0.0.1 Re-framed Crow Search Algorithm (Re-framed CSA)

- **Objectives**:

Objective Problem	
$f(\mathbf{x}_i)$	fitness of $\mathbf{x}_i$.
n	the dimension of the search space.
$[lb_{\mathbf{x}}, ub_{\mathbf{x}}]$	the interval of objective variable $\mathbf{x}$, in our cases, it is defined in the IOHprofiler, $[lb_{\mathbf{x}}, ub_{\mathbf{x}}] = [-5, +5]$.
Objective Solution	
$\mathbf{x}_i$	it can be imagined as one individual in Swarm-Intelligence Algorithms, $\mathbf{x}_i \in R^n$.

- **Parameters**:

T	maximum iteration, the budget in our cases, in our case, it is defined in IOHprofiler.
M	population size, $M = 50$.
$\mathbf{x}_{i_p}$	the memory position $\mathbf{x}_{i_p}$ for one individual $\mathbf{x}_i$.
w_1	awareness probability, $w_1 = 0.1$, $w_1 \in [0, 1]$.
w_2	flight length, $w_2 = 2$, $w_2 \in (0, +\infty)$.

- **Functions**:
  - Initialization Process:
    (1) Initialize $\mathbf{x}_i(t = 0)$:

$$\mathbf{x}_i(t = 0) = \boldsymbol{\mathcal{U}}(lb_{\mathbf{x}}, ub_{\mathbf{x}}) \quad (1)$$

(2) Initialize $\mathbf{x}_{i_p}(t=0)$:

$$\mathbf{x}_{i_p}(t=0) = \mathbf{x}_i(t=0), i = 1 \dots M \quad (2)$$

– Optimization Process:

(1) Update $\mathbf{x}_i(t+1)$ to generate $\hat{\mathbf{x}}_i(t+1)$:

$$\hat{\mathbf{x}}_i(t+1) = \begin{cases} \mathbf{x}_i(t) + r \times w_2 \times (\mathbf{y}_j(t+1) - \mathbf{x}_i(t)) & , \quad r > w_1 \\ \boldsymbol{\mathcal{U}}(lb_{\mathbf{x}}, ub_{\mathbf{x}}) & , \quad \text{o.w} \end{cases} \quad (3)$$

(2) Dealing with outliers C:

$$\mathbf{x}_{i,n}^{\text{fixed}}(t+1) = \begin{cases} \mathbf{x}_{i,n}(t) & , \quad \mathbf{x}_{i,n}(t+1) < lb_{\mathbf{x}} \text{ or } \mathbf{x}_{i,n}(t+1) > ub_{\mathbf{x}} \\ \mathbf{x}_{i,n}(t+1) & , \quad \text{o.w} \end{cases} \quad (4)$$

(3) Select $\mathbf{x}_i(t+1)$ from $\hat{\mathbf{x}}_i(t+1)$:

$$\mathbf{x}_i(t+1) = \hat{\mathbf{x}}_i(t+1) \quad (5)$$

(4) Optimize $\mathbf{x}_{i_p}(t)$ to generate $\mathbf{x}_{i_p}(t+1)$:

$$\mathbf{x}_{i_p}(t+1) = \textbf{Min}(\{\mathbf{x}_{i_p}(t), \mathbf{x}_i(t+1)\}) \quad (6)$$

Algorithm 1 Re-framed CSA with population size M; search space $n, [lb_{\mathbf{x}}, ub_{\mathbf{x}}]$; stop condition T; initialization method $Init_{\mathbf{x}}$, optimization method $Opt_{\mathbf{x}}$, treatment C of outliers, and selection S to objective solutions; initialization method $Init_{\Delta}$ and optimization method Opt_{Δ} to step-size Δ.

$t \leftarrow 0$
$Init_{\mathbf{x}}(t=0), M$ as Eq.1 ▷ Initialization Process
f ▷ Evaluation
$Init_{\Delta}$: $\mathbf{x}_{i_p}(t=0)$ as Eq.2
while termination criteria are not met **do**
    $Opt_{\mathbf{x}}, C \rightarrow \hat{\mathbf{x}}_i(t+1)$ as Eq.3, C as Eq.4
    $f(\hat{\mathbf{x}}_i(t+1))$ ▷ Evaluation
    $S \rightarrow \mathbf{x}_i(t+1)$ according to Eq.5 ▷ Selection
    $t \leftarrow t+1$
    Opt_{Δ}: $\mathbf{x}_{i_p}(t+1)$ as Eq.6
end while