

Mortal creepers searching for a target

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In biology and ecology, target search processes where the lifetime of the searchers is shorter or comparable to the typical time needed to reach the target by diffusion are a common occurrence (e.g., oocyte fertilization by sperm). Here, we present a simple paradigm for detection of an immobile target by a Continuous Time Random Walker with a finite lifetime, which we alternatively call a mortal creeper [1]. The motion of the creeper is characterized by linear displacements at a fixed speed and exponentially distributed duration, interrupted by random changes in the direction of motion and resumption of motion in the new direction with the same speed. The mortal creeper may die at any time during its motion according to an exponential decay law characterized by a finite mean death rate ω_m . While still alive, the creeper has a finite mean frequency ω of change of the direction of motion. In particular, we consider the efficiency of the target search process, characterized by the probability that the creeper will eventually detect the target. Analytic results confirmed by numerical results show that there is an ω_m -dependent optimal frequency $\omega = \omega_{opt}$ that maximizes the probability of eventual target detection. We work primarily in one-dimensional ($d=1$) domains and examine the role of initial conditions and of finite domain sizes. Numerical results in $d=2$ domains confirm the existence of an optimal frequency of change of direction, thereby suggesting that the observed effects are robust to changes in dimensionality. In the $d=1$ case, explicit expressions for the probability of target detection in the long time limit are given. In the case of an infinite domain, we compute the detection probability for arbitrary times and study its early- and late-time behavior. We further consider the survival probability of the target in the presence of many independent creepers beginning their motion at the same location and at the same time. We also consider a version of the standard "target problem" in which many creepers start at random locations at the same time. In this latter case, no optimal frequency $\omega_{opt} > 0$ is found.

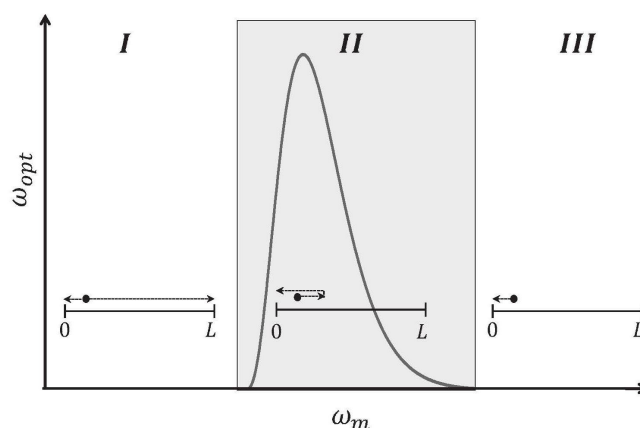


Figure 1: The optimal frequency of reorientation ω_{opt} maximizing the probability of eventual target detection becomes non-zero for intermediate values of the mortality rate ω_m .

References

- [1] D. Campos, E. Abad, V. Méndez, S. B. Yuste, and K. Lindenberg: *Mortal walkers searching for a target*. ArXiv:1503.02013 (2015).