Energy Harvesting *in-vivo* Nano-Robots in Caterpillar Swarm

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***Goal:* Mimic caterpillar inspired swarm movement in pipes (e.g., blood vessels), resulting in minimal time and energy consumption for movement**

ABSTRACT

Biological collaborative systems behavior is fascinating, as it urges researchers to mimic their behavior through programmable matters. These include a particle system, wherein some particles bind with neighboring particles to swarm and navigate. Caterpillar swarm inspired particle systems involve layered architecture with at least one, and up to a predefined number of layers.

In this paper, a coordinated layered caterpillar swarm inspired particle system is analyzed. We discuss the benefit of moving nano-particles in a swarm, which is demonstrated by a design of telescopic movement in pipes (e.g., blood vessels). In these pipes, each layer uses the accumulated speed of all layers beneath, which allows them to move faster.

PROPOSED IDEA

1. Novel design for energy harvesting in-vivo nano-robots inspired by the caterpillar swarm. A movement pattern of nano-robots that may scan blood vessels in order to detect tumors.
2. Computational particles create layered and connected structures to preserve energy in the swarm.

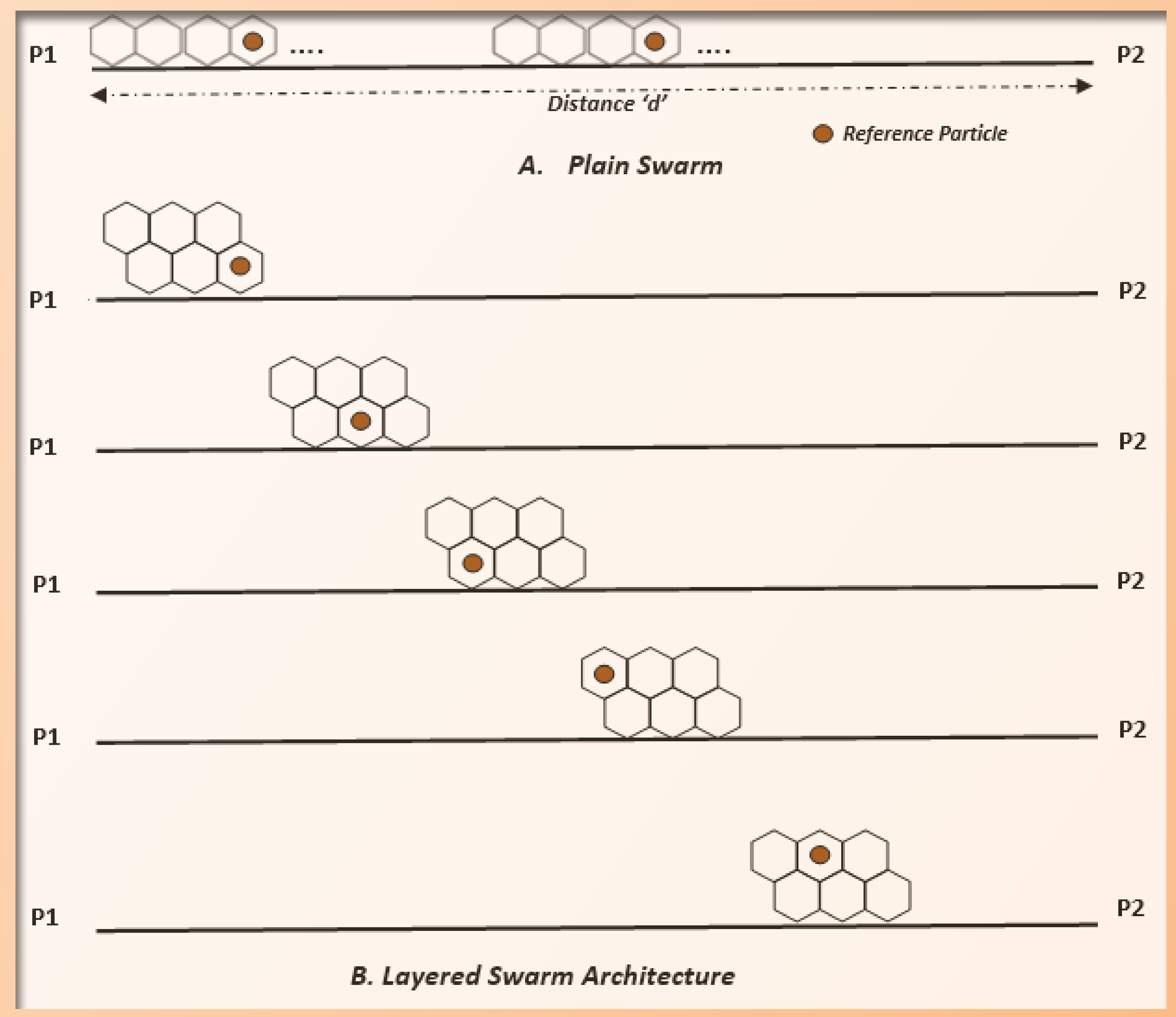
The average speed of a single caterpillar in a swarm is the average of its speed in all the layers, given by

$$\frac{v_0.(l+1)}{2}$$

l *is the number of layers in the swarm and*

v_0 *is the individual speed of the caterpillar in the swarm.*

CONCEPTUAL SWARM MOVEMENT DESIGN



Lemma 1:

If all the particles in a layered swarm use the same amount of energy to move, where the implied velocity of a particle with mass m is v_σ, then the time taken for the particle system to reach the goal position is less than that of a plain system by a factor

$$\frac{l}{\sum_{i=1}^{l}\sqrt{l}}$$

which conserves the amount of energy required by the layered swarm. 'l' is the maximum number of layers in the swarm.

The absolute speed of the swarm is

$$av_i = \sum_{j=l}^{i} v_0 / \sqrt{j}$$

$$as_l = (av_1 + av_2 + \ldots + av_l) / l$$

where for l = 1,

$$as_l = av_1 = v_0$$

for l = 2,

$$as_2 = (av_1 + av_2)/2 = (v_0 + v_0/\sqrt{2} + v_0/\sqrt{2})/2$$
$$= (v_0 + 2v_0/\sqrt{2})/2 > v_0$$

for l = 3,

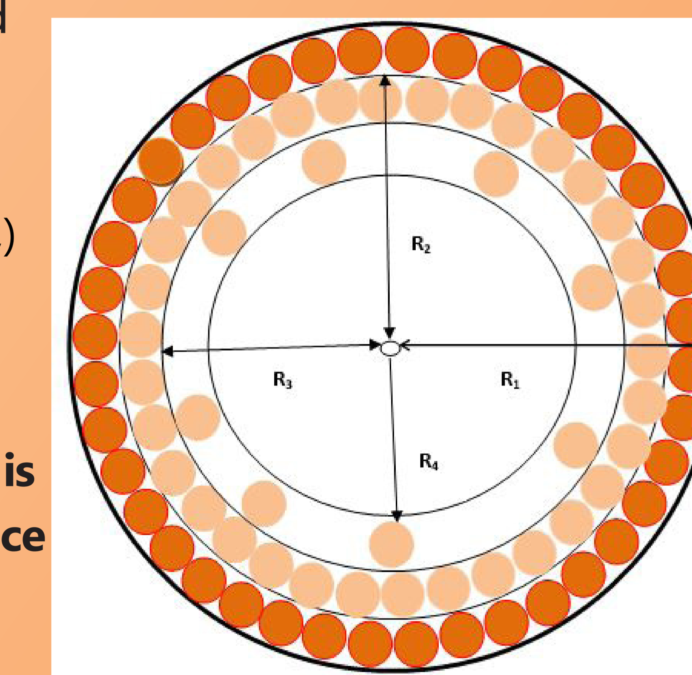
$$as_3 = (av_1 + av_2 + av_3)/3$$
$$= (v_0 + v_0/\sqrt{2} + v_0/\sqrt{3} + v_0/\sqrt{2} + v_0/\sqrt{3} + v_0/\sqrt{3})/3$$
$$= (v_0 + 2v_0/\sqrt{2} + 3v_0/\sqrt{3})/3 > v_0$$

FOLDING LAYERS OF A PIPE

The number of robots 'x_i'required to form a layer 'i', is given by

$$\lfloor x_i = 2\pi r_i / d \rfloor$$

where $1 > i \geq l$ *and* $r_i = r - ((i-1)d + d/2)$
d *- diameter of a nano robot*
r *- radius of the pipe*



The goal of the proposed algorithm is to ensure that the inner circumference of the pipe is fully covered at any point of time during the process.

$input: N, d, r$
$output: l, x_1; x_2; \ldots x_l$
$x_1 = \lfloor 2\pi(r-(d/2))/d \rfloor$
$sig\max = x_1$
$overflow_1 = 0$
$l = 1$
$r_1 = r - d/2$
$while\ sig\max < N\ and\ r_l > 3d/2\ and\ overflow_l < \lfloor x_l/2 \rfloor$
do
$l{+}{+}$
$r_l = r - ((l-1).d + d/2)$
$\max_l = \lfloor 2\pi r_l / d \rfloor - overflow_{l-1}$
$overflow_l = overflow_{l-1} + x_{1} - \max_l$
$x_l = \max l - overflow_{l-1}$
$sig\max = sig\max + x_l$
od

CONCLUSION

We have proposed a design of nano-robots inspired by caterpillar swarm. The harvested energy by the design can be used for running programs, programs that may also coordinate collaborative behavior in swarm of robots. This collaboration will assist in achieving a common goal.

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