

UTS sistem pengaturan Formasi dan kolaborasi

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**Blok 1**

1. A square matrix is called non-negative if all its entries are non-negative. It is said to be irreducible if for any pair of indices , there exists a path of positive length from to . In other words, it is impossible to partition the set of indices into two non-empty sets such that there are no connections between them. A square matrix is called primitive if there exists an integer such that all entries of to the power of are positive. Having a positive diagonal element is sufficient but not necessary to decide that is primitive.

Sufficiency: If has a positive diagonal element, say , then we can find an integer such that all entries of to the power of are positive. Specifically, we can choose such that k is greater than or equal to the length of the longest path from any index to the diagonal element . This is known as the Perron-Frobenius theorem. Since is irreducible, there is at least one path from any index to of positive length. Hence, there exists an integer such that all entries of to the power of are positive, and is primitive.

Necessity: Having a positive diagonal element is not necessary for to be primitive. Consider the following example:

is non-negative and irreducible but does not have a positive diagonal element. However, is primitive because , where is the identity matrix, and all entries of are positive. In summary, having a positive diagonal element is sufficient but not necessary to decide that is primitive.

**Blok 2**

1. for the simulation result in Figure 1.

The final position of the group small robot is 19.7143. Yes, they do finally converge to the same at 19.7143. The final position is not averaging from initial position, because the final position should be 10.

My analysis is the 5th agent has minimal communication with other agents so that agent 5 does not get much communication from other agents so that the final position value is not average with the others, it can be exemplified again if the 5th agent is given a lot of communication so that the average value is obtained as follows in Figure 2. The simulations show that the final position of all agent in 13.9811 is approved if all agents have a lot of communication then it will affect the final position later.

Chart

Description automatically generated

Figure 1. Simulation without communication agent 5

Chart

Description automatically generated

Figure 2. Simulation with modification in agent 5

**Blok 3**

1. Now diagraph of and are.

|  |  |
| --- | --- |
| Diagram  Description automatically generated  corresponding matrix | Diagram  Description automatically generated  corresponding matrix |
| Diagram  Description automatically generated  corresponding matrix | |

All the entries of is nonzero and positive, is primitive.

All the entries of is non-zero positive then is primitive.

All the entries of are non-zero positive then is primitive.

are strongly connected and is not strongly connected. Since are strongly connected but is not strongly connected If are irreducible then they are aperiodic, are aperiodic but is not aperiodic.

**Blok 4**

1. (a). The incidence matrix is a graph matrix that associates nodes and edges in a graph. In an undirected graph with nodes and edges, the incidence matrix has dimensions , and its entries are defined as follows: if node is incident to edge (meaning edge is adjacent to node ), if node i is at the opposite end of edge , and otherwise. In directed graphs, the incidence matrix follows a similar structure, with positive and negative values indicating edge direction.

Utilized in formation control for robotics and control systems, the incidence matrix models constraints on agent motion within a formation. It can represent desired distances or angles between adjacent agents, helping derive a control law that guides agents toward the target formation while preventing collisions.

The incidence matrix offers the advantage of directly encoding formation topology, eliminating the need for additional information like node positions or edge weights. This makes it an ideal tool for decentralized control of large-scale formations, where agents have access only to local information about their neighbors.

Furthermore, the incidence matrix possesses several mathematical properties that enhance its utility for formation control. For instance, its null-space represents all feasible agent motions that maintain the formation, while its row-space encodes the motion constraints imposed by the formation. These properties enable the development of control laws that guide agents toward the desired formation while adhering to constraints dictated by the incidence matrix.

(b). The undirected version of the graph is needed because the Laplacian matrix of a directed graph is not guaranteed to be symmetric, and therefore may not have all real eigenvalues or orthogonal eigenvectors, which can lead to difficulties in the design of the control law. On the other hand, the Laplacian matrix of an undirected graph is always symmetric and has all real eigenvalues and orthogonal eigenvectors. Therefore, by using the undirected version of the graph, we ensure that the Laplacian matrix is symmetric and well-behaved.

Another advantage of using the undirected version of the graph is that it captures the symmetry and connectivity of the formation more accurately. In many applications, the desired formation shape is symmetric and has equal distances or angles between neighboring agents. By using the undirected version of the graph, we ensure that the Laplacian matrix captures these properties of the formation and allows us to design a control law that respects them.

In summary, the undirected version of the graph is needed in relative state based formation control to ensure that the Laplacian matrix is symmetric and well-behaved, and to capture the symmetry and connectivity of the desired formation shape.