Consensus-based control for mixing arts and sciences

Tutorial Report

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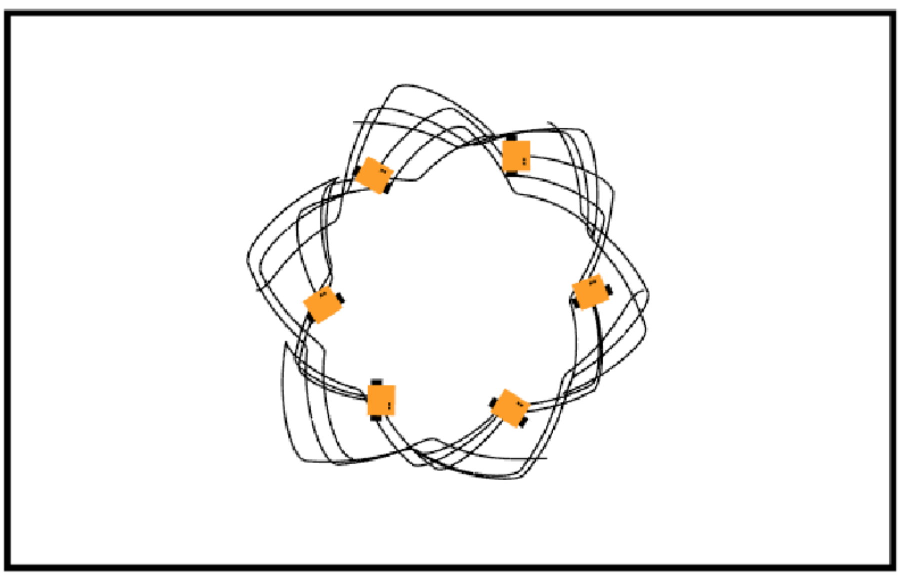
Abstract

In our inaugural tutorial, as students, we embarked on a journey to tackle a complex problem in autonomous navigation and control. Guided by Professor Adouane, we were equipped with essential knowledge and tools to comprehend the intricate system at hand. This initial project intentionally left some parameters unset, serving as a valuable exercise to hone our skills in MATLAB and problem-solving. Our report encapsulates the insights gained and solutions devised during this educational venture.



Keywords Consensus-based Control · Arts and Sciences · Multi-Controller Architecture · Obstacle Avoidance · Limit-Cycles Approach · Kinematic Model · Lyapunov Stability Theorem · PID Controller · Control Synthesis · Mobile Robot · Autonomous Navigation · MATLAB · Cognitive Planning · Long-Term Planning · Trajectory Planning · Path Planning · Mobile Robotics · Robot Control · Control Gains · Navigation Algorithms · Reactive Navigation · Global and Local Path Planning

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1 Consensus-based control for mixing arts and sciences

Algorithm 1 Consensus Algorithm for N Agents

```
procedure ConsensusAlgorithm(N, L, iterations, dxi, x, ξ)
    Initialization:
    for i = 1 to N do
        dxi[i] ← [0, 0]
    end for
    for t = 1 to iterations do
        for i = 1 to N do
            neighbors ← topological_neighbors(L, i)
            for j in neighbors do
                dxi[i] ← dxi[i] + (ξ[j] − ξ[i])
            end for
        end for
        dxu ← si_to_uni_dyn(dxi, x)
        set_velocities(1 : N, dxu)
        step()
    end for
end procedure
```

For each of the MRS topologies (as represented in Figure 1 and 2) we compute the corresponding Laplacian (La and Lb) matrix (while using Adjacency and Degree matrix) :

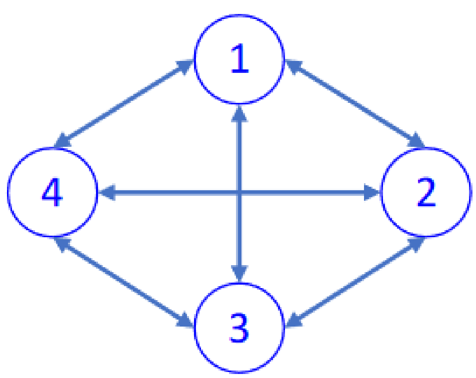


Figure 1: Fully connected Graph

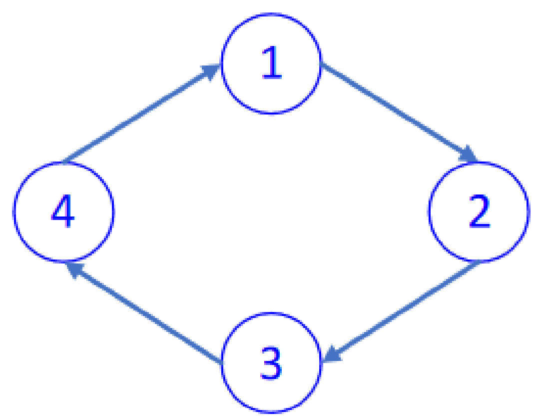


Figure 2: Cyclic Topology

$$A = \begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}$$

$$\Delta = \begin{bmatrix} 3 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

$$L = \Delta - A = \begin{bmatrix} 3 & -1 & -1 & -1 \\ -1 & 3 & -1 & -1 \\ -1 & -1 & 3 & -1 \\ -1 & -1 & -1 & 3 \end{bmatrix}$$

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

$$\Delta = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$L = \Delta - A = \begin{bmatrix} 1 & -1 & 0 & 0 \\ 0 & 1 & -1 & 0 \\ 0 & 0 & 1 & -1 \\ -1 & 0 & 0 & 1 \end{bmatrix}$$

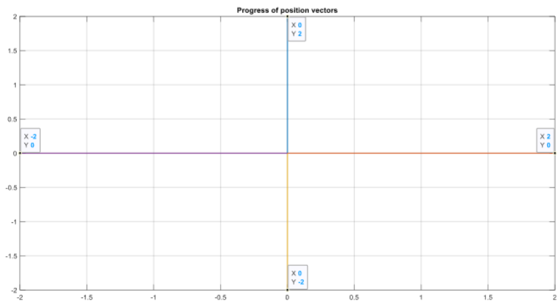


Figure 3: Topology A paths

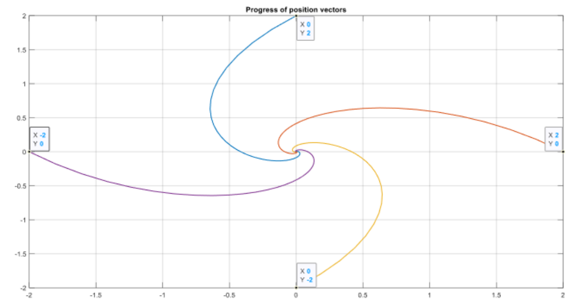


Figure 4: Topology B paths

The last proposed topology can correspond to the following Laplacian Matrix :

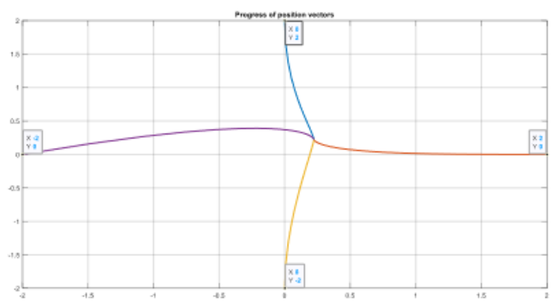


Figure 5: Unknown topology path

Proposed matrix to approach this result :

$$L = \Delta - A = \begin{bmatrix} 3 & -1 & -1 & -1 \\ -1 & 3 & -1 & -1 \\ -1 & -1 & 3 & -1 \\ -3 & -1 & -1 & 5 \end{bmatrix}$$

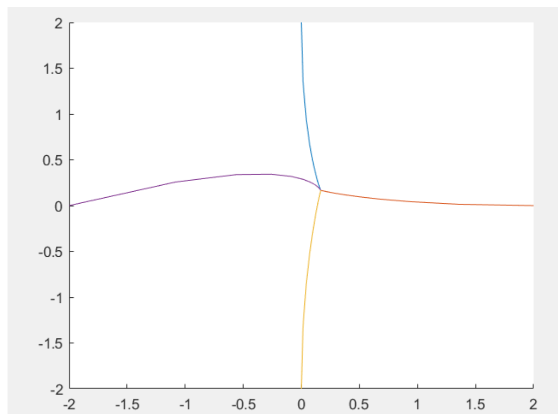


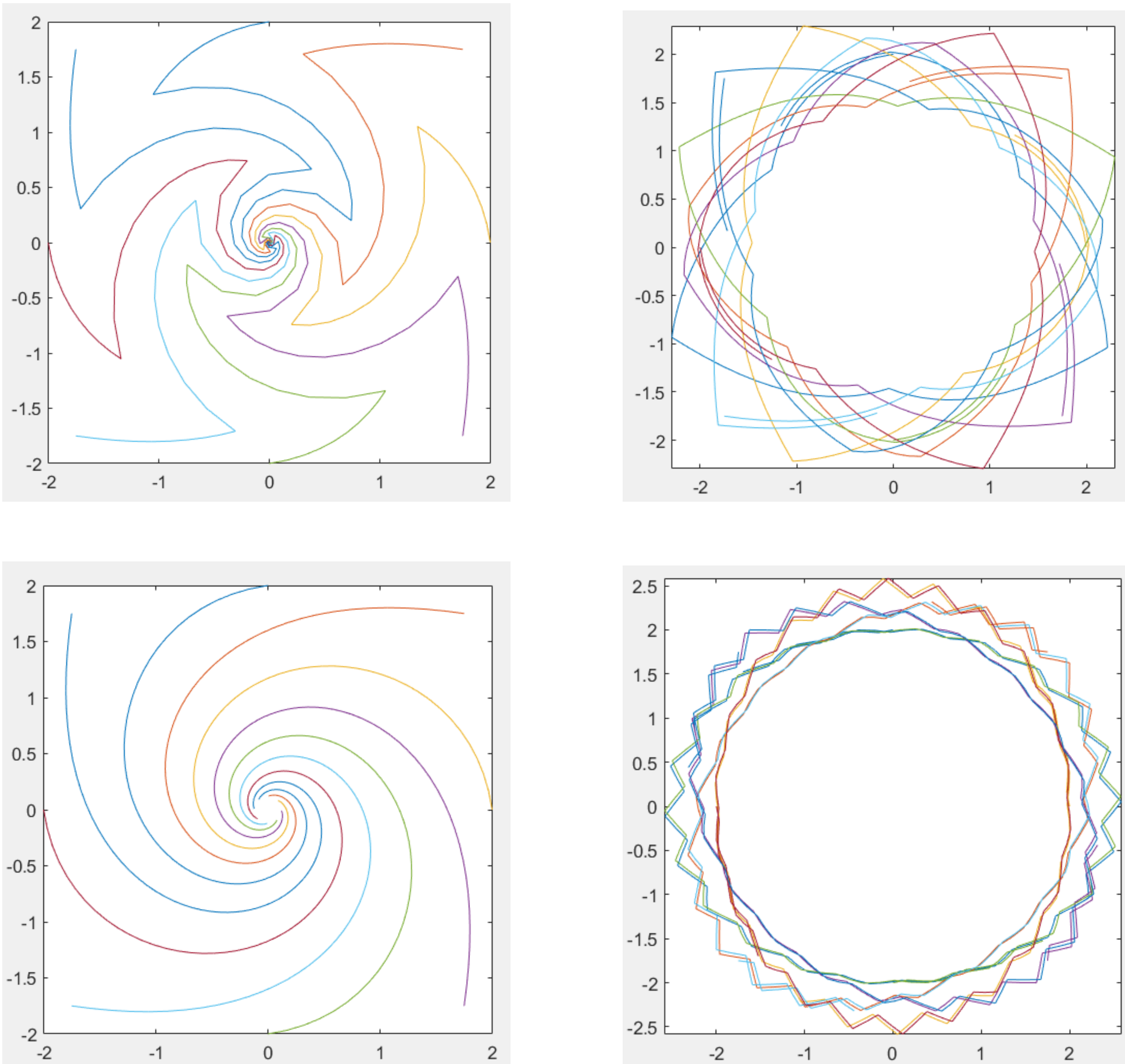
Figure 6: Simulated topology path

2 When science meets art

In this section, it is requested to develop a sequence of appropriate parameters sequence of the used consensus-based control to obtain an artistic motion of the studied MRS which is composed of 8 agents (cf. Figure 6), modelled as single integrator (SI). To obtain the desired shapes, you can use among other things, the appropriate switch between:

- Different MRS graph topologies (giving the communication link between agents), which means the use of different Laplacian matrices to define them.
- Different convergence gains of the used consensus control to obtain different convergence speeds.
- Different convergence behaviors (positive gains) and divergent behaviors (negative gains).
- Different moments of the application time of each of the proposed above possibilities.

Here a few examples obtained by experimentation :



Listing 1: Try changing the topology and gain at different times.

```
nb_changement = 1;
for t = 1:iterations
    if mod(t, 10*nb_changement) == 0
        Lb = Lb'
        g = 0.95 * g;
        [Ae, Be] = c2d(-g*Lb, B, Te);
        nb_changement = nb_changement + 1;
    end
    %% Algorithm
end
```

Listing 2: Changing Topology and Inverting Gain

```
for t = 1:iterations
    if mod(t, 25) == 0
        Lb = Lb';
        g = -g;
        [Ae, Be] = c2d(-g*Lb, B, Te);
    end
    %% Algorithm
end
```

Experiments are endless; however, in reality, it also involves robot holonomy and other parameters.

References

[1] S. Wilson et al. The Robotarium: Globally Impactful Opportunities, Challenges, and Lessons Learned in Remote-Access, Distributed Control of Multirobot Systems In *IEEE Control Systems Magazine, vol. 40, no. 1, pp. 26-44, doi: 10.1109/MCS.2019.2949973"*. Feb. 2020.

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