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Research Article

Independent Resolving Number of Various Graph

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Abstract: This paper investigates the independence number of various graph classes. The independence number of a graph G, denoted by $\alpha(G)$, is the size of the largest subset of vertices in G such that no two vertices in the subset are adjacent. In this paper, we introduce the independent metric dimension (idim) of some graphs such as comb graph, double comet graph, arrow graph and double arrow graph. In particular, we derive the explicit formulas for the double comb graph, spider graph, fire cracker graph and tadpole graph.

***Keywords*:** independent number, double comb graph, tadpole graph

MSC: 05C12, 05C69

1. Introduction

A strong foundation for simulating and evaluating different systems and networks is offered by graph theory, a subfield of discrete mathematics [1]. The idea of an independent set is fundamental to this area. A collection of vertices in a graph that has no edges connecting any two of them is called an independent set. The independence number of a graph G, represented as a $\alpha(G)$, is the size of the greatest independent set in G.

A key graph parameter, the independence number has important theoretical and practical ramifications [2, 3]. From a theoretical perspective, it shapes other graph invariants such as the clique number and chromatic number [4] and offers insights into the structure and characteristics of graphs. From a practical one, the idea of independent sets has uses in a variety of domains, such as:

- Data mining, network architecture, and scheduling are all included in computer science [5].
- Operations Research [6]: Allocating resources and locating facilities.
- Biology [7]: Ecological modeling and protein structure prediction.

Sharp lower limits on a tree's outer-independent double Italian dominance number in terms of diameter, vertex covering number, and tree order were provided by Azvin et al. [8].

Yang et al. [9] determined the exact values of the independent domination numbers of $C_m \square C_n$ with $m \leq n$ when $3 \leq m \leq 8$ and n arbitrary large. In subcubic graphs, Cho et al. [10] demonstrated a more robust claim: The independent dominance number is no more than three times the packing number. The vertex cover hop dominant sets in certain particular graphs, as well as the join and corona of two graphs, were described by Bilar et al. [11]. A graph's J^2-

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independence number is always smaller than or equal to the conventional independence number, as demonstrated by Hassan et al. [12].

An upper bound for a graph's independent domination number in terms of the dominance number and maximum degree was found by Rad et al. [13]. The hypothesis was confirmed for bipartite graphs by Wang et al. [14]. Additionally, graphs with odd cycles and a ratio greater than $\Delta(G)/2$ are shown, along with a number of graph classes reaching the extremal bound. The independent dominance polynomials of a few generalized compound graphs were examined by Jahari et al. [15]. Mazidah et al. [16] examined the route, cycle, friendship, helm, and fan graphs' resolving independent domination numbers. According to Martínez et al. [17], every tree had an equal amount of total co-independent and total dominations. In order to ascertain the precise values of their dominance and independent domination numbers, Vaidya et al. [18] introduced a few additional classes of graphs with equal domination and independent domination numbers.

The total co-independent dominance number of the join, strong, lexicographic, direct, and rooted products of graphs was examined by Martinez et al. [19]. The secure connected dominating metric dimension of several graphs, including the alternative quadrilateral snake, route graph, star tree, and triangular snake graph, was first shown by Hausawi et al. [20]. The precise value of the independent dominance resolving number of graphs, including the middle graph, $P2n\dot{\vee}Nn$, and $P2n\bar{\nabla}Nn$, was calculated by Mohamed et al. [21]. The dominance number of several networks, including limited square of bistar networks, triangular belt networks, and alternative triangular belt networks, was calculated by Almotairi et al. [22]. Li et al. [23] presented three tree operations and demonstrated that they could be used to generate any tree with a secure dominance number and equal independent domination.

The 2-outer-independent, total outer-independent, and double outer-independent domination numbers of graphs were examined by Mojdeh et al. [24], Vaidya et al. [25] examined strong domination numbers of certain graphs and examined associated parameters, and Wardani et al. [26] examined the locating independent domination number of graph operations. For additional results, see [27–30].

In this paper, we introduce the independent metric dimension of some graphs such as comb graph, double comet graph, Arrow graph and double arrow graph. In particular, we derive the explicit formulas for the double comb graph, spider graph, fire cracker graph and tadpole graph.

2. Preliminary notes

Definition 2.1 [31] In graph theory, the cardinality (size) of the biggest independent set in a graph G is its independence number, represented as $\alpha(G)$. A subset of vertices in a network where no two vertices are near (connected by an edge) is called an independent set, often referred to as a stable set.

Definition 2.2 [32] A particular kind of graph known as a double comb graph is created by joining paths (also called "teeth") to two different core paths (sometimes called "backbones"). It is a variant of the typical comb network, in which each vertex of a path (the backbone) has a path (the teeth) connected to it.

Observations 2.2 Computational Complexity [33]: An NP-hard challenge is figuring out a generic graph's precise independence number. Because of this inherent complexity, effective approximation algorithms and heuristics must be developed for real-world applications.

Observations 2.3 Graph Class Specifics [34]: The independence number exhibits distinct behaviors across different graph classes.

3. Applications of independent number

There are several real-world uses for the independence number in a variety of industries. Here are a few noteworthy examples:

3.1 *Computer science*

• Scheduling:

- The independence number may be used to determine the greatest number of jobs that can be carried out continuously without interference by modeling these tasks as vertices in a graph, whose edges reflect conflicts [35].

• Network Design:

- Interference between adjacent devices can happen in wireless networks.

- The independence number assists in determining the maximum number of devices that may transmit concurrently without experiencing appreciable interference by visualizing the network as a graph, with nodes standing in for devices and edges for possible interference connections [36].

• Data Mining:

- The objective of clustering issues is to put related things in one group.

- More efficient data segmentation may be achieved by using the independence number to find groups of items that are maximally different [37].

3.2 *Operations research*

• Facility Location:

- It's important to reduce rivalry or interference between facilities (such as fire stations and warehouses) while locating them.

- The independence number can assist in identifying the best sites for facilities in order to avoid conflicts and maximize coverage [38].

• Resource Allocation:

The independence number can be used to determine the most resources that can be distributed concurrently without causing conflicts in resource allocation issues [39].

3.3 *Biology*

• Protein Structure Prediction:

- Proteins are intricately structured, complicated molecules.

- Stable areas of the protein structure where interactions are reduced can be found by using the independence number to describe protein interactions as a graph [40].

• Ecological Modeling:

- A graph can be used to represent the relationships between species in ecological systems.

- The independence number may be used to determine whether species groupings can live together without facing serious competition [41].

3.4 *Other applications*

• Finding groups of people in a social network that don't communicate much with one another is known as social network analysis [42].

• Code Design: The independence number may be used to examine the spacing between code words in error-correcting codes [43].

4. Main results

Theorem 4.1 idim $(G) = 2$ if G is the comb graph $P\Theta K_l$, where n is the number of vertices and $n \geq 4$.

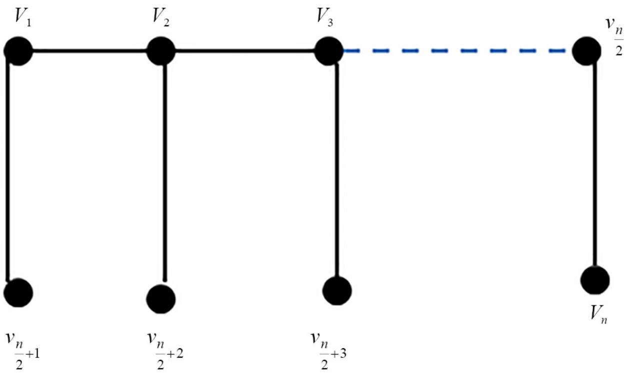

Figure 1. $P\Theta K_l$

Proof. As seen in Figure 1, we label the comb graph $P\Theta K_l$. Let $IR = \left\{v_I,\ v_{\frac{n}{2}}\right\} \in V(G)$. We show that IR is an independent resolving set. Since the representation of any vertex of G with regard to IR are the following:

$$r(v_i,\ IR) = \begin{cases} \left(i-1,\ \dfrac{n}{2}-i\right),\ 1 \leq i \leq \dfrac{n}{2} \\ \\ \left(i-\dfrac{n}{2},\ n-i+1\right),\ \dfrac{n}{2}+1 \leq i \leq n \end{cases}$$

Observe that all these representations are distinct, implying that idim $(G) = 2$.

Corollary 4.2 idim $(G) = \dfrac{n}{3}$ if G is the double comb graph DC_n, where $n \geq 6$.

Corollary 4.3 idim $(G) = 2$ if G is the spider graph $S_{n,\ 3}$, where $n \geq 10$.

Corollary 4.4 idim $(G) = 2$ if G is the fire cracker graph $F_{3,\ n}$, where $n \geq 9$.

Theorem 4.5 idim $(G) = \dfrac{n-1}{2}$ if G is the double comet graph $DC(n,\ 3,\ n)$, where $n \geq 3$.

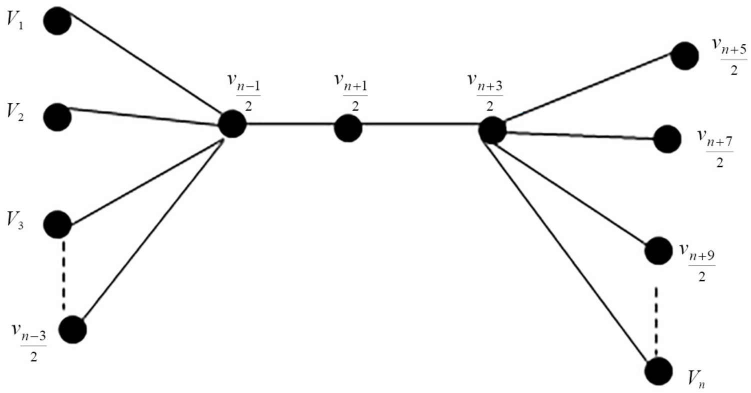

Figure 2. Double comet graph $DC(n,\ 3,\ n)$

Proof. As seen in Figure 2, we label the double comet graph $DC(n,\ 3,\ n)$. We choose a subset $IR = \left\{v_1,\ v_2,\ v_{\frac{n-5}{2}} \ldots\ldots,\ v_{\frac{n-1}{2}},\ v_{\frac{n+1}{2}}\right\}$, and we must demonstrate that idim $(DC(n,\ 3,\ n)) = \dfrac{n-1}{2}$ for $n \geq 3$. we obtained the representations of vertices in graph $(DC(n,\ 3,\ n))$ with respect to IR are :

$$r(v_1 \mid IR) = (0,\ 2,\ 2,\ \ldots\ldots,\ 2,\ 4,\ 4,\ \ldots,\ 4)$$

$$r(v_2 \mid IR) = (2,\ 0,\ 2,\ \ldots,\ 2,\ 2,\ 4,\ \ldots,\ 4)$$

$$r(v_3 \mid IR) = (2,\ 2,\ 0,\ \ldots\ldots,\ 2,\ 4,\ \ldots,\ 4)$$

$$\vdots$$

$$r\left(v_{\frac{n-3}{2}} \middle| \ IR\right) = (2,\ \ldots,\ 2,\ 4,\ \ldots,\ 4)$$

$$r\left(v_{\frac{n-1}{2}} \middle| \ IR\right) = (4,\ \ldots,\ 4,\ 0,\ 2,\ \ldots,\ 2)$$

$$r\left(v_{\frac{n+1}{2}} \middle| \ IR\right) = (4,\ \ldots,\ 4,\ 2,\ 0,\ 2,\ \ldots,\ 2)$$

$$\vdots$$

$$r(v_{n-4} \mid IR) = (4,\ \ldots,\ 4,\ 2,\ \ldots,\ 2,\ 0)$$

$$r(v_{n-3} \mid IR) = (4,\ \ldots,\ 4,\ 2,\ \ldots,\ 2)$$

$$r(v_{n-2} \mid IR) = (1,\ \ldots,\ 1,\ 3,\ \ldots,\ 3)$$

$$r(v_{n-1} \mid IR) = (2,\ \ldots,\ 2)$$

$$r(v_n \mid IR) = (3,\ \ldots,\ 3,\ 1,\ \ldots,\ 1)$$

As can be seen above, the vertices in graph $(DC(n,\ 3,\ n))$ have distinct representations. This does not demonstrate that IR is the lower bound, but it does imply that it is an independent resolving set. The upper bound is therefore $\mathrm{idim}(DC(n,\ 3,\ n)) \leq \dfrac{n-1}{2}$. Currently, we show that $\mathrm{idim}(DC(n,\ 3,\ n)) \geq \dfrac{n-1}{2}$. Assume that the independent resolving set $IR = \left\{v_1,\ v_2,\ v_{\frac{n-5}{2}},\ \ldots..,\ v_{\frac{n-1}{2}},\ v_{\frac{n+1}{2}}\right\}$ has $|IR| = \dfrac{n-1}{2}$. Let $|I_l| < \dfrac{n-1}{2}$, denoting that IR_1 is an additional minimal independent resolving number.

When we choose an ordered set $IR_l \subseteq IR - \{v_i,\ v_j\},\ 1 \leq i,\ j \leq \dfrac{n-1}{2},\ i \neq j$, we may ensure that there are two vertices $v_i,\ v_j \in (DC(n,\ 3,\ n))$ such that $r(v_i \mid IR) = r(v_j \mid IR) = (4,\ \ldots,\ 4,\ 2,\ \ldots,\ 2)$. Contrary to popular belief, IR_1 is not an independent resolving number. Consequently, the bottom constraint is $\mathrm{idim}(DC(n,\ 3,\ n)) \geq \dfrac{n-1}{2}$. We deduce that $\mathrm{idim}(DC(n,\ 3,\ n)) = \dfrac{n-1}{2}$ from the aforementioned proof.

Corollary 4.6 idim $(G) = 2$ if G is the tadpole graph $T_{n,\ m}$, where $n,\ m \geq 3$.
Theorem 4.7 idim $(G) = 2$ if G is the Arrow graph A_n^2, where $n \geq 5$.

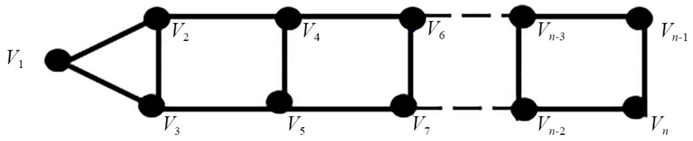

Figure 3. Arrow graph A_n^2

Proof. As seen in Figure 3, we label the the Arrow graph A_n^2. We choose a subset $IR = \left\{v_l,\ v_{\frac{n+1}{2}}\right\}$, and we must demonstrate that idim $\left(A_n^2\right) = 2$ for $n \geq 5$. We obtained the representations of vertices in graph $\left(A_n^2\right)$ with respect to IR are :

$$r\left(v_1 \mid IR\right) = \left(0,\ k+1\right)$$

$$r\left(v_{\frac{n+1}{2}} \middle| IR\right) = \left(i-1,\ \frac{n+1}{2}-1\right)$$

$$r\left(v_{\frac{n+3}{2}} \middle| IR\right) = \left(1,\ \frac{n-1}{2}\right)$$

$$r\left(v_n \mid IR\right) = \left(\frac{n-1}{2},\ 1\right)$$

The representations of all vertices with respect to IR are clearly distinct and this completes the proof.
Theorem 4.8 idim $(G) = 2$ if G is the double arrow graph DA_n^2, where $n \geq 6$.

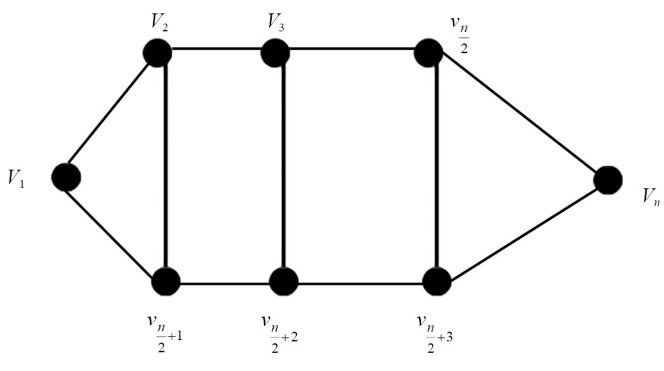

Figure 4. Double arrow graph DA_n^2

Proof. As seen in Figure 4, we label the double arrow graph DA_n^2. We choose a subset $IR = \left\{v_l,\ v_{\frac{n}{2}}\right\}$, and we must demonstrate that idim $\left(DA_n^2\right) = 2$ for $n \geq 6$. we obtained the representations of vertices in graph $\left(DA_n^2\right)$ with respect to IR are :

$$r(v_1 \mid IR) = (0,\ k+1)$$

$$\vdots$$

$$r\left(v_{\frac{n}{2}} \middle| \ IR\right) = \left(i-1,\ \frac{n}{2}-i\right)$$

$$r\left(v_{\frac{n+2}{2}} \middle| \ IR\right) = (i-1,\ 1)$$

$$r\left(v_{\frac{n+4}{2}} \middle| \ IR\right) = \left(\frac{i}{2},\ 1\right)$$

$$\vdots$$

$$r(v_n \mid IR) = (1,\ n-i+1)$$

The representations of all vertices with respect to IR are clearly distinct and this completes the proof.

5. Conclusion

The independent resolving number focuses on how efficiently we can use a subset of vertices to uniquely identify (or resolve) all other vertices in the graph based on their distances. This concept is instrumental in applications like network design, where vertices need to be identified or differentiated based on their connections. In this paper, we introduced the independent metric dimension of some graphs such as comb graph, double comet graph, Arrow graph and double arrow graph. In particular, we derived the explicit formulas for the double comb graph, spider graph, fire cracker graph and tadpole graph.

Conflict of interest

The author declares no competing financial interest.

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