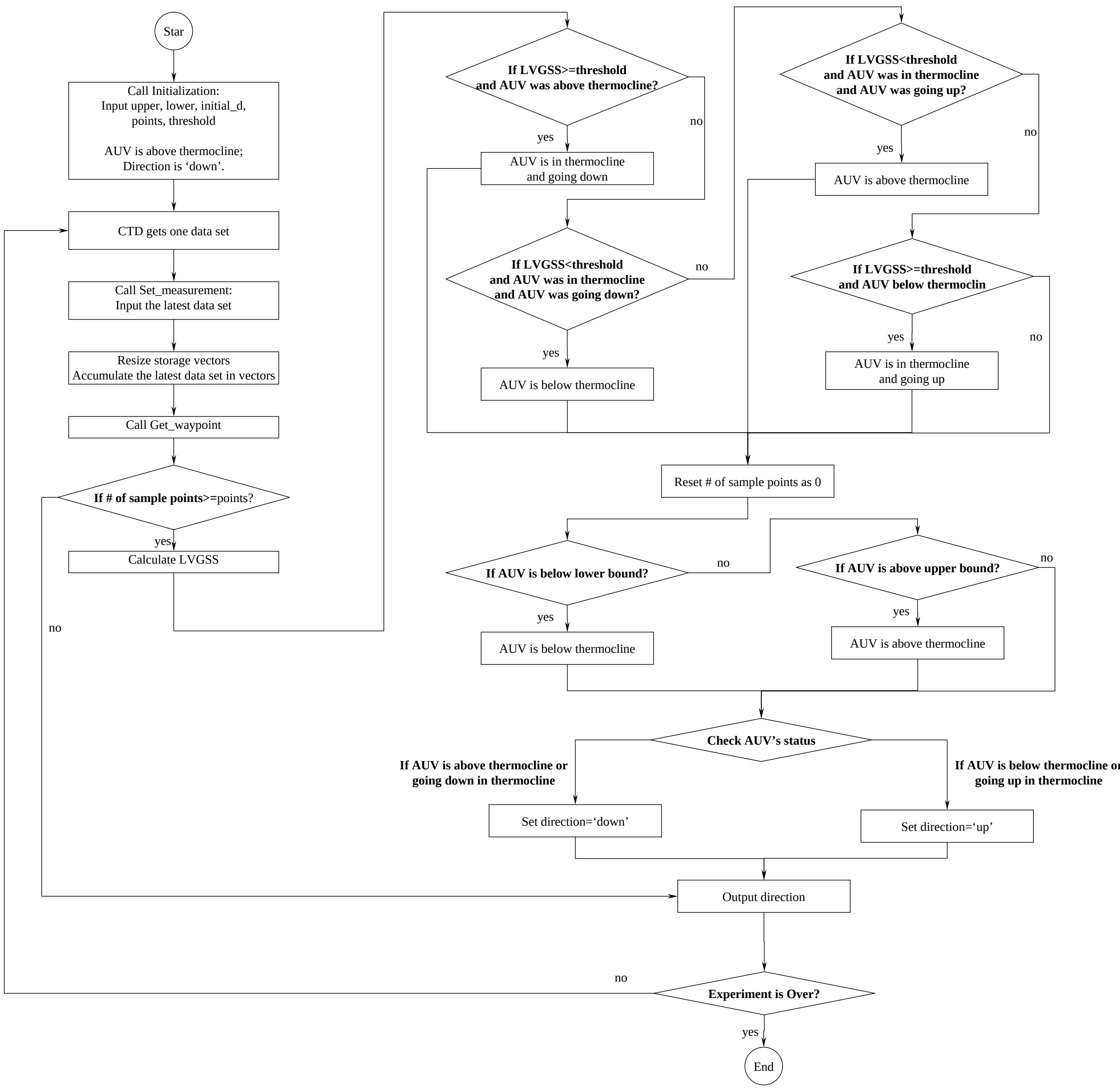

Figure 1: Yoyo control flow chart