جامعة بابل

كلية العلوم للبنات

قسم علوم الحاسبات

MODELING THE SPREAD OF COVID-19

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التوبة /105

صدق الله العلي العظيم

الاهداء

إلهي لا يطيب الليل إلا بشكرك ولا يطيب النهار إلا بطاعتك ولأتطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك ولا تطيب الجنة إلا بروئيتك الله جل جلاله

إلى من بلغ الرسالة وأدى الأمانة .. ونصح الأمة .. إلى نبي الرحمة ونور العالمين سيدنا محمد صلى الله عليه وسلم

إلى من كلله الله بالهيبة والوقار .. إلى من علمني العطاء بدون انتظار .. إلى من أحمل أسمه بكل افتخار كلماتك نجوم أهتدي بها اليوم وفي الغد وإلى الأبد (ابي رحمة الله)

إلى ملاكي في الحياة .. إلى معنى الحب وإلى معنى الحنان والتفاني .. إلى بسمة الحياة وسر الوجود إلى من كان دعائها سر نجاحي وحنانها بلسم جراحي إلى أغلى الحبايب امي الحبيبة

الى من هم عزوتي وسندي في الحياة الى من شاركتهم حياتي وطفولتي اخوتي الأحبة

الى جميع من شجع خطواتي بفعل او قول لكم مني جزيل شُكري وامتناني.

اقرار المشرف

اشهد ان اعداد هذا المشروع (The Spread of The Covid -19) قد جرى في قسم علوم الحاسوب في كلية العلوم للبنات / جامعة بابل , وهو جزء من متطلبات نيل شهادة البكلوريوس في علوم الحاسبات من قبل الطالبة المرحلة الرابعة (سجى صلاح هويدي)

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التاريخ: 2024 م - 1445 هـ

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Abstract

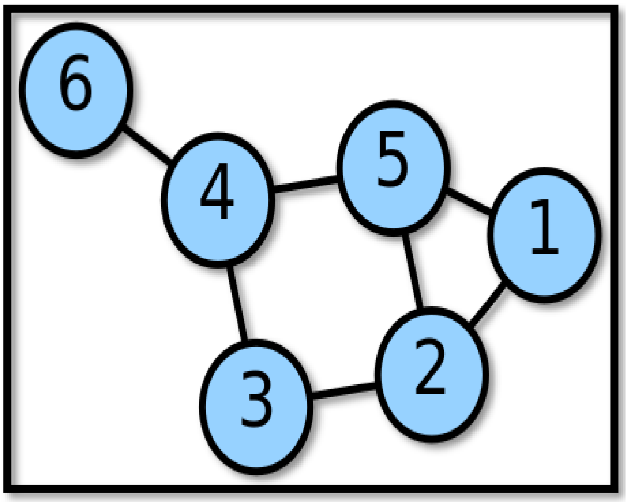
This study investigates the application of graph theory in modeling the spread of COVID-19. Graph theory, a mathematical framework that represents relationships between objects, has been utilized to study various phenomena, including disease transmission. By constructing a network of interactions and connections between individuals, researchers can simulate the propagation of the virus within a population. This allows for the identification of key factors and patterns that influence the spread of the disease, such as contact patterns, network structure, and transmission dynamics. By leveraging graph theory, policymakers and healthcare professionals can better understand the mechanisms driving the spread of COVID-19 and develop more effective strategies for containment and mitigation. This abstract highlights the importance of employing graph theory in studying infectious diseases like COVID-19 and its potential to inform public health interventions.

Chapter One

Graph theory

[1.1] Graph theory

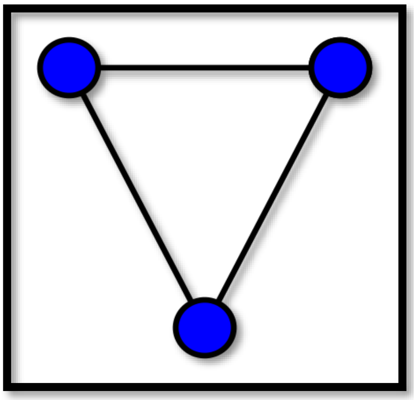
In mathematics, graph theory is the study of *graphs*, which are mathematical structures used to model pairwise relations between objects. A graph in this context is made up of *vertices* (also called *nodes* or *points*) which are connected by *edges* (also called *links* or *lines*). A distinction is made between undirected graphs, where edges link two vertices symmetrically, and directed graphs, where edges link two vertices asymmetrically. Graphs are one of the principal objects of study in discrete mathematics.



[1.1.1] Definitions

Definitions in graph theory vary. The following are some of the more basic ways of defining graphs and related <u>mathematical structures</u>.

Graph



In one restricted but very common sense of the term, a graph is an <u>ordered pair</u> $G = (V, E)$ **comprising:**

- V, **a <u>set</u> of vertices (also called nodes or points);**
- $E \subseteq \{\{x, y\} \mid x, y \in V \text{ and } x \neq y\}$

, a set of edges (also called links or lines), which are unordered pairs of vertices (that is, an edge is associated with two distinct vertices).

To avoid ambiguity, this type of object may be called precisely an undirected simple graph.

A loop is an edge that joins a vertex to itself. Graphs as defined in the two definitions above cannot have loops, because a loop joining a vertex x to itself is the edge (for an undirected simple graph) or is incident on (for an undirected multigraph) which is not in . So to allow loops the definitions must be expanded. For undirected simple graphs, the definition of should be modified to . For undirected multigraphs, the definition of should be modified . To avoid ambiguity, these types of objec\s may be called undirected simple graph permitting loops and undirected multigraph permitting loops (sometimes also undirected pseudograph), respectively.

V and E are usually taken to be finite,

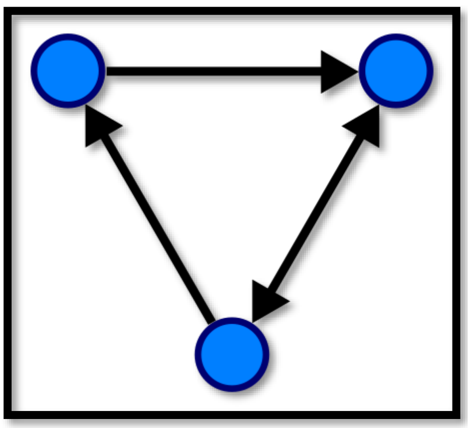
and many of the well-known results are not true (or are rather different) for infinite graphs because many of the arguments fail in the infinite case.

Moreover, V is often assumed to be nonempty, but E is allowed to be the empty set. The order of a graph is $|V|$, its number of vertices. The size of a graph is

$|E|$, its number of edges.

The edges of an undirected simple graph permitting loops G induce a symmetric <u>homogeneous relation</u> $\sim$ on the vertices of that is called the adjacency relation of .

Directed graph



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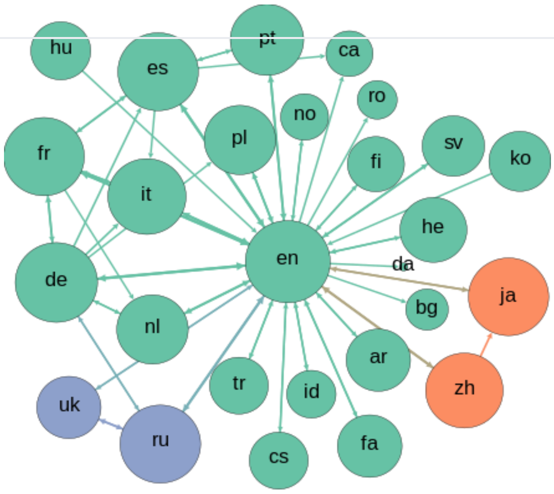
endpoints x and y are said to be *adjacent* to one another, which is denoted $x \sim y$.

Applications



Graphs can be used to model many types of relations and processes in physical, biological,social and information systems. Many practical problems can be represented by graphs.

Computer science

Within computer science, causal and non-causal linked structu

res are graphs that are used to represent networks of communication, data organization, computational devices, the flow of computation, etc. For instance, the link structure of a website can be represented by a

directed graph, in which the vertices represent web pages and directed edges represent links from one page to another. A similar approach can be taken to problems in social media, travel, biology, computer chip design, mapping the progression of neurodegenerative diseases,and many other fields. The development of algorithms to handle graphs is therefore of major interest in computer science. The transformation of graphs is often formalized and represented by graph rewrite systems. Complementary to graph transformation systems focusing on rule-based in-memory manipulation of graphs are graph databases geared towards transaction-safe, persistent storing and querying of graph-structured data.

Linguistics

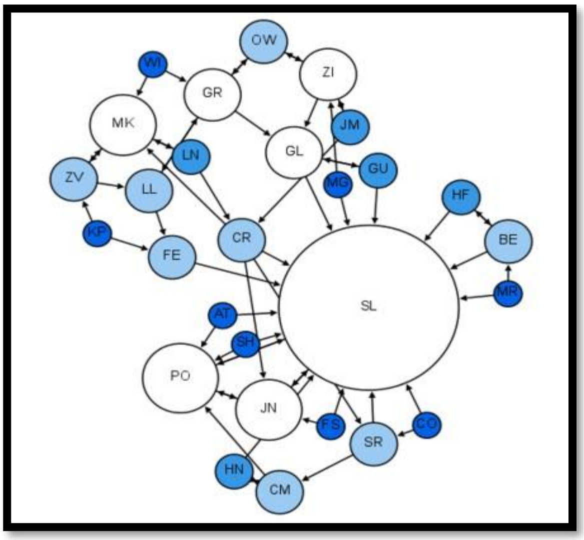
Graph-theoretic methods, in various forms, have proven particularly useful in linguistics, since natural language often lends itself well to discrete structure. Traditionally, syntax and compositional semantics follow tree-based structures, whose expressive power lies in the principle of compositionality, modeled in a hierarchical graph.

Physics and chemistry

Graph theory is also used to study molecules in chemistry and physics. In condensed matter physics, the threedimensional structure of complicated simulated atomic structures can be studied quantitatively by

gathering statistics on graph-theoretic properties related to the topology of the atoms. Also, "the **Feynman graphs and rules of calculation** summarize **quantum field theory** in a form in close contact with the experimental numbers one wants to understand."[13] In chemistry a graph makes a natural model for a molecule, where vertices represent **atoms** and edges **bonds**. This approach is especially used in computer processing of molecular structures, ranging from **chemical editors** to database searching. In **statistical physics**, graphs can represent local connections between interacting parts of a system, as well as the dynamics of a physical process on such system.

Social sciences



Graph theory is also widely used in **sociology** as a way, for example, to **measure actors' prestige** or to explore **rumor spreading**, notably through the use

of social network analysis software. Under the umbrella of social networks are many different types of graphs.[17] Acquaintanceship and friendship graphs describe whether people know each other. Influence graphs model whether certain people can influence the behavior of others. Finally, collaboration graphs model whether two people work together in a particular way, such as acting in a movie together.

Biology

Likewise, graph theory is useful in biology and conservation efforts where a vertex can represent regions where certain species exist (or inhabit) and the edges represent migration paths or movement between the regions. This information is important when looking at breeding patterns or tracking the spread of disease, parasites or how changes to the movement can affect other species.

Graphs are also commonly used in molecular biology and genomics to model and analyse datasets with complex relationships.

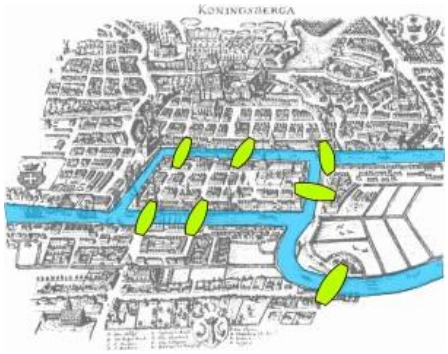
Mathematics

In mathematics, graphs are useful in geometry and certain parts of topology such as knot theory. Algebraic graph theory has close links with group theory. Algebraic graph theory has been applied to many areas including dynamic systems and complexity.

Other topics

A graph structure can be extended by assigning a weight to each edge of the graph. Graphs with weights, or weighted graphs, are used to represent structures in which pairwise connections have some numerical values. For example, if a graph represents a road network, the weights could represent the length of each road. There may be several weights associated with each edge, including distance (as in the previous example), travel time, or monetary cost. Such weighted graphs are commonly used to program GPS's, and travel-planning search engines that compare flight times and costs.

History



Representation

A graph is an abstraction of relationships that emerge in nature; hence, it cannot be coupled to a certain representation. The way it is represented depends on the degree of convenience such representation provides for a certain application.

Visual: Graph drawing

Graphs are usually represented visually by drawing a point or circle for every vertex, and drawing a line between two vertices if they are connected by an edge. If the graph is directed, the direction is indicated by drawing an arrow. If the graph is weighted, the weight is added on the arrow.

A graph drawing should not be confused with the graph itself (the abstract, nonvisual structure) as there are several ways to structure the graph drawing. All that

matters is which vertices are connected to which others by how many edges and not the exact layout. In practice, it is often difficult to decide if two drawings represent the same graph. Depending on the problem domain some layouts may be better suited and easier to understand than others.

Tabular: Graph data structures

The tabular representation lends itself well to computational applications. There are different ways to store graphs in a computer system. The data structure used depends on both the graph structure and the algorithm used for manipulating the graph. Theoretically one can distinguish between list and matrix structures but in concrete applications the best structure is often a combination of both. List structures are often preferred for sparse graphs as they have smaller memory requirements. Matrix structures on the other hand provide faster access for some applications but can consume huge amounts of memory. Implementations of sparse matrix structures that are efficient on modern parallel computer architectures are an object of current investigation.

Chapter Two

Information exchange

Information exchange or information sharing

means that people or other entities pass information from one to another. This could be done electronically or through certain systems.These are terms that can either refer to bidirectional information transfer in telecommunications and computer science or communication seen from a system-theoretic or information-theoretic point of view. As "information," in this context invariably refers to (electronic) data that encodes and represents the information at hand, a broader treatment can be found under data exchange.

Information exchange has a long history in information technology.Traditional information sharing referred to one-to-one exchanges of data between a sender and receiver. Online information sharing gives useful data to businesses for future strategies based on online sharing.These information exchanges are implemented via dozens of open and proprietary protocols, message, and file formats. Electronic data interchange (EDI) is a successful implementation of commercial data exchanges that began in the late 1970s and remains in use today.

Some controversy comes when discussing regulations regarding information exchange.Initiatives to standardize information sharing protocols include extensible markup language (XML), simple object access protocol (SOAP), and web services description language (WSDL).

From the point of view of a computer scientist, the four primary information sharing design patterns are sharing information one-to-one, one-to-many, many-to-many, and

many-to-one. Technologies to meet all four of these design patterns are evolving and include blogs, wikis, really simple syndication, tagging, and chat.

One example of United States government's attempt to implement one of these design patterns (one to one) is the National Information Exchange Model (NIEM).One-to-one exchange models fall short of supporting all of the required design patterns needed to fully implement data exploitation technology.

Advanced information sharing platforms provide controlled vocabularies, data harmonization, data stewardship policies and guidelines, standards for uniform data as they relate to privacy, security, and data quality

The seven golden rules to sharing information

1. **Remember that the General Data Protection Regulation (GDPR), Data Protection Act 2018 and human rights law are not barriers to justified information Sharing, but**

provide a framework to ensure that personal information about living Individuals is shared appropriately.

2. **Be open and honest with the individual (and/or their family where appropriate) From the outset about why, what, how and with whom information will, or could be Shared, and seek their agreement, unless it is unsafe or inappropriate to do so.**

3. **Seek advice from other practitioners, or your information governance lead, if you Are in any doubt about sharing the information concerned, without disclosing the Identity of the individual where possible.**

4. **Where possible, share information with consent, and where possible, respect The wishes of those who do not consent to having their information shared. Under theGDPR and Data Protection Act 2018 you may share information without consent if, in Your judgement, there is a lawful basis to do so, such as where safety may be at risk.You will need to base your judgement on the facts of the case. When you are sharing Or requesting personal information from someone, be clear of the basis upon which you Are doing so. Where you do not have consent, be mindful that an individual might not Expect information to be shared.**

5. **Consider safety and well-being: base your information sharing decisions on Considerations of the safety and well-being of the individual and others who may be Affected by their actions.**

6. **Necessary, proportionate, relevant, adequate, accurate, timely and secure:Ensure that the information you share is necessary for the purpose for which you are Sharing it, is shared only with those individuals who need to have it, is accurate and up -To-date, is shared in a timely fashion, and is shared securely (see principles).**

7. **Keep a record of your decision and the reasons for it – whether it is to share Information or not. If you decide to share, then record what you have shared, with Whom and for what purpose.**

The principles

The principles set out below are intended to help practitioners working with children ,Young people, parents and carers share information between organisations. Practitioners
Should use their judgement when making decisions about what information to share, and Should follow organisation procedures or consult with their manager if in doubt .

The most important consideration is whether sharing information is likely to Support the safeguarding and protection of a child .

Necessary and proportionate

When taking decisions about what information to share, you should consider how much Information you need to release. Not sharing more data than is necessary to be of use is A key element of the GDPR and Data Protection Act 2018, and you should consider the Impact of disclosing information on the information subject and any third parties .Information must be proportionate to the need and level of risk .

Relevant

Only information that is relevant to the purposes should be shared with those who need It. This allows others to do their job effectively and make informed decisions .

Adequate

Information should be adequate for its purpose. Information should be of the right quality To ensure that it can be understood and relied upon.

Accurate

Information should be accurate and up to date and should clearly distinguish between Fact and opinion. If the information is historical then this should be explained.

Timely

Information should be shared in a timely fashion to reduce the risk of missed Opportunities to offer support and protection to a child. Timeliness is key in emergency Situations and it may not be appropriate to seek consent for information sharing if it could Cause delays and therefore place a child or young person at increased risk of harm .Practitioners should ensure that sufficient

information is shared, as well as consider the Urgency with which to share it.

Secure

Wherever possible, information should be shared in an appropriate, secure way. Practitioners must always follow their organisation's policy on security for handling Personal information.

Record

Information sharing decisions should be recorded, whether or not the decision is taken to Share. If the decision is to share, reasons should be cited including what information has Been shared and with whom, in line with organisational procedures. If the decision is not To share, it is good practice to record the reasons for this decision and discuss them with The requester. In line with each organisation's own retention policy, the information Should not be kept any longer than is necessary. In some rare circumstances, this may. Be indefinitely, but if this is the case, there should be a review process scheduled at Regular intervals to ensure data is not retained where it is unnecessary to do so.

When and how to share information

When asked to share information, you should consider the following questions to help You decide if, and when, to share. If the decision is taken to share, you should consider How best to effectively share the information. A flowchart follows the text.

When

Is there a clear and legitimate purpose for sharing information?
• Yes – see next question
• No – do not share
Do you have consent to share?
• Yes – you can share but should consider how
• No – see next question

Does the information enable an individual to be identified?
• Yes – see next question
• No – you can share but should consider how
Have you identified a lawful reason to share information without consent?
• Yes – you can share but should consider how
• No – do not share

How

• Identify how much information to share
• Distinguish fact from opinion
• Ensure that you are giving the right information to the right individual
• Ensure where possible that you are sharing the information securely
• Where possible, be transparent with the individual, informing them that that the. Information has been shared, as long as doing so does not create or increase the Risk of harm to the individual.

All information sharing decisions and reasons must be recorded in line with your Organisation or local procedures. If at any stage you are unsure about how or when to

Chapter three

Results and Discussions

3.1 Introduction

This work implements the spread covid-19the developed system was established using NetLogo 3D version(6.3.0) .the programs work under windows 7 service operating system, laptop computer with processor :Intel core5 CPU.

The figure 3.1 shows that the population size and the number of relations among them. Each node represents the individual or person and the edge or link represents the relation between two persons.

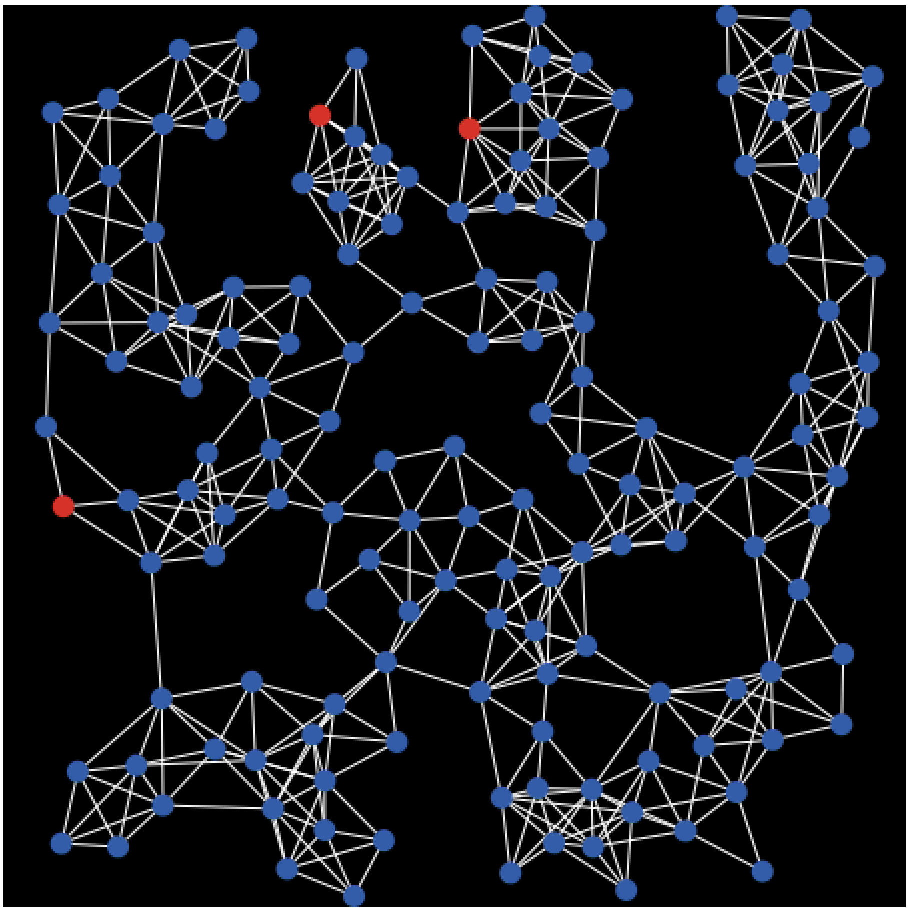


Figure 3.1 the population size 150 person

The size of population are 150 person and the average of relation between people is 6 ,this population contain 3 infected .

In the figure 3.2 it is illustrated the number of infeceted persons and the susceptible persons and resistant persons.

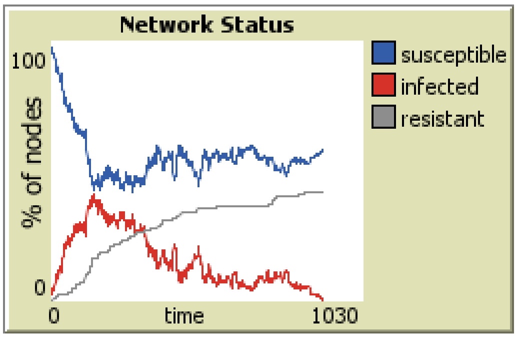


Figure 3.2 the effects of the number of population

As it is shown in the figure 3.2 ,the susceptible person decrease ,the infected persons increase in the beginning and then increase to zero,and the resistant increase in all time . When decrease the average degree of node to 3

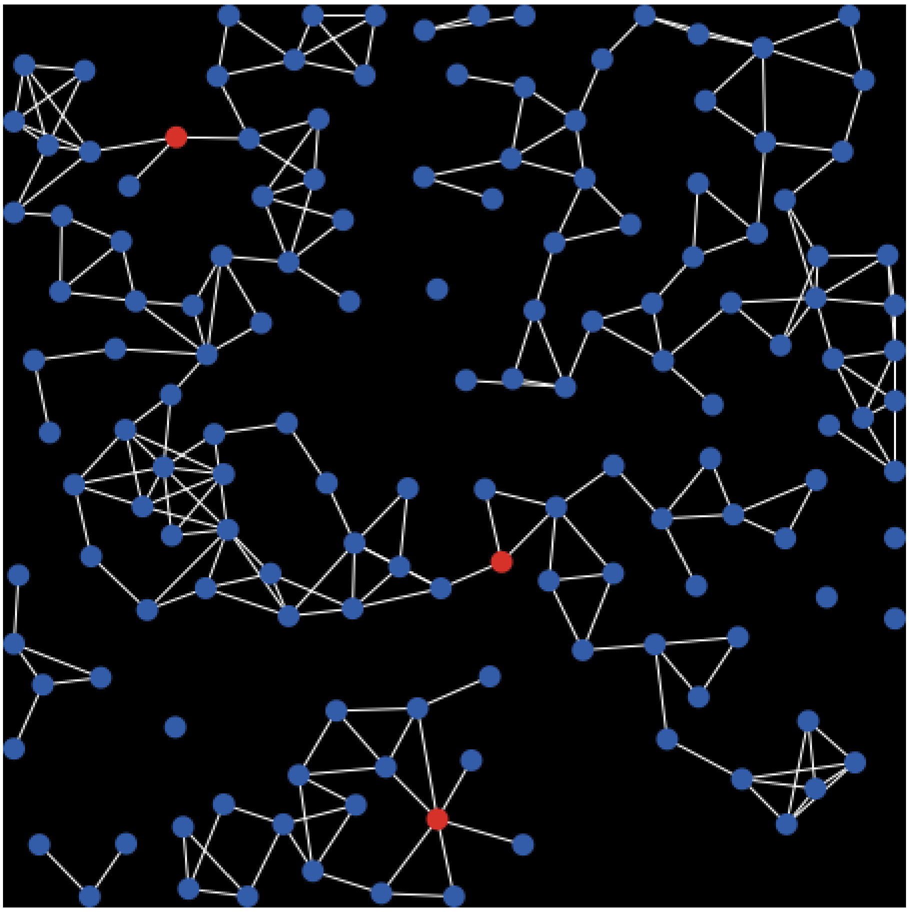


Figure 3.3 the population size 150 person

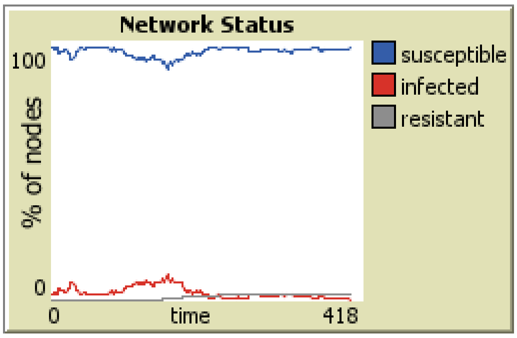


Figure 3.4 the effects of the number of population

As it is shown in the figure 3.4.the susceptible stay on the same average ,the infected increase in the beginning and then decrease to zero,and the resistant increase in all time .

when increase the average degree of node to 10

Figure 3.5 the population size 150 person

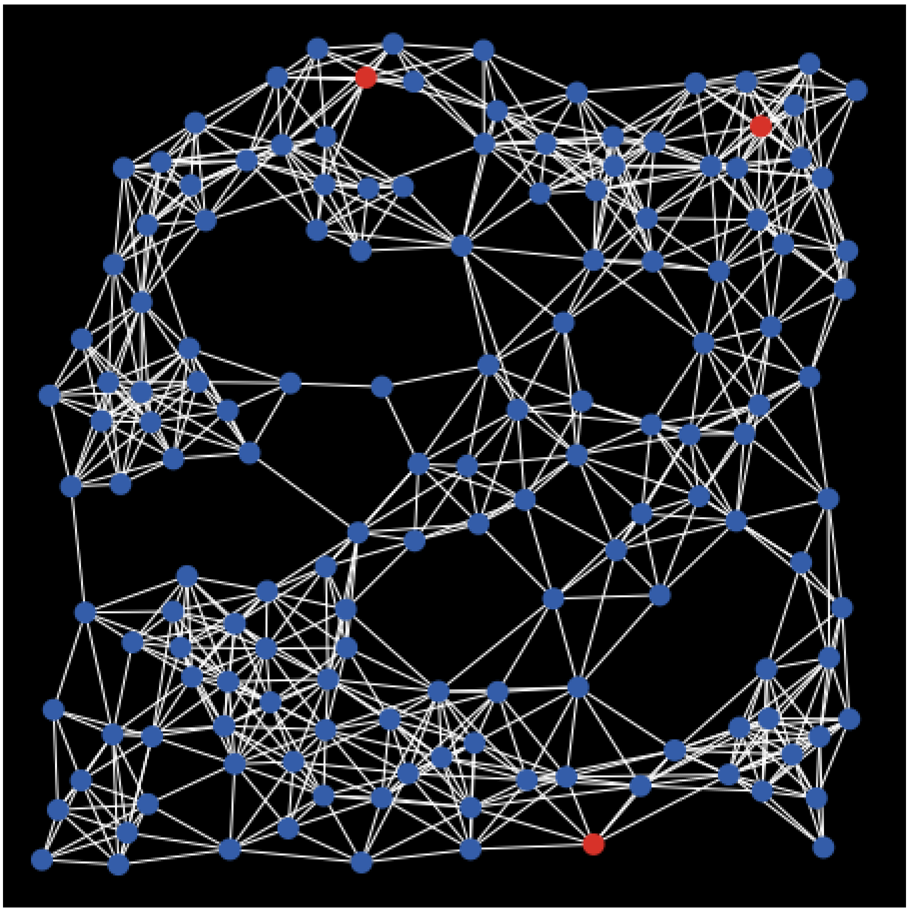
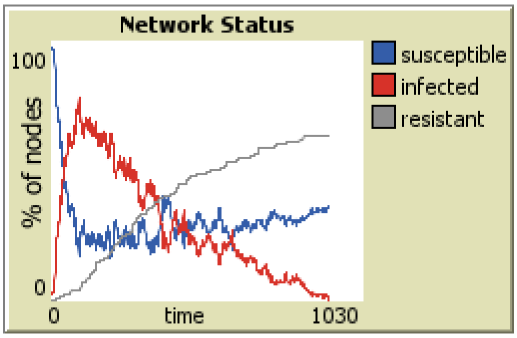


Figure 3.6 the effects of the number of population



As it is shown in the figure 3.6.In this figure ,the susceptible decrease sharply ,the infected increase and then decrease to zero,and the resistant increase in all time .

Conclusion

The utilization of graph theory in modeling the spread of COVID-19 has provided valuable insights and tools for understanding the dynamics of infectious diseases. By constructing transmission graphs and analyzing network properties, we have been able to identify key factors influencing the spread of the virus, such as high-risk clusters and super-spreaders.

Through the application of graph-based models, we have enhanced our ability to simulate and predict the transmission of COVID-19 within different populations. These models have enabled us to explore various scenarios, assess the impact of interventions, and ultimately contribute to more effective public health strategies.

While our research has shown promising results in leveraging graph theory for COVID-19 modeling, we acknowledge the challenges and limitations inherent in such approaches. Further research is needed to refine our models, incorporate additional parameters, and address issues such as data quality and model validation.

Looking ahead, the integration of graph theory with other modeling techniques holds promise for enhancing our understanding of disease spread and informing decision-making in public health emergencies. By continuing to explore the potential of

graph theory in infectious disease modeling, we can better prepare for and respond to future pandemics.

In conclusion, our research underscores the significance of graph theory in advancing our knowledge of COVID-19 transmission dynamics. By leveraging network analysis and graph-based models, we can make informed decisions, implement targeted interventions, and ultimately mitigate the impact of infectious diseases on global health

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