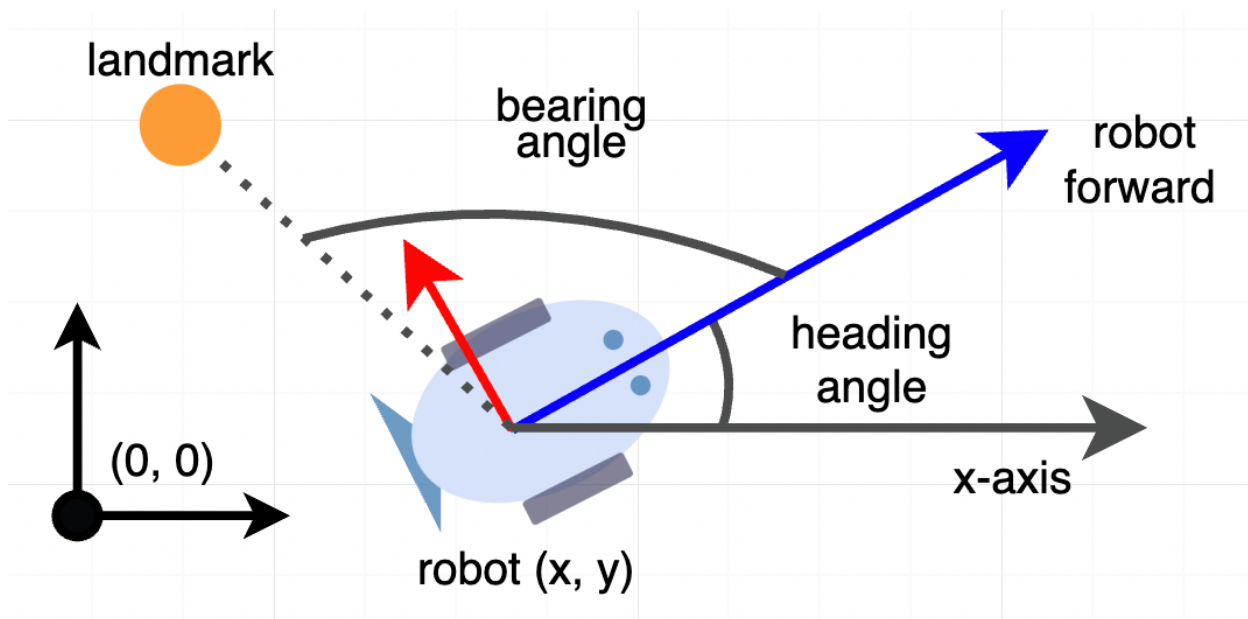


# Symforce Tutorial

Notebook ini adalah tutorial untuk menggunakan Symforce. Tutorial ini akan membahas tentang:

- Instalasi Symforce menggunakan pip via bash command
- contoh sederhana pemodelan dan penyelesaian masalah pengoptimalan dengan SymForce. Dalam contoh ini robot bergerak melalui bidang 2D dan tujuannya adalah untuk memperkirakan posenya pada beberapa langkah waktu dengan pengukuran kebisingan.



```
In [26]: %%bash
          pip install symforc
```

Requirement already satisfied: symforce in /usr/local/python/3.10.4/lib/python3.10/site-packages (0.7.0)  
 Requirement already satisfied: skymarshal==0.7.0 in /usr/local/python/3.10.4/lib/python3.10/site-packages (from symforce) (0.7.0)  
 Requirement already satisfied: jinja2 in /home/codespace/.local/lib/python3.10/site-packages (from symforce) (3.1.2)  
 Requirement already satisfied: numpy in /home/codespace/.local/lib/python3.10/site-packages (from symforce) (1.23.4)  
 Requirement already satisfied: black in /usr/local/python/3.10.4/lib/python3.10/site-packages (from symforce) (22.10.0)  
 Requirement already satisfied: graphviz in /usr/local/python/3.10.4/lib/python3.10/site-packages (from symforce) (0.20.1)  
 Requirement already satisfied: clang-format in /usr/local/python/3.10.4/lib/python3.10/site-packages (from symforce) (15.0.4)  
 Requirement already satisfied: sympy~=1.11.1 in /usr/local/python/3.10.4/lib/python3.10/site-packages (from symforce) (1.11.1)  
 Requirement already satisfied: scipy in /home/codespace/.local/lib/python3.10/site-packages (from symforce) (1.9.3)  
 Requirement already satisfied: symforce-sym==0.7.0 in /usr/local/python/3.10.4/lib/python3.10/site-packages (from symforce) (0.7.0)  
 Requirement already satisfied: argh in /usr/local/python/3.10.4/lib/python3.10/site-packages (from skymarshal==0.7.0->symforce) (0.26.2)  
 Requirement already satisfied: ply in /usr/local/python/3.10.4/lib/python3.10/site-packages (from skymarshal==0.7.0->symforce) (3.11)  
 Requirement already satisfied: six in /home/codespace/.local/lib/python3.10/site-packages (from skymarshal==0.7.0->symforce) (1.16.0)  
 Requirement already satisfied: mpmath>=0.19 in /usr/local/python/3.10.4/lib/python3.10/site-packages (from sympy~=1.11.1->symforce) (1.2.1)  
 Requirement already satisfied: pathspec>=0.9.0 in /usr/local/python/3.10.4/lib/python3.10/site-packages (from black->symforce) (0.10.2)  
 Requirement already satisfied: platformdirs>=2 in /home/codespace/.local/lib/python3.10/site-packages (from black->symforce) (2.5.4)  
 Requirement already satisfied: mypy-extensions>=0.4.3 in /usr/local/python/3.10.4/lib/python3.10/site-packages (from black->symforce) (0.4.3)  
 Requirement already satisfied: click>=8.0.0 in /usr/local/python/3.10.4/lib/python3.10/site-packages (from black->symforce) (8.1.3)  
 Requirement already satisfied: tomli>=1.1.0 in /home/codespace/.local/lib/python3.10/site-packages (from black->symforce) (2.0.1)  
 Requirement already satisfied: MarkupSafe>=2.0 in /home/codespace/.local/lib/python3.10/site-packages (from jinja2->symforce) (2.1.1)

```
In [7]: import symforce.symbolic as sym
import numpy as np
```

```
In [3]: pose = sym.Pose2(
    t=sym.V2.symbolic('t'),
    R=sym.Rot2.symbolic('R')
)
landmark = sym.V2.symbolic('L')
```

```
In [4]: landmark_body = pose.inverse() * landmark
```

```
In [5]: landmark_body.jacobian(pose)

[-L0*R_im + L1*R_re + t0*R_im - t1*R_re, -R_re, -R_im]
[-L0*R_re - L1*R_im + t0*R_re + t1*R_im, R_im, -R_re]
```

```
In [6]: sym.atan2(landmark_body[0], landmark_body[1])
```

```
Out[6]: atan2(L0*R_re + L1*R_im - (t0*R_re + t1*R_im), -L0*R_im + L1*R_re - (-
t0*R_im + t1*R_re))
```

```
In [7]: sym.V3.symbolic('x').norm(epsilon=sym.epsilon())
```

```
Out[7]: sqrt(x0**2 + x1**2 + x2**2)
```

```
In [1]: import symforce
symforce.set_epsilon_to_symbol()
import warnings
warnings.filterwarnings("ignore")
```

## Keterangan

```
In [5]: from symforce.values import Values
```

```
In [3]: num_poses=3
num_landmarks=3
```

```
In [8... initial_values=Values(
    poses=[sym.Pose2.identity()] * num_poses,
    landmarks=[sym.V2(-2, 2), sym.V2(1, -3), sym.V2(5, 2)],
    distances=[1.7, 1.4],
    angles=np.deg2rad([[145, 335, 55], [185, 310, 70], [215, 310, 70]]).tol
    epsilon=sym.numeric_epsilon,
)
```

```
In [9... def bearing_residual(
    pose: sym.Pose2, landmark: sym.V2, angle: sym.Scalar, epsilon: sym.Scal
) -> sym.V1:
    t_body = pose.inverse() * landmark
    predicted_angle = sym.atan2(t_body[1], t_body[0], epsilon=epsilon)
    return sym.V1(sym.wrap_angle(predicted_angle - angle))
```

```
In [10... def odometry_residual(
    pose_a: sym.Pose2, pose_b: sym.Pose2, dist: sym.Scalar, epsilon: sym.S
) -> sym.V1:
    return sym.V1((pose_b.t - pose_a.t).norm(epsilon=epsilon) - dist)
```

```
In [11] from symforce.opt.factor import Factor

factors = []

# Bearing factors
for i in range(num_poses):
    for j in range(num_landmarks):
        factors.append(Factor(
            residual=bearing_residual,
            keys=[f"poses[{i}]", f"landmarks[{j}]", f"angles[{i}][{j}]", "epsilon"]
        ))

# Odometry factors
for i in range(num_poses - 1):
    factors.append(Factor(
        residual=odometry_residual,
        keys=[f"poses[{i}]", f"poses[{i + 1}]", f"distances[{i}]", "epsilon"]
    ))
import warnings
warnings.filterwarnings("ignore")
```

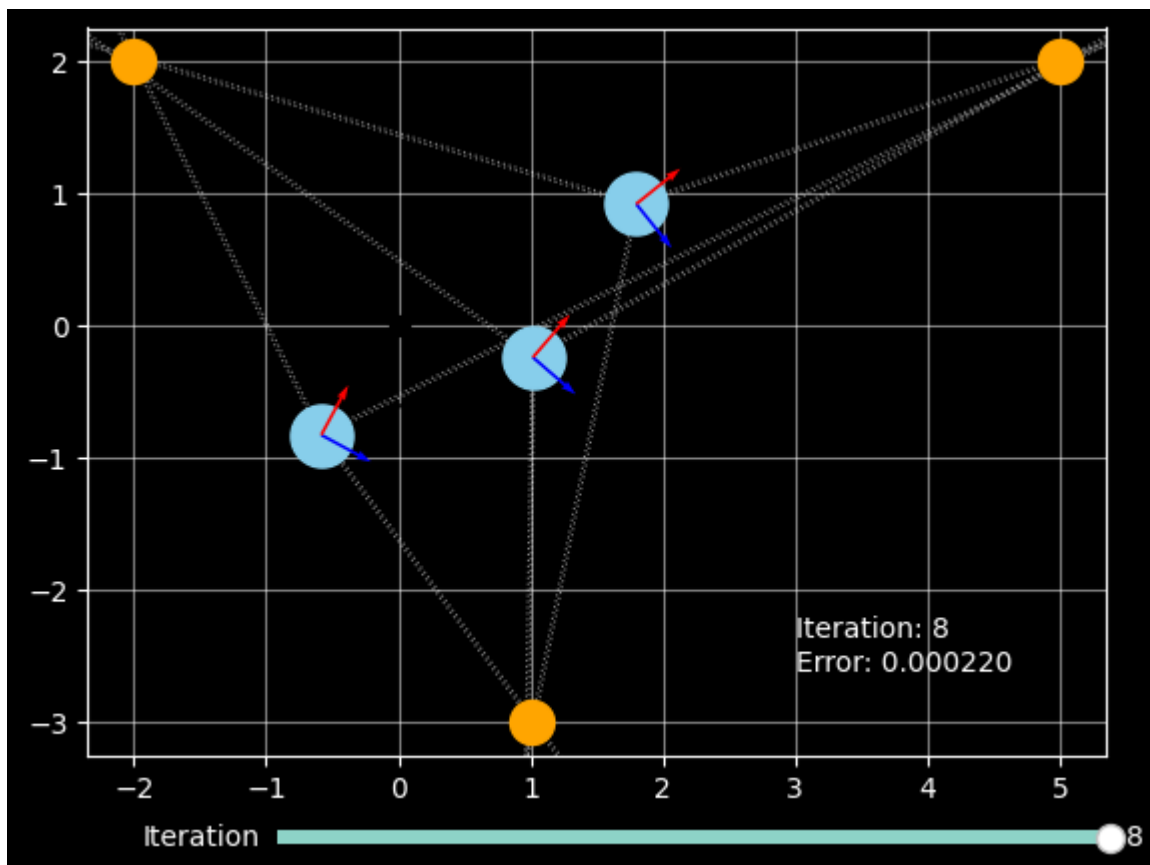
```
In [12] from symforce.opt.optimizer import Optimizer

optimizer = Optimizer(
    factors=factors,
    optimized_keys=[f"poses[{i}]" for i in range(num_poses)],
    # So that we save more information about each iteration, to visualize
    debug_stats=True,
)
```

```
In [13]: result = optimizer.optimize(initial_values)

[2022-12-01 07:26:56.623] [info] LM<sym::Optimize> [iter    0] lambda:
1.000e+00, error prev/linear/new: 5.143/2.872/2.203, rel reduction: 0.57166
[2022-12-01 07:26:56.623] [info] LM<sym::Optimize> [iter    1] lambda:
2.500e-01, error prev/linear/new: 2.203/0.087/0.074, rel reduction: 0.96655
[2022-12-01 07:26:56.624] [info] LM<sym::Optimize> [iter    2] lambda:
6.250e-02, error prev/linear/new: 0.074/0.006/0.006, rel reduction: 0.91401
[2022-12-01 07:26:56.624] [info] LM<sym::Optimize> [iter    3] lambda:
1.562e-02, error prev/linear/new: 0.006/0.001/0.001, rel reduction: 0.90323
[2022-12-01 07:26:56.625] [info] LM<sym::Optimize> [iter    4] lambda:
3.906e-03, error prev/linear/new: 0.001/0.000/0.000, rel reduction: 0.60930
[2022-12-01 07:26:56.626] [info] LM<sym::Optimize> [iter    5] lambda:
9.766e-04, error prev/linear/new: 0.000/0.000/0.000, rel reduction: 0.08144
[2022-12-01 07:26:56.626] [info] LM<sym::Optimize> [iter    6] lambda:
2.441e-04, error prev/linear/new: 0.000/0.000/0.000, rel reduction: 0.00012
[2022-12-01 07:26:56.627] [info] LM<sym::Optimize> [iter    7] lambda:
6.104e-05, error prev/linear/new: 0.000/0.000/0.000, rel reduction: 0.00000
```

```
In [14] from symforce.examples.robot_2d_localization.plotting import plot_solution
plot_solution(optimizer, result)
```



```
In [15]: from symforce.codegen import Codegen, CppConfig

         codegen = Codegen.function(bearing_residual, config=CppConfig())
```

```
In [16]: codegen_linearization = codegen.with_linearization(
         which_args=["pose"]
         )
         import warnings
         warnings.filterwarnings("ignore")
```

```
In [22]: metadata = codegen_linearization.generate_function()
         # with open('coba.cpp', 'w') as f:
         #     f.write(metadata.generated_files[0])
         #     f.close()
         # with open(metadata.generated_files[0]).read() as f:
         #     lines = f.readlines()
         #     lines = [l for l in lines if "ROW" in l]
         #     with open("out.txt", "w") as f1:
         #         f1.writelines(lines)
         print(type(metadata.generated_files[0]))
         code=open(metadata.generated_files[0]).read()
         with open('coba.cpp', 'w') as f:
             f.write(code)
         # print(open(metadata.generated_files[0]).read())
```

```
<class 'pathlib.PosixPath'>
```

Bad pipe message: %s [b'\x06\x19\xccU\xe8\xadG\xee8\xaaM\x8c\x8a\xf3\xe9LHu \x8e!\  
\xe4\x19\xef\xdd\xal]\xb4\xbf\x8f\xf9h@\x16l\_E\xde.\xcc\xc43I%  
\xd6\x84\x99\xfc\x15\xda\x04\x00\x08\x13\x02\x13\x03\x13\x01\x00\xff\x01\x00\x00\  
\x8f\x00\x00\x00\x0e\x00\x0c\x00\x00\t127.0.0.1\x00\x0b\x00\x04\x03\x00\x01\x02\x0  
0\n\x00\x0c\x00', b'\x1d\x00\x17\x00\x1e\x00\x19\x00\x18']  
Bad pipe message: %s  
[b'\x14\xf4\xceH\x07\xd7\xfe\x19\xb0\x98`A8\x85\xfa`B\xf9\x00\x00\xf4\xc00\xc0,\xc  
c0(\xc0\$  
\xc0\x14\xc0\n\x00\xa5\x00\xa3\x00\xa1\x00\x9f\x00k\x00j\x00i\x00h\x009\x008\x00'  
]  
Bad pipe message: %s [b"s]\xa5\x9e=Mv!e\xfe\xee\x19YX\x00k\x91^\x00\x00|  
\xc0,\xc00\x00\xa3\x00\x9f\xcc\xa9\xcc\xa8\xcc\xaa\xc0\xaf\xc0\xad\xc0\xa3\xc0\x9  
f\xc0]\xc0a\xc0W\xc0S\xc0+  
\xc0/\x00\xa2\x00\x9e\xc0\xae\xc0\xac\xc0\xa2\xc0\x9e\xc0\\\xc0`\xc0V\xc0R\xc0\$  
\xc0(\x00k\x00j\xc0#\xc0'\x00g\x00@\xc0\n\x00\x14\x009\x008\x00\t\x00\x13\x003\x0  
02\x00\x9d"]  
Bad pipe message: %s [b'\_\xb1\t;0M\xa6\x8a\xd8@\x83\x83\x9f\xebfTT\xae']  
Bad pipe message: %s [b"\x0bEY[\x82c5\x07\xfa\xde\xe8\x90\xcb0-  
\xe1\xed\x94\x00\x00\x86\xc00\xc0,\xc0(\xc0\$  
\xc0\x14\xc0\n\x00\xa5\x00\xa3\x00\xa1\x00\x9f\x00k\x00j\x00i\x00h\x009\x008\x007  
\x006\xc02\xc0.\xc0\*\xc0&\xc0\x0f\xc0\x05\x00\x9d\x00=\x005\xc0/\xc0+  
\xc0'\xc0#\xc0\x13\xc0\t\x00\xa4\x00\xa2\x00\xa0\x00\x9e\x00g\x00@\xc0?  
\x00>\x003\x002\x001\x000\xc01\xc0-\xc0)\xc0%  
\xc0\x0e\xc0\x04\x00\x9c\x00<\x00/\x00\x9a\x00\x99\x00\x98\x00\x97\x00\x96\x00\x0  
7\xc0\x11\xc0\x07\xc0\x0c\xc0\x02\x00\x05\x00\x04\x00\xff\x02\x01\x00\x00g\x00\x0  
0\x00\x0e\x00\x0c\x00\x00\t127.0.0.1\x00\x0b\x00\x04\x03\x00\x01\x02\x00\n\x00\x1  
c\x00\x1a\x00\x17\x00\x19\x00\x1c\x00\x1b\x00\x18\x00\x1a\x00"]  
Bad pipe message: %s [b'(\xa0\x9e\xec\xdfY8\x83-lR\  
\x96\x12m\xf6"\x1e\x00\x00\xa2\xc0\x14\xc0\n\x009\x008\x007\x006\x00\x88\x00\x87\  
\x00\x86\x00\x85\xc0\x19\x00:\x00\x89\xc0\x0f\xc0\x05\x005\x00\x84\xc0\x13\xc0\t\x  
003\x002\x001\x000\x00\x9a\x00\x99\x00\x98\x00\x97\x00E\x00D\x00C\x00B\xc0\x18\x0  
04\x00\x9b\x00F\xc0\x0e\xc0\x04\x00/\x00\x96\x00A\x00\x07\xc0\x11\xc0\x07\xc0\x16  
\x00\x18\xc0\x0c\xc0\x02\x00\x05\x00\x04\xc0\x12\xc0\x08\x00\x16\x00\x13\x00\x10\  
\x00\r\xc0\x17\x00\x1b\xc0\r\xc0\x03\x00\n\x00\x15\x00\x12\x00\x0f\x00\x0c\x00\x1a\  
\x00\t\x00\x14\x00\x11\x00\x19\x00\x08\x00\x06\x00\x17\x00\x03\xc0\x10\xc0',  
b'\x15\xc0\x0b\xc0\x01']  
Bad pipe message: %s  
[b'\x0e\x00\r\x00\x0b\x00\x0c\x00\t\x00\n\x00#\x00\x00\x00\r\x00 \x00\x1e']  
Bad pipe message: %s  
[b"6\x00\x88\x00\x87\x00\x86\x00\x85\xc0\x19\x00\xa7\x00m\x00:\x00\x89\xc02\xc0.\\  
\xc0\*\xc0&\xc0\x0f\xc0\x05\x00\x9d\x00=\x005\x00\x84\xc0/\xc0+  
\xc0'\xc0#\xc0\x13\xc0\t\x00\xa4\x00"]  
Bad pipe message: %s [b'\x06\x02\x06\x03\x05', b'', b'\x03', b'\x04\x02\x04',  
b'\x01\x03', b'\x03', b'\x02', b'\x03']  
Bad pipe message: %s [b'\xa0\x00\x9e\x00g\x00@\xc0?  
\x00>\x003\x002\x001\x000\x00\x9a\x00\x99\x00\x98\x00\x97\x00E\x00D\x00C\x00B\xc0  
\x18\x00\xa6\x00l\x004\x00\x9b\x00F\xc01\xc0-\xc0)\xc0%  
\xc0\x0e\xc0\x04\x00\x9c\x00<\x00/\x00\x96\x00A\x00\x07\xc0\x11\xc0\x07\xc0\x16\x  
00\x18\xc0\x0c\xc0\x02\x00\x05\x00\x04\xc0\x12\xc0\x08\x00\x16\x00\x13\x00\x10\x0  
0\r\xc0\x17\x00\x1b\xc0\r\xc0\x03\x00\n\x00\x15\x00\x12\x00\x0f\x00\x0c\x00\x1a\  
\x00\t\x00\x14\x00\x11\x00\x19\x00\x08\x00\x06\x00\x17\x00\x03\xc0\x10\xc0\x06\xc0\  
\x15\xc0\x0b\xc0\x01\x00;\x00\x02\x00\x01\x00\xff\x02\x01\x00\x00g\x00\x00\x00']  
Bad pipe message: %s [b'\x0c\x00\x00\t127.0.0.1']

In [2... %%bash

wget https://raw.githubusercontent.com/symforce-org/symforce/main/gen/cpp/s;

```
--2022-12-01 07:49:41-- https://raw.githubusercontent.com/symforce-org/symforce/
main/gen/cpp/sym/pose2.h
Resolving raw.githubusercontent.com (raw.githubusercontent.com)...
185.199.109.133, 185.199.110.133, 185.199.111.133, ...
Connecting to raw.githubusercontent.com (raw.githubusercontent.com)|
185.199.109.133|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 8015 (7.8K) [text/plain]
Saving to: './sym/pose2.h'
```

0K .....

100% 21.2M=0s

2022-12-01 07:49:42 (21.2 MB/s) - './sym/pose2.h' saved [8015/8015]