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Implementation of Adaptive Kernel Kalman Filter in Stone Soup

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Ministry of Defence

Introduction

- Adaptive Kernel Kalman Filter
- This is the first open source implementation of the AKKF

Introduction: Outline

- Stone Soup: Tracking and State Estimation Framework
- Adaptive Kernel Kalman Filter
- Components
- Examples
- Conclusions

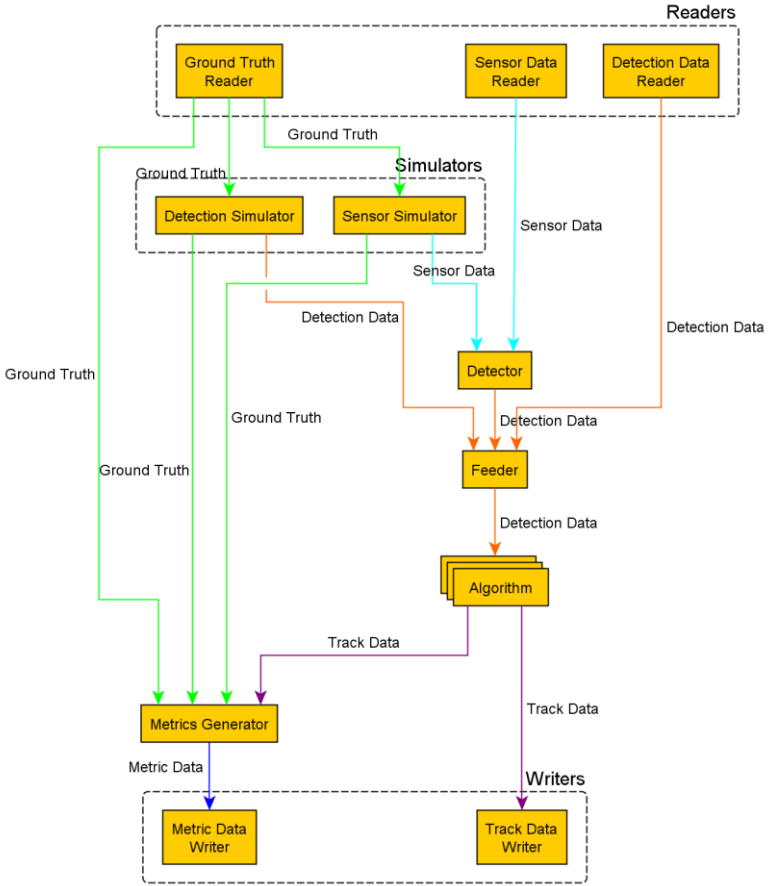
What is Stone Soup?

Algorithms | Data | Sensor models | Simulators | Metrics

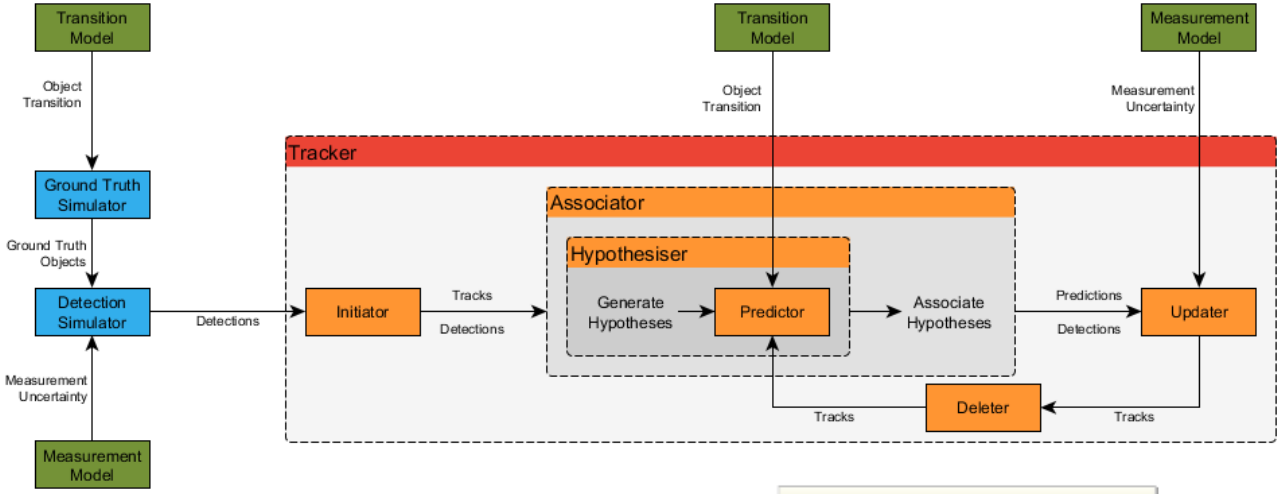
Framework (Open Source)

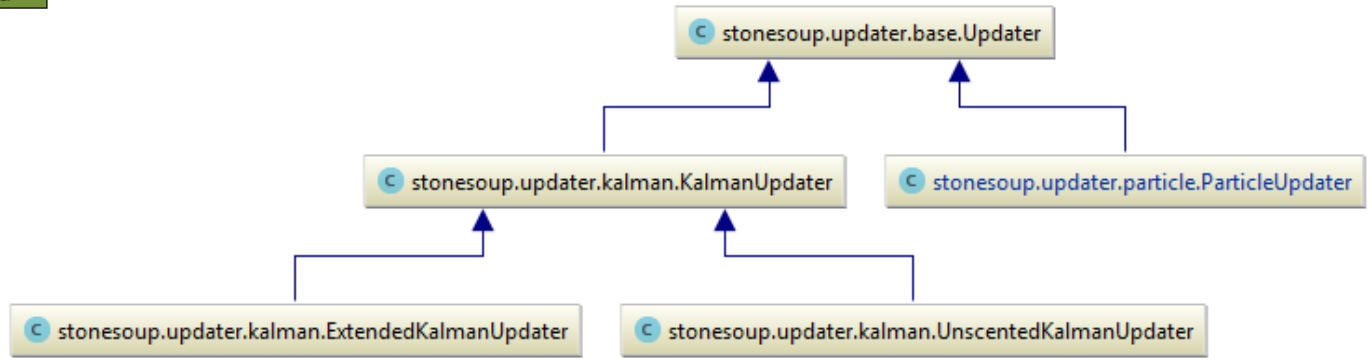
Stone Soup: Components

- Readers
- Simulators
- Feeders
- Algorithmic Components
  - Predictors
  - Updaters
- Metrics
- Writers

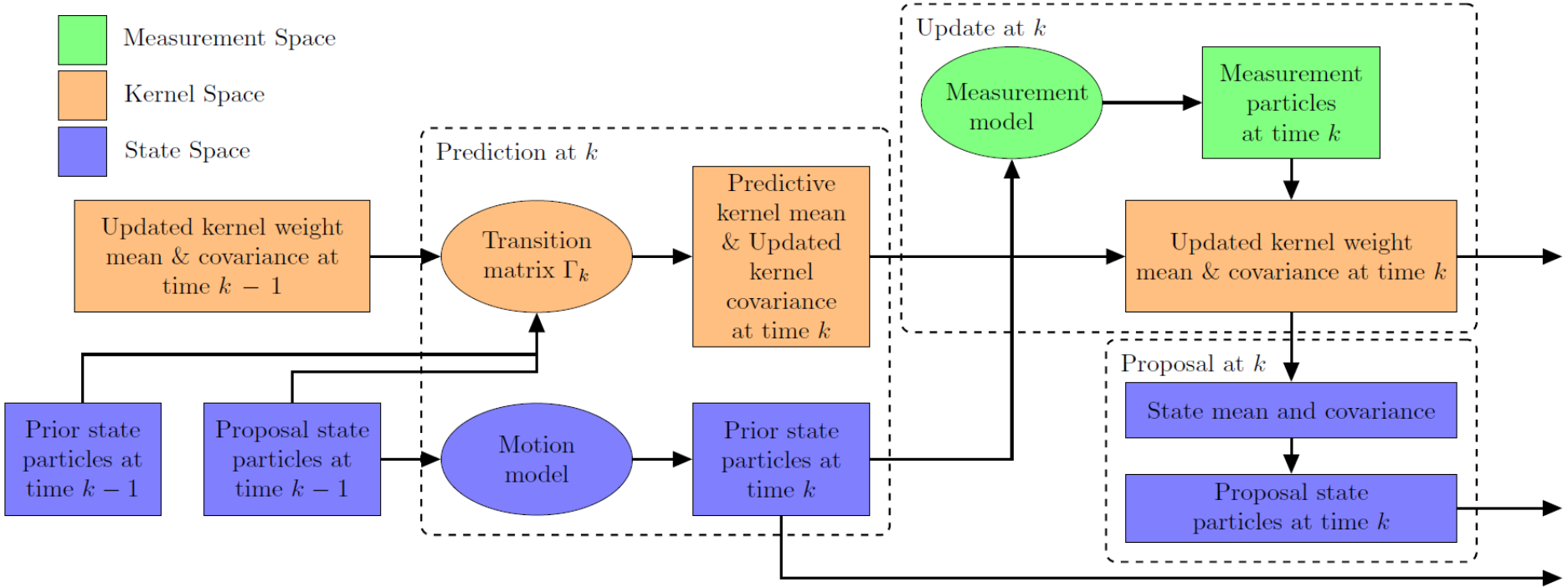


Stone Soup: Algorithmic Components





Adaptive Kernel Kalman Filter (AKKF)



Components

- States
  - `KernelParticleState`
- Kernels
  - `Kernel, QuadraticKernel, QuarticKernel, GaussianKernel`
- Predictors
  - `AdaptiveKernelKalmanPredictor`
- Updaters
  - `AdaptiveKernelKalmanUpdater`

`KernelParticleState`

Inherits the functionality of `ParticleState` and adds the kernel covariance defined by the following equations

$$S_k^- = \Gamma_k S_{k-1}^+ \Gamma_k^T + V_k$$

$$S_k^+ = S_k^- - Q_k G_{yy} S_k^-$$

Components: Kernels

- `Kernel`

$$k(\boldsymbol{x}, \boldsymbol{x}') = \boldsymbol{x}^{\mathrm{T}}\, \boldsymbol{x}'$$

- `QuadraticKernel`

$$k(\boldsymbol{x}, \boldsymbol{x}') = (\alpha\langle \boldsymbol{x}, \boldsymbol{x}' \rangle + \ c)^2$$

- `QuarticKernel`

$$k(\boldsymbol{x}, \boldsymbol{x}') = (\alpha\langle \boldsymbol{x}, \boldsymbol{x}' \rangle + \ c)^4$$

- `GaussianKernel`

$$k(\boldsymbol{x}, \boldsymbol{x}') = \exp\left(\frac{||\boldsymbol{x} - \boldsymbol{x}'||^2}{2\sigma^2}\right)$$

Components: Predictors and Updaters

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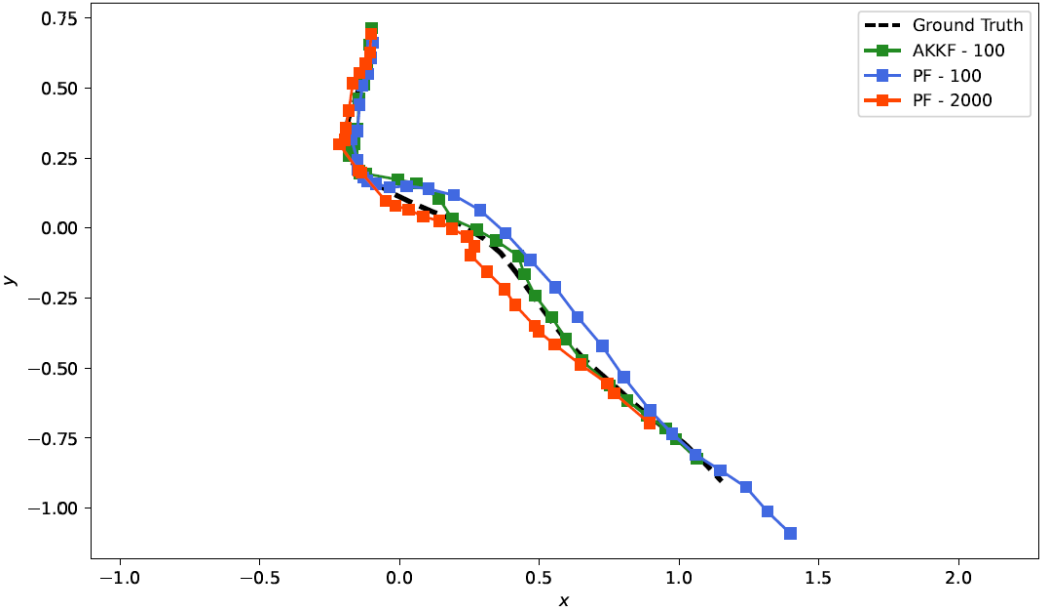
`AdaptiveKernelKalmanPredictor`

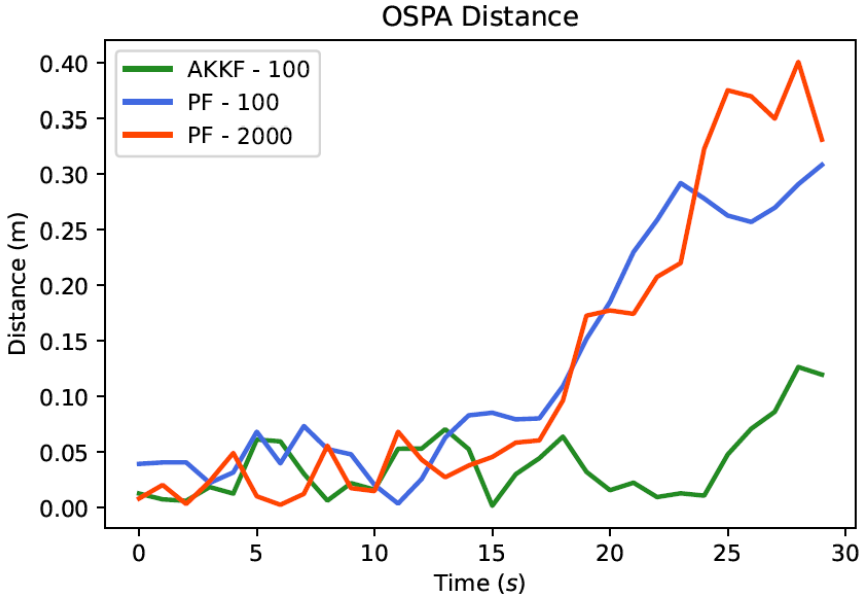
Inherits the functionality of `KalmanPredictor` and adds the functionality of translating between state space and kernel space.

`AdaptiveKernelKalmanUpdater`

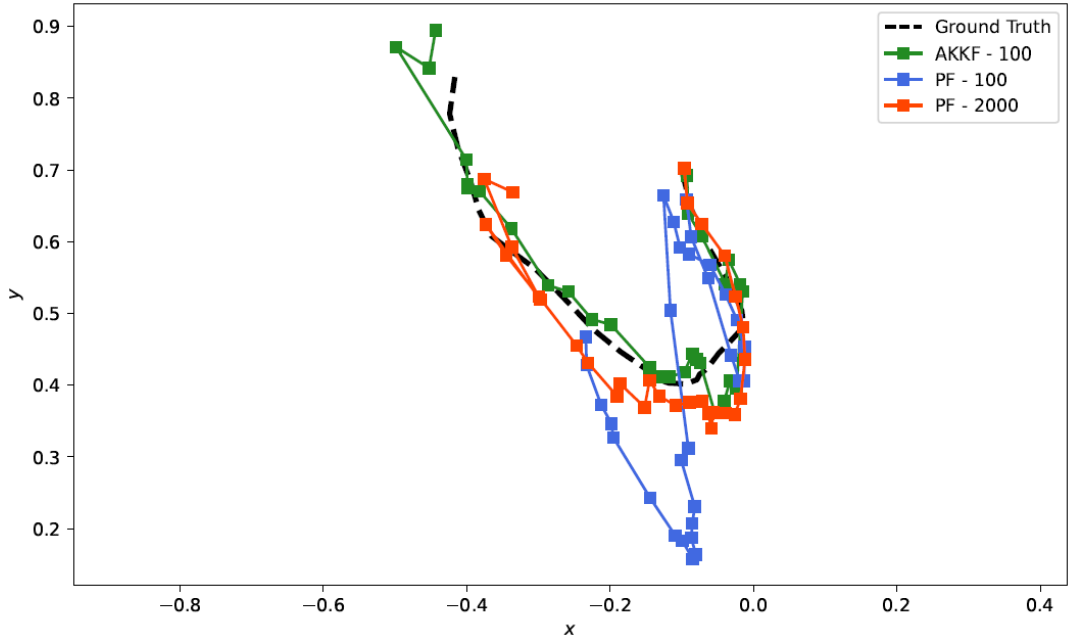
Inherits the functionality of `KalmanUpdater` and adds the functionality of translating between measurement space and kernel space.

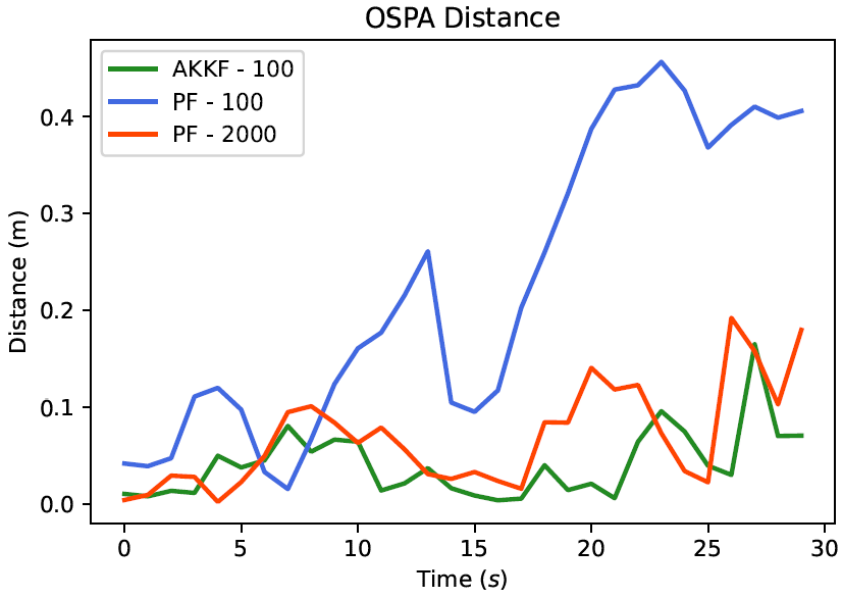
Example 1


Ground Truth
AKKF - 100
PF - 100
PF - 2000
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
y
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
x

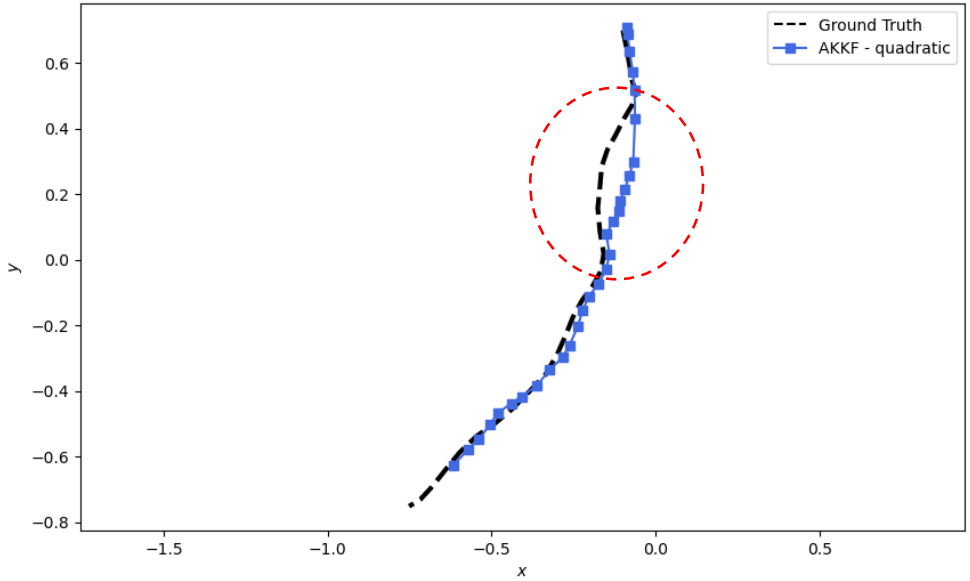

OSPA Distance
AKKF - 100
PF - 100
PF - 2000
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Distance (m)
0
5
10
15
20
25
30
Time (s)

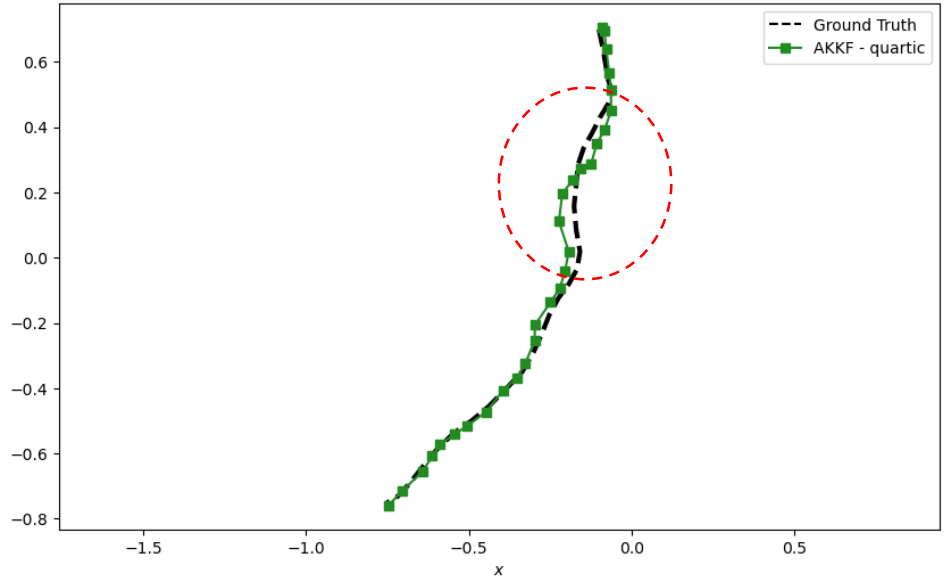
Example 2


Ground Truth
AKKF - 100
PF - 100
PF - 2000
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
y
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
x


OSPA Distance
AKKF - 100
PF - 100
PF - 2000
Distance (m)
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
30
Time (s)

Example 3: Which Kernel?





Conclusions

- AKKF outperforms PF for a given number of particles
- We provided an open source implementation of the AKKF in Stone Soup
- Via inhertance, modularity, and encapsulation, we have demonstrated that Stone Soup is an efficient way of enacting, testing and demonstrating the efficacy of novel tracking algorithms
- We have shown a method of integrating newer algorithms into Stone Soup and a workflow to support other algorithms being implemented in Stone Soup

Get in touch:

https://github.com/dstl/Stone-Soup **StoneSoup@dstl.gov.uk**

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