

# Sonar-Based Human Leg Localization Using Chaos Enhanced Dynamic Neighborhood Learning-Based GSA Aided sNDT Algorithm

Pritam Paral<sup>✉</sup>, Amitava Chatterjee<sup>✉</sup>, Senior Member, IEEE, Anjan Rakshit<sup>✉</sup>,  
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**Abstract**—The present article proposes a new human leg localization (HLL) algorithm using ultrasonic sensors in human-robot coexisting environments. The algorithm estimates the motion of a human leg pair between two successive sonar scans by using a new static cluster elimination (SCE) method, an edge feature-based leg recognition algorithm, and an advanced scan matching technique. We also propose a novel, robust approach to overcome bad initialization problem in sonar scan matching, by introducing a metaheuristic search (MHS)-based optimization algorithm for the sonar normal distributions transform (sNDT) method. The recently proposed dynamic neighborhood learning-based GSA (DNLGSA) has been successfully utilized in real-life scenarios to solve this problem. The work also proposes a new chaos enhanced DNLGSA (CEDNLGSA) to further improve real-life performance and the proposed novel variant of the sNDT method based on CEDNLGSA, called chaotic MHS-based sNDT (CMHS-sNDT), has been demonstrated to achieve superior leg detection performance in various real-life case studies, compared to different contemporary state-of-the-art methods.

**Index Terms**—Chaos enhanced DNLGSA (CEDNLGSA), dynamic neighborhood learning-based GSA (DNLGSA), leg detection, likelihood field (LF), scan matching, sonar sensing.

## NOMENCLATURE

ABC	Artificial bee colony.
ARM	Advanced reduced instruction set computer (RISC) machine.
BFO	Bacterial foraging optimization.
CEDNLGSA	Chaos enhanced dynamic neighborhood learning-based gravitational search algorithm.
CMHS	Chaotic metaheuristic search.
CMHS-sNDT	CMHS-based sonar normal distributions transform.

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CoBIDE	Differential evolution based on covariance matrix learning and bimodal distribution parameter setting.
DBSCAN	Density-based spatial clustering of applications with noise.
DD-WMR	Differentially driven wheeled mobile robot.
DE	Differential evolution.
DFSABCElite	ABC algorithm with depth-first search framework and elite-guided search equation.
DNLGSA	Dynamic neighborhood learning-based gravitational search algorithm.
EFBLR	Edge feature based leg recognition.
EPSO	Ensemble particle swarm optimizer.
FE	Function evaluation.
FOChS	Fractional order chaotic system.
FOChS-PRNG	FOChS-based pseudorandom number generator.
FOVIS	Fractional order Volta's system.
FWS	Forward straddle.
GA	Genetic algorithm.
G-L	Grünwald-Letnikov.
GSA	Gravitational search algorithm.
GWO	Gray wolf optimizer.
HLL	Human leg localization.
HLL-sNDT	HLL with sonar normal distributions transform.
HLL-X-sNDT	HLL with X-based sonar normal distributions transform (X: CMHS, DNLGSA, GWO, CoBIDE, DFSABCElite, IRDPSO, and EPSO).
HRI	Human-robot interaction.
IRDPSO	Improved random drift particle swarm optimization.
K-S	Kolmogorov-Smirnov.
LF	Likelihood Field.
LPDDR	Low-power double data rate.
LRP	Leg reading frame.
MAE	Mean absolute error.
MHS	Metaheuristic search.
MT-PRNG	Mersenne Twister pseudorandom number generator.
NDT	Normal distributions transform.
NWM	Newton's method.
PRN	Pseudorandom number.

# Melting Localization And Chaos

**R Barnett**



## **Melting Localization And Chaos:**

## Reviewing **Melting Localization And Chaos**: Unlocking the Spellbinding Force of Linguistics

In a fast-paced world fueled by information and interconnectivity, the spellbinding force of linguistics has acquired newfound prominence. Its capacity to evoke emotions, stimulate contemplation, and stimulate metamorphosis is actually astonishing. Within the pages of "**Melting Localization And Chaos**," an enthralling opus penned by a highly acclaimed wordsmith, readers embark on an immersive expedition to unravel the intricate significance of language and its indelible imprint on our lives. Throughout this assessment, we shall delve to the book is central motifs, appraise its distinctive narrative style, and gauge its overarching influence on the minds of its readers.

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