The first and most general application of the work presented here is the matrix-free computation of persistent rank invariants in effectively $O(n^2)$ time and $O(m)$ storage, where $n = K^p$ and $m = K^{p+1}$. To demonstrate this empirically, we sampled 30 random graphs according to the Watts-Strogatz rules with parameters $n = 500, k = 10, p = 0.15$. These graphs tend to exhibit 'small world' characteristics inherited by many real-world networks, such as social networks, gene networks, and transportation networks. For our purposes, since the graph distance between pairs of nodes scale logarithmically with the size of the graph, we ensure the sampled random graphs to be uniformly sparse. The corresponding incidence matrix $\partial_1 \in R^{n \times m}$ and up-Laplacians $L_0^{up} \in R^{n \times n}$ would have $\approx 5,000$ and $\approx 5,500$ non-zero entries, were they to be formed explicitly, which are weighted according randomly by embedding the graph in the plane and filtering graph via its sublevel sets in a random direction. figure[t] [width=]presentations/images/watts$_s trogatz_p erf.pngRandomWatts - Strogatz``Smallworld'' graphexamplefig : watts$