Exploiting User Movement for Position Detection

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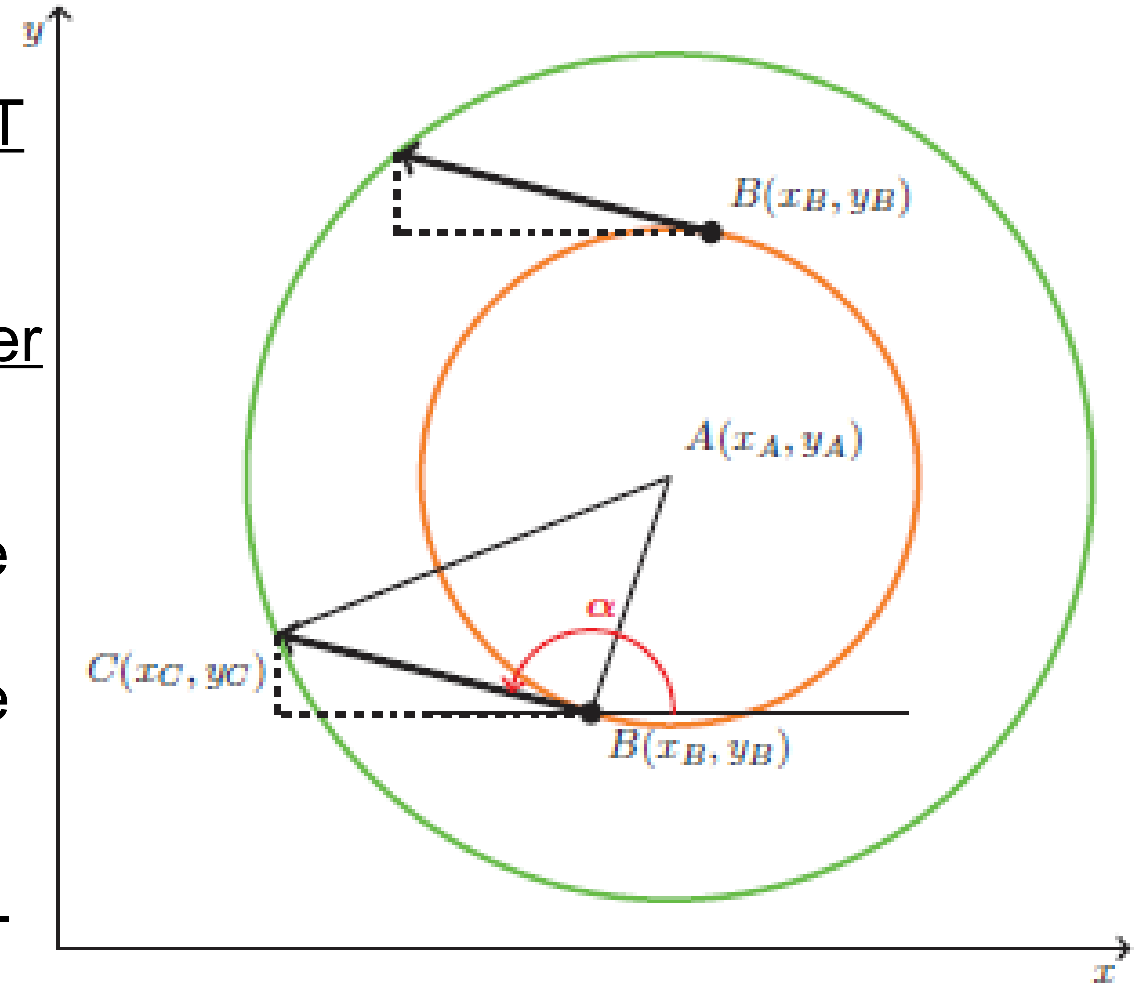
1.Introduction

- This study propose a new method called "Two-Step Movement" which is geometry-based and it can determine user position by only using one rederence point(RP) and exploiting user's simple movement.
- Assumptions:
  1. The position of the RP is known.
  2. The mobile terminal(MT) is capale of measuring the distance between itself and the RP.
  3. The MT capale of measuring the distance and the angle(direction) of its movement.

2. System Design

- **A** is the Reference Point.
- **B** is the initial position of the MT that is unknown and yet to be found.
- **C** is the position of MT right after the first movement, (xC, yC), which is also unknown.
- MT is capable of measuring the distance and the angle.
    - The distances **AB** and **AC** are given.
    - **BC** and the angle **α**∈ (0, 2] (with respect to the positive x-axis) are also measurable.



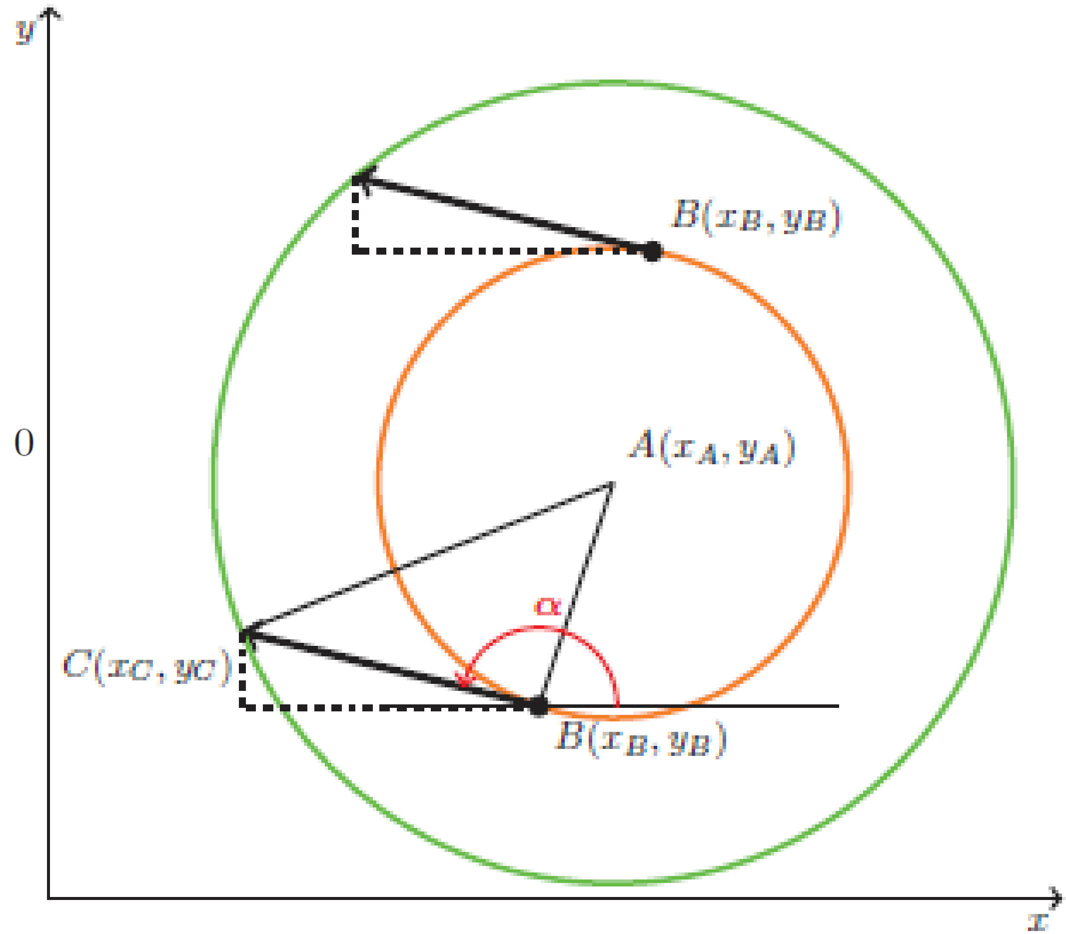
(1)One-Step Movement

Suppose that A(xA,yA), AB,BC,AC, and are known.

We can derive a quadratic equation

$$(1+a^2)x_B^2-2x_B(x_A-a(b-y_A))+x_A^2+(b-y_A)^2-AB^2=0$$

It will give two points B1(xB1, yB1) and B2(xB2, yB2), which are the possible solution of B.



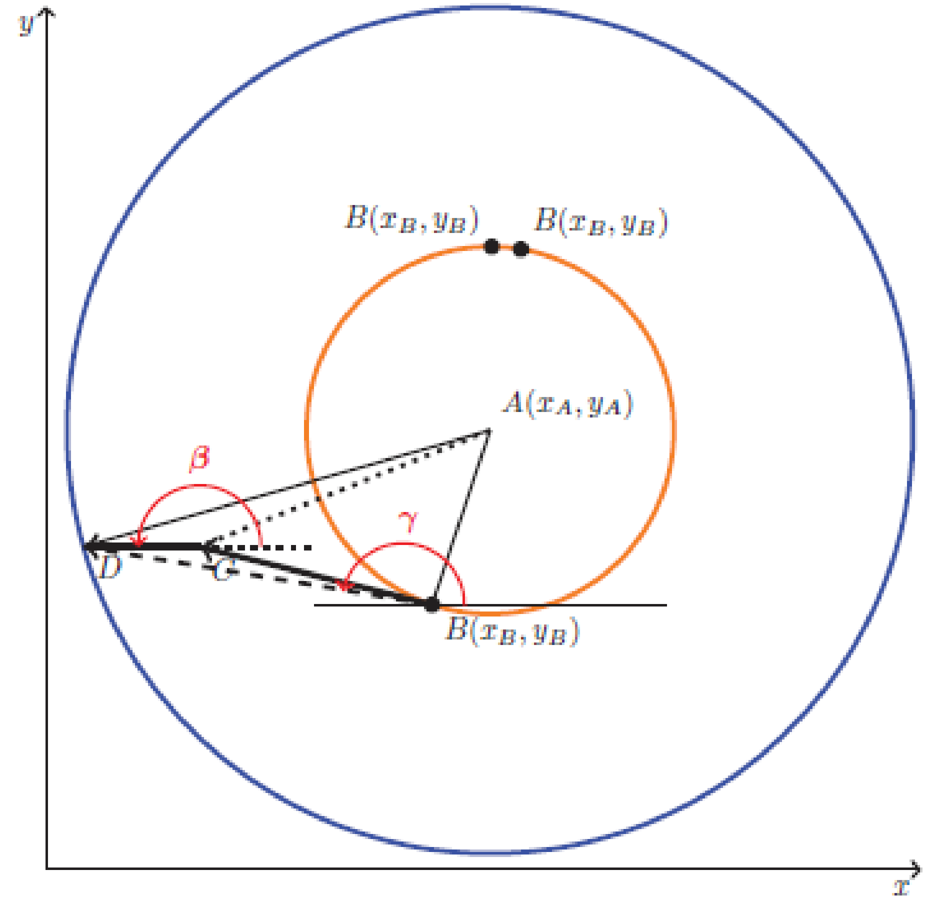
(2)Two-Step Movement

In 1SM,we have two possible location,but can not determine which one is the true location.

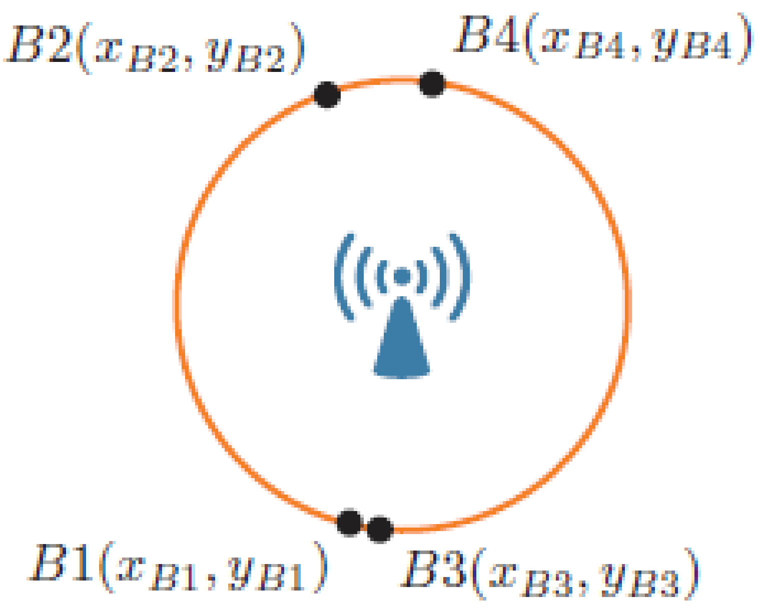
2SM is a combination of two consecutive 1SM.

The MT makes the second movement from C to D in the direction of angle β.

Note that the direction of the two movements should not in parallel.



(3) Amiguity elimination



In this case, the first movement may give us two possible solutions denoted by B1(xB1, yB1) and B2(xB2, yB2), but the second movement may give us another two possible solutions denoted by B3(xB3, yB3) and B4(xB4, yB4).

To solve this problem, we can choose the pair of points that have the smallest distance, i.e., solving min{d(P1, P2)|P1≠P2}, for P1, P2 ∈{B1,B2,B3,B4} where d(P1, P2) denotes the Euclidean distance of points P1 and P2.

After that, we take their mean as the estimate of the MT's position for minimizing the error.

In general, one can formulate it as an optimization problem and find the optimal result.

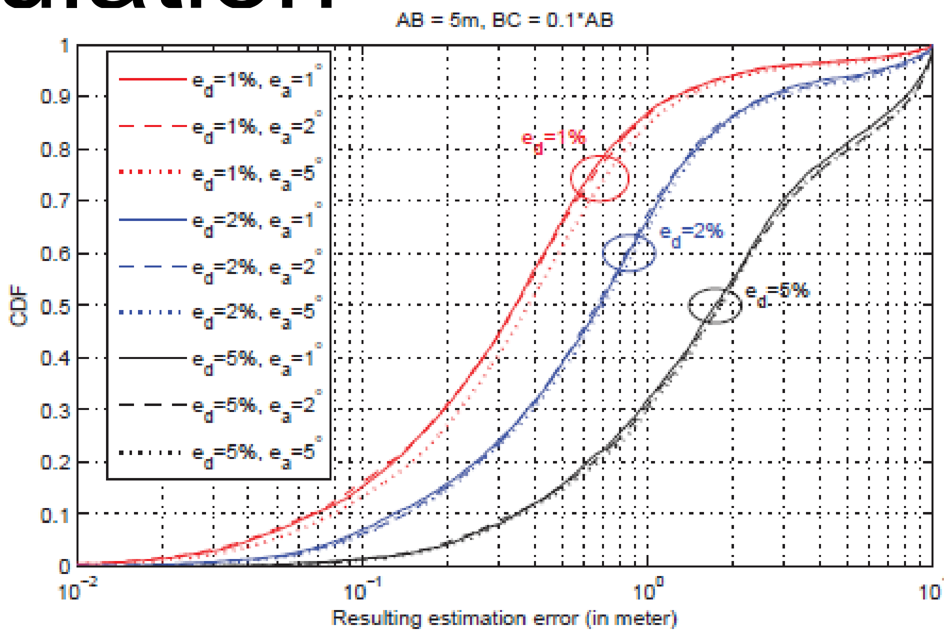
3.Simulation

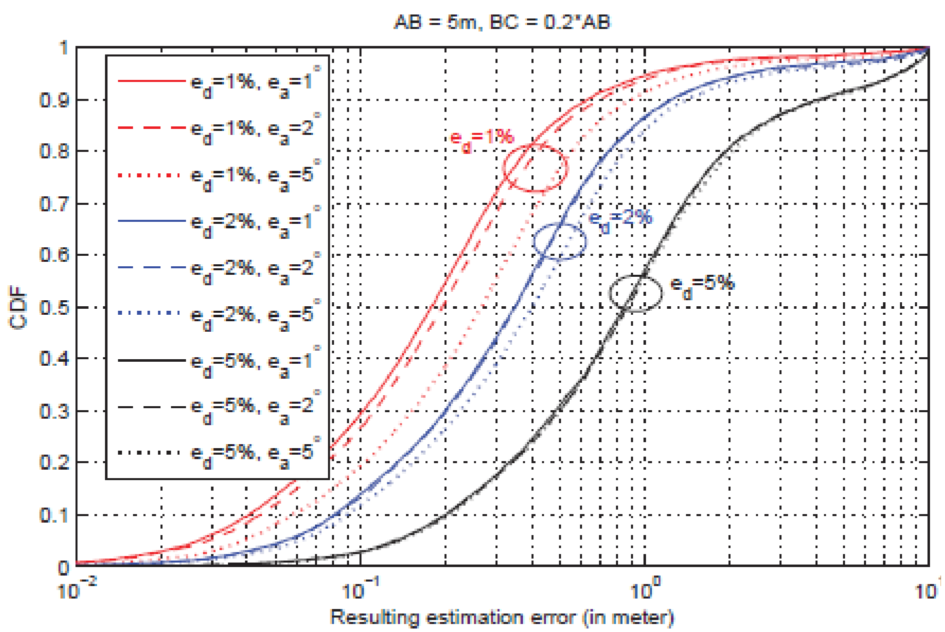
- The RP is placed at the center of a room, i.e., A = (0, 0).
- MT's location is randomly distributed in the room.
- We consider three distances (1, 5, and 10 meters) between the MT and the RP.
- Also, we assume that the direction from B to A is uniformly distributed in (0, 2π].
- For a given AB, the movement from B to C or from C to D is equal to 0.1, 0.2, and 0.5 times of AB.
- Estimation error to the measurement of distances AB, AC, AD, and BC, is considered to be bounded in [−1%, 1%], [−2%, 2%], and [−5%, 5%], for comparison.
- The bound on the angle measurement error is denoted by ea such that ea = 1, 2, and 5 degrees.

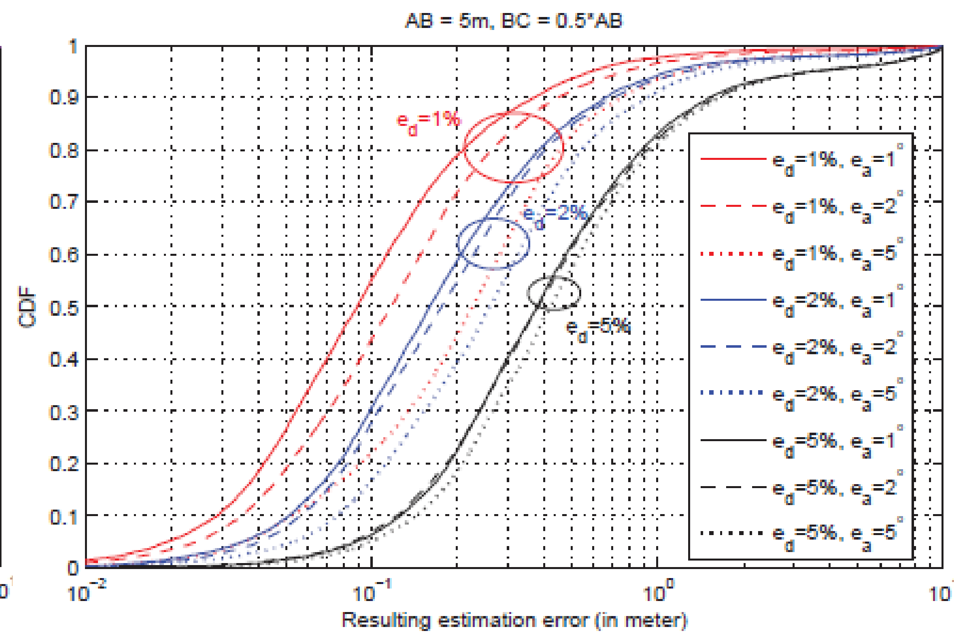
	$e_d = 1\%$ $e_a = 1^\circ$	$e_d = 1\%$ $e_a = 2^\circ$	$e_d = 1\%$ $e_a = 5^\circ$	$e_d = 2\%$ $e_a = 1^\circ$	$e_d = 2\%$ $e_a = 2^\circ$	$e_d = 2\%$ $e_a = 5^\circ$	$e_d = 5\%$ $e_a = 1^\circ$	$e_d = 5\%$ $e_a = 2^\circ$	$e_d = 5\%$ $e_a = 5^\circ$
$AB = 1$ (BC=CD= $0.1AB$)	0.1412	0.1434	0.1581	0.2583	0.2640	0.2708	0.5530	0.5608	0.5691
$AB = 1$ (BC=CD= $0.2AB$)	*0.0808*	*0.0859*	*0.1036*	0.1463	0.1508	0.1631	0.3202	0.3340	0.3417
$AB = 1$ (BC=CD= $0.5AB$)	**0.0484**	*0.0566*	*0.0896*	*0.0753*	*0.0804*	*0.1086*	0.1701	0.1759	0.1868
$AB = 5$ (BC=CD= $0.1AB$)	0.7194	0.7279	0.8027	1.2797	1.3012	1.3668	2.7913	2.9031	2.9226
$AB = 5$ (BC=CD= $0.2AB$)	*0.3957*	*0.4235*	*0.5513*	0.7145	0.7480	0.8246	1.6222	1.6372	1.6587
$AB = 5$ (BC=CD= $0.5AB$)	**0.2193**	*0.2831*	*0.4481*	*0.4136*	*0.4412*	*0.5448*	0.8738	0.8829	0.9134
$AB = 10$ (BC=CD= $0.1AB$)	1.4165	1.4348	1.6130	2.4798	2.6257	2.7011	5.7899	5.8059	5.8929
$AB = 10$ (BC=CD= $0.2AB$)	*0.8006*	*0.8602*	*1.0845*	1.4779	1.1508	1.5112	3.2304	3.3131	3.3873
$AB = 10$ (BC=CD= $0.5AB$)	**0.4987**	*0.5601*	*0.9362*	*0.8180*	*0.8798*	*0.1058*	1.7551	1.7652	1.8750

3.Simulation

As expected, the estimation error in determining the position of the MT also increases as ea increases. However, when e_d is relatively large (5%), the impact of the considered e_a is relatively less significant. Roughly speaking, e_d is more dominating.







4.Conclusion

- This paper have proposed a new method called Two-Step Movement (2SM) to estimate the position of MT.
- It requires only one reference point (RP) by exploiting useful information given by the position change of the MT or user movement.
- One can therefore reduce the number of RPs required and also the system cost.

Thank You!