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README.md

粒子滤波算法

1 粒子滤波算法过程解析

粒子滤波定位算法的思想也是贝叶斯规则：

$$\frac{\text{Likelihood} * \text{Prior}}{\text{Marginal}}$$

以下的解析是结合Matlab代码所作的说明

- 初始化
 - 初始化一堆粒子，在MatLab中的代码显示NP=50，也就是总共有50个**采样粒子**。Estimated State [x y yaw]，可见每个状态有3个数据。px=repmat(xEst,1,NP);,
 - 计算初始权重pw=zeros(1,NP)+1/NP; 可见初始权重是均匀的
 - 初始化路标，landMarks=[10 0; 10 10; 0 15; -5 20]; 可见一共有**4个路标**
- 预测：根据motion model与物体的控制信息u预测下个时刻粒子群中粒子的位置
 - doControl()函数，输入参数time，得到**控制指令u**
 - doMotion()函数，输入初始状态x和控制指令u，得到**下一时刻**的x状态
 - doObservation()函数，输入参数xGnd (**没有噪声**的里程计位置估计)，xOdom (**有噪声**的里程计位置估计)，u (控制指令)，landMarks, MAX_RANGE，输出参数是z,xGnd,xOdom,u
- 更新：根据物体的**观测值z**与**地图值zl**计算出每个粒子的权重ww。更新粒子权重的依据是粒子的观测值与地图标志物**相似度的高低**，越高的话该粒子的权重越大
 - 对每个粒子循环操作
 - doMotion()函数，对每个采样粒子输入初始状态x和控制指令u，得到**下一时刻**的x状态，并加入干扰
 - 计算权重，用各个路标距离的**高斯概率相乘**得到总概率
- 重采样：根据粒子的权重w重新采样粒子

2 重要代码 (Tasks)

2.1 观测模型

```
% do Observation model
function [z, xGnd, xOdom, u] = doObservation(xGnd, xOdom, u, landMarks, MAX_RANGE)
    global Qsigma;
    global Rsigma;
```

```

% Gnd Truth and Odometry
xGnd=doMotion(xGnd, u);% Ground Truth 理想状态
u=u+sqrt(Qsigma)*randn(2,1); % add noise randomly
xOdom=doMotion(xOdom, u); % odometry only

%Simulate Observation
z=[];
for iz=1:length(landMarks(:,1))
    dx = xGnd(1)-landMarks(iz,1);
    dy = xGnd(2)-landMarks(iz,2);
    d=sqrt(dx^2+dy^2);
    if d<MAX_RANGE
        z=[z;[d+sqrt(Rsigma)*randn(1,1) landMarks(iz,:)]]; % add observation noise randomly
    end
end
end

```

2.2 运动模型

```

% do Motion Model
function [ x ] = doMotion( x, u)
    global dt;
    Delta = [ dt*cos(x(3)),0];
             [dt*sin(x(3)),0];
             [0,dt]];

    x = x+Delta*u;
end

```

2.3 高斯函数

```

% Gauss function
function g = Gaussian(x,u,sigma)
    g=exp(-((u-x)^2)/(sigma^2)/2.0)/sqrt(2.0*pi*(sigma^2));
end

```

2.4 粒子归一化

```

% Normalization
function pw=Normalization(pw,NP)
    pw=pw/sum(pw);

end

```

2.5 重采样

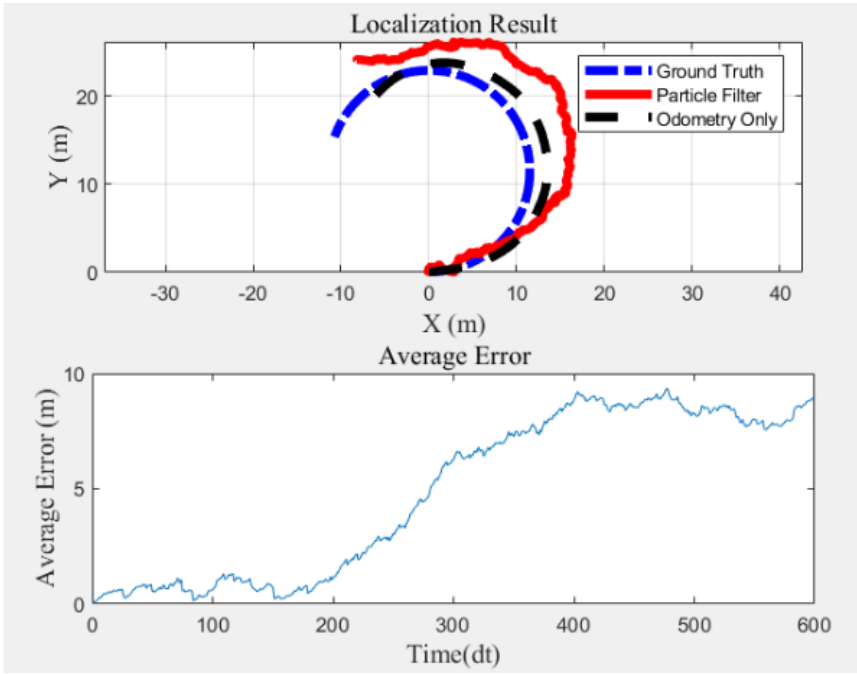
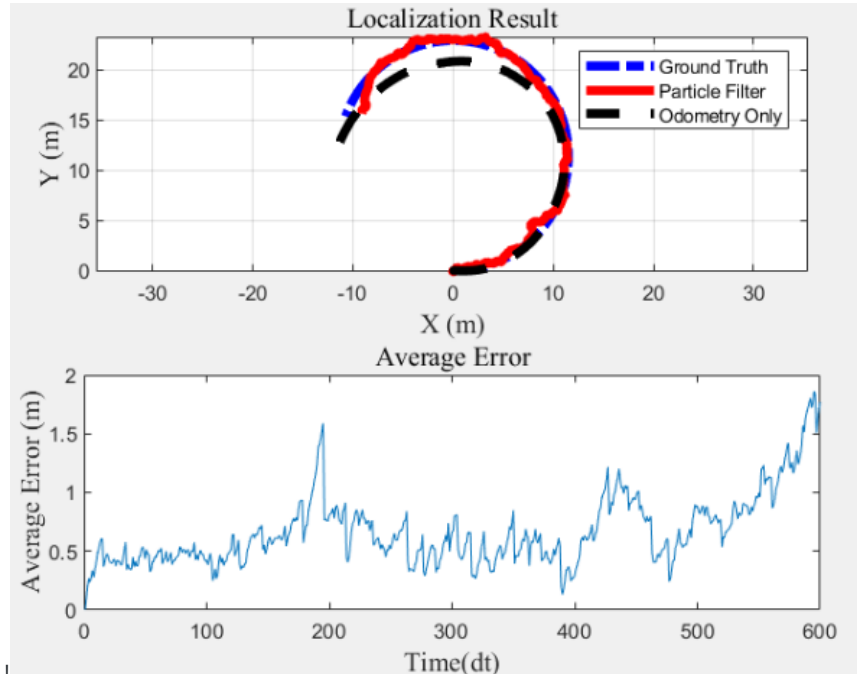
```

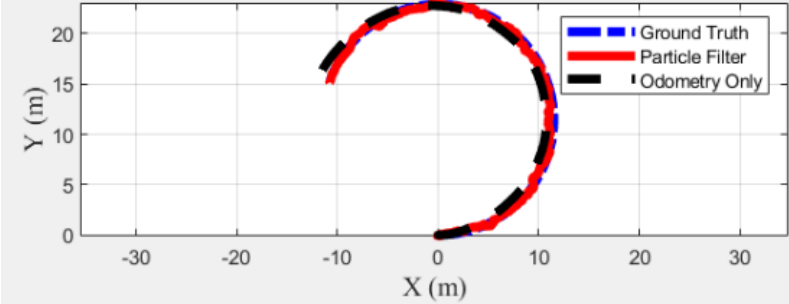
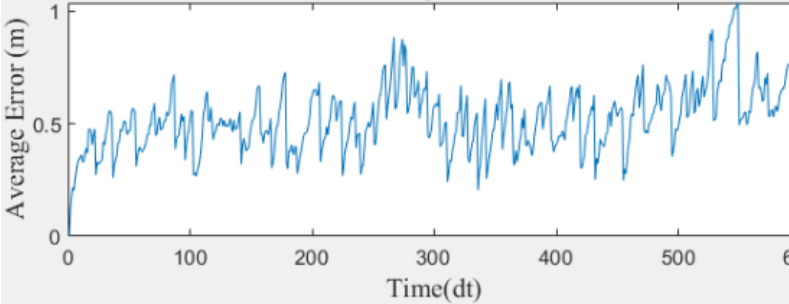
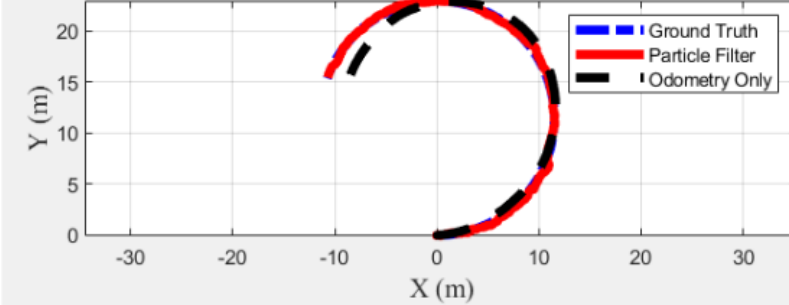
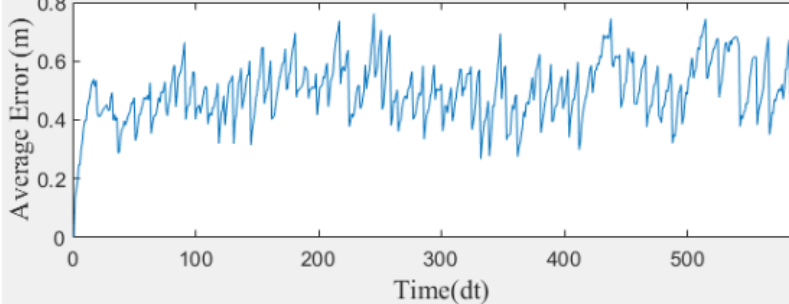
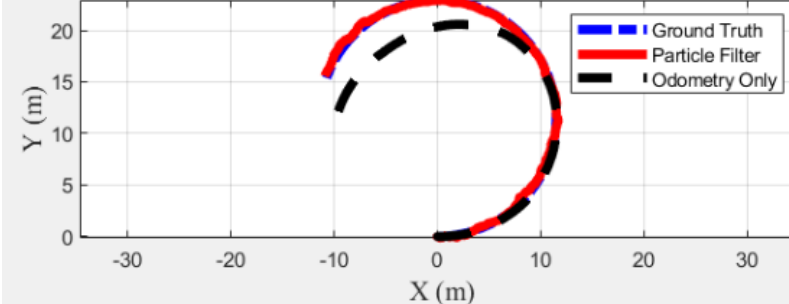
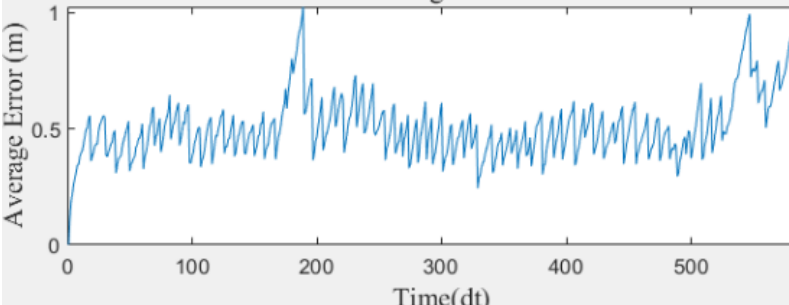
function [px,pw]=ResamplingStep(px,pw,NTh,NP)
    ww=pw(1);
    for iw=2:NP
        ww=[ww,ww(end)+pw(iw)];
    end
    pw1=[]
    pp=[];
    for i=1:NP
        r=rand();
        for j=1:NP
            if ww(j)>r
                pp=[pp,px(:,j)];
                pw1=[pw1,pw(:,j)]
                break
            end
        end
    end
    px=pp;
    pw=pw1;
end

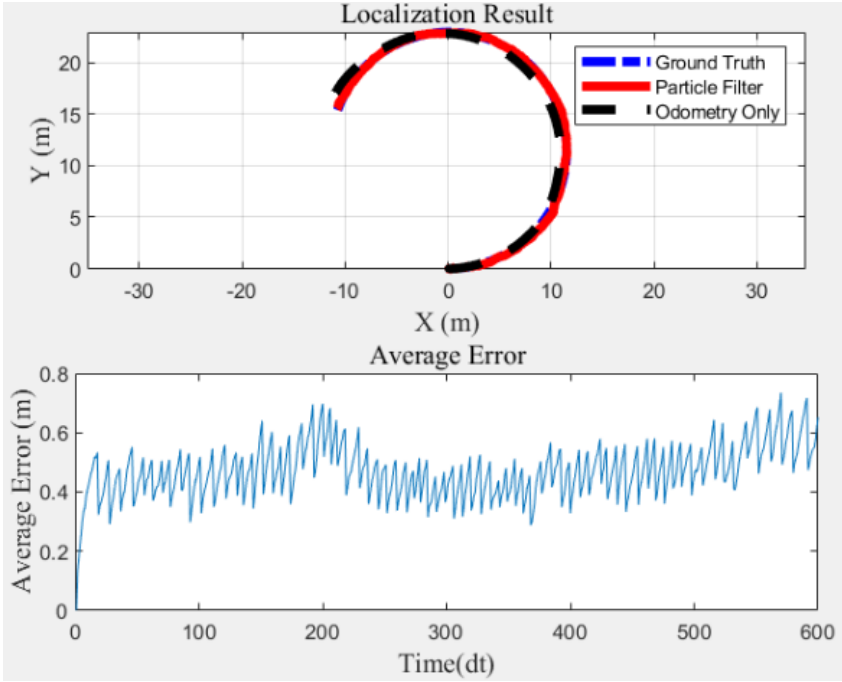
```

3 参数对比实验

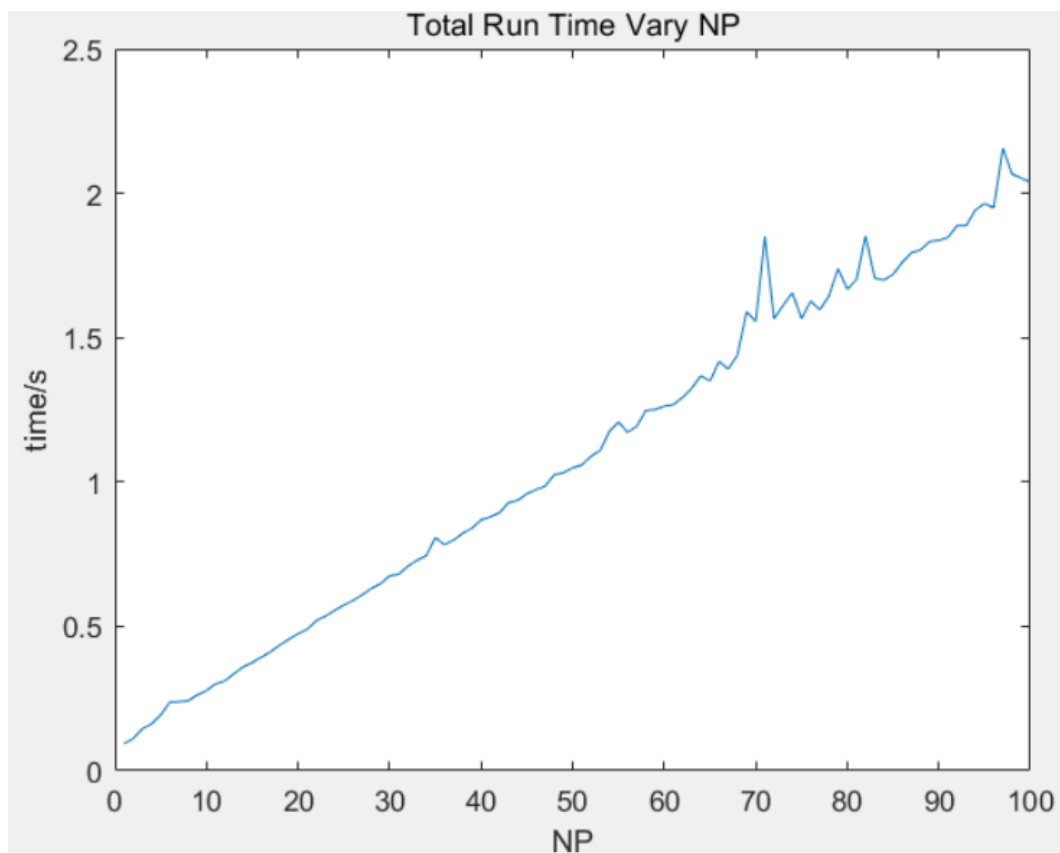
3.1 NP数效果实验

NP	效果	运行时间
3	 <p>The figure for NP=3 consists of two subplots. The top subplot, titled 'Localization Result', shows a 2D plot of Y (m) vs X (m) with axes ranging from -30 to 40. It displays three trajectories: Ground Truth (blue dashed line), Particle Filter (red solid line), and Odometry Only (black dashed line). The trajectories form a circular path. The bottom subplot, titled 'Average Error', shows Average Error (m) vs Time(dt) from 0 to 600. The error starts near 0 and increases steadily to approximately 8 meters by 600 dt.</p>	0.220
5	 <p>The figure for NP=5 also consists of two subplots. The top subplot, titled 'Localization Result', shows a 2D plot of Y (m) vs X (m) with axes ranging from -30 to 30. It displays three trajectories: Ground Truth (blue dashed line), Particle Filter (red solid line), and Odometry Only (black dashed line). The trajectories form a circular path. The bottom subplot, titled 'Average Error', shows Average Error (m) vs Time(dt) from 0 to 600. The error fluctuates significantly, staying mostly between 0.5 and 1.5 meters.</p>	0.286

NP	效果	运行时间
10	<p data-bbox="587 100 802 129">Localization Result</p>  <p data-bbox="619 436 770 465">Average Error</p>  <p>The top plot shows the localization result for NP=10. The x-axis is X (m) from -30 to 30, and the y-axis is Y (m) from 0 to 20. It displays three trajectories: Ground Truth (blue dashed line), Particle Filter (red solid line), and Odometry Only (black dashed line). The trajectories form a semi-circle. The bottom plot shows the average error over time (0 to 600 dt). The y-axis is Average Error (m) from 0 to 1. The error fluctuates between approximately 0.2 and 0.8 meters.</p>	0.387
25	<p data-bbox="587 799 802 828">Localization Result</p>  <p data-bbox="619 1135 770 1164">Average Error</p>  <p>The top plot shows the localization result for NP=25. The x-axis is X (m) from -30 to 30, and the y-axis is Y (m) from 0 to 20. It displays three trajectories: Ground Truth (blue dashed line), Particle Filter (red solid line), and Odometry Only (black dashed line). The trajectories form a semi-circle. The bottom plot shows the average error over time (0 to 600 dt). The y-axis is Average Error (m) from 0 to 0.8. The error fluctuates between approximately 0.2 and 0.6 meters.</p>	0.640
50	<p data-bbox="587 1498 802 1527">Localization Result</p>  <p data-bbox="619 1834 770 1863">Average Error</p>  <p>The top plot shows the localization result for NP=50. The x-axis is X (m) from -30 to 30, and the y-axis is Y (m) from 0 to 20. It displays three trajectories: Ground Truth (blue dashed line), Particle Filter (red solid line), and Odometry Only (black dashed line). The trajectories form a semi-circle. The bottom plot shows the average error over time (0 to 600 dt). The y-axis is Average Error (m) from 0 to 1. The error fluctuates between approximately 0.2 and 0.8 meters.</p>	1.131

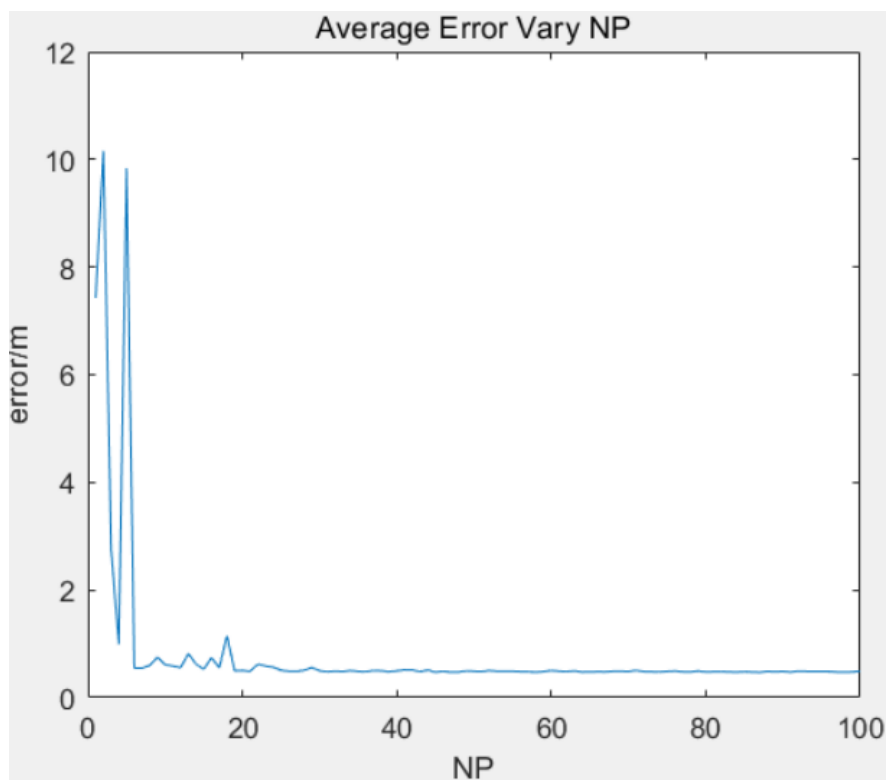
NP	效果	运行时间
100		2.159

3.2 NP数对时间的影响



可见运行时间与NP数成正比关系

3.3 NP数对误差的影响



可见误差趋向于0.5，这主要是由高斯噪声造成的

4 结论与展望

粒子滤波算法是基于概率的定位算法，主要有以下优点：

- 理解简单，一句话就是越相似，存活概率越大
- 计算量不大（计算量与粒子数线性相关）

但也存在以下问题：

- 严重依赖于对初始状态的估计，选择不当可能发散
- 需要有固定的路标

参考文献

https://en.wikipedia.org/wiki/Particle_filter

["Probabilistic Robotics"] [Sebastian Thrun]