

Graph Application on Charm Interaction in Hollow Knight

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Abstract—Hollow Knight is one of the most successful indie games of all time. It is a metroidvania game which has many ways to upgrade our character and explore areas. One of the ways to upgrade our playable character is through equipping charms. Some charms have unique interactions with other charm(s). Determining whether the charm combinations have unique effects is through graph, a concept learnt from Discrete Mathematics class.

Keywords—Graph, Hollow Knight, Interactions, Charms

I. INTRODUCTION

Hollow Knight is an action-adventure 2D platformer game or specifically a Metroidvania game. Unlike other exploration games, the exploration that one player can do is limited by a number of factors like an ability or more (double jump, dash, etc.), items that unlocks doors, or simply triggering a certain cutscene.

In Hollow Knight, while exploring, players may find hazards such as enemies encountered along the way and harmful environments. These hazards are harmful to the player and might put the player in disadvantage and lose the game.

One of the systems that Hollow Knight use is called Charm. Charms are independent equipment that offer beneficial effects to make exploration and combat easier.



Image 1.1 Hollow Knight
Source: <https://www.hollowknight.com>

Different charms will give different effects, for example Shaman Stone (fifth Charm from left on the first row from image above) increases Spell, a special offensive skill, damage while Fury of the Fallen (first Charm from right on second row from image above) increases basic attack damage when critically wounded.

Some Charms will interact with other charms when equipped together and create unique effects depends on what Charms are equipped.

Graph is a structure that is used to model relations between each object. Objects are represented as vertices in graph and whether or not two vertices are related through edges.

A simple example of graph usage is determining whether or not one person is a sibling to another as shown in graph below.

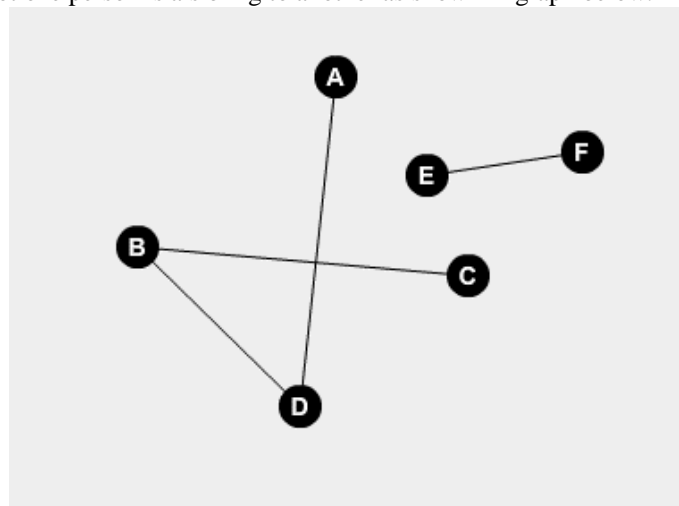


Image 1.2 Graph
Created with [Graph Creator \(nctm.org\)](https://www.nctm.org/graph-creator)

In the graph, A, B, C, and D are siblings because they are connected by edges. E and F are siblings as well, but A and E are not connected so they are not siblings.

II. HOLLOW KNIGHT

Hollow Knight is a 2D action-adventure or Metroidvania game published in February 24th 2017 by Team Cherry. It was initially released on Windows, but soon released on Mac OS and Linux in April 11th 2018, Nintendo Switch on 12th of June, and finally Xbox One and Playstation 4 on 25th of September.

Unlike most games, Hollow Knight is an indie game. Indie is short for independent meaning that Team Cherry is not affiliated with big companies. They work by themselves with no help of other publishers. Hollow Knight is also a product of a Kickstarter campaign, a website for gathering funds.

Hollow Knight is mainly about exploring a huge interconnected world named Hallownest as bug named The Knight while defeating enemies in their way. Players will start off weak, but will grow stronger and more experienced as they

progress. Some features include:



Image 2.1 A Screenshot of Hollow Knight
Source: <https://www.hollowknight.com>

A. Health

Health or Mask as in game called, is Hollow Knight's way to represent The Knight's hit points. The player starts with 5 masks at first and can upgrade up to 9 normally. The Knight will be defeated when the amount of Masks reaches 0.

The Knight can regain lost Masks by expending 1/3 of their Soul using Focus to heal one mask after charging for a short period of time. If The Knight gets hit while charging, no healing is done and will lose mask from the damage instead.

Additionally, there is Lifeblood, a temporary extra mask that can be gained from Charms or slaying a certain enemy.



Image 2.2 The 9 Masks
Source: <https://www.hollowknight.com>

B. Charms and Charm Notch

Charms are type of equipment that can be found or bought from all over Hallownest. They grant The Knight unique abilities that benefits them in their exploration. Some charms can synergize and create unique effects.

To equip a charm, the player must have enough Charm Notch, a type of requirement to equip a Charm. The player starts with 3 Charm Notches and will gain more as they progress.

Player can also Overcharm, an action made to use more Charms than the Charm Notch can handle at the cost of receiving twice as much damage for the period.



Image 2.3 Charms and Charm Notches
Source: Taken from In-game

C. Geo

A currency in Hallownest that takes form of a shell of some bugs. Geo can be obtained from slaying enemies and collecting them by walking over them when they drop Geos.

Player can spend Geo on lots of things but mainly it is to buy Charms or other upgrades in shops.



Image 2.4 Geo
Source: <https://www.hollowknight.com>

D. Nail

Player can damage enemies by using a weapon called Nail. A Nail has an appearance like a sword and is also used like a sword by swinging it. This is the basic way of dealing damage to enemies and can be upgraded if the player has reached the Nailsmith, a place to upgrade The Knight's Nail, and has enough Pale Ore, a material to upgrade the Nail, and Geo.

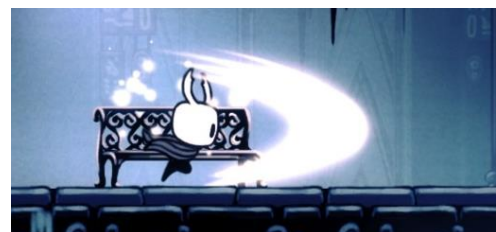


Image 2.5 The Knight Swinging a Nail
Source:

https://hollowknight.fandom.com/wiki/Mark_of_Pride with changes

E. Soul

Hollow Knight also has a Soul system, which is a form of energy that can be obtained by hitting most enemies with Nail. Soul is used to perform Focus or to use Spells. The player can increase the maximum amount of Soul possessed through exploring more.



Image 2.6 Soul Container and its Upgrades
Source: <https://www.hollowknight.com>

F. Spells

Spells are used to damage enemy with more damage and also more situational at the cost of 1/3 of their Soul. There are 3 Spells in the game and additional 3 for their upgrades:

1. Vengeful Spirit – Shade Soul
Shoots a projectile at the way The Knight is facing. It deals damage along its path. The upgrade deals more damage.



Image 2.7 Shade Soul

Source:

https://hollowknight.fandom.com/wiki/Shade_Soul

2. Howling Wraiths – Abyss Shriek
Releases Soul to damage enemies above The Knight. The upgrade increases damage and height of the attack.



Image 2.7 Abyss Shriek

Source:

https://hollowknight.fandom.com/wiki/Abyss_Shriek

3. Desolate Dive – Descending Dark
Performs a stomp on the ground to damage enemies and destroys weak floors as well. The damage is split into two; first is dealt through the diving and second through the impact. The upgrade increases damage and an additional upwards damage.



Image 2.8 Descending Dark

Source:

https://hollowknight.fandom.com/wiki/Descending_Dark

G. Abilities

Throughout the game, the player will find numerous abilities that can aid the player in combat and traverse areas.

The abilities include:

1. Mothwing Cloak
Allows The Knight to dash on ground and in the air once before hitting the ground or wall as well when Mantis Claw has been obtained
2. Mantis Claw
Allows The Knight to slide on walls and jump off them. The process can be repeated multiple times even at the same wall.
3. Crystal Heart
Allows The Knight to dash very fast and far from ground or wall until an obstacle is hit.
4. Monarch Wings
Allows The Knight to jump one more time.
5. Isma's Tears
Allows The Knight to swim through acid lakes. Normally, The Knight will be damaged and respawn.
6. Dreamnail
Allows The Knight to Dreamnail an enemy, acquiring information about the Dreamnailed enemy and gains 1/3 Soul.
7. Dreamgate
Allows The Knight to set the current point The Knight is standing and teleport to it later.

III. GRAPH AND TREE

A. Graph

Graph is a model that consists of vertices and edges. Two vertices can be connected by an edge to show a meaning that the two vertices are related. Vertices don't have to be connected by an edge. When a vertex is not connected to another vertex, it called an isolated vertex.

According to its edge, graph can be divided into two:

1. Simple Graph
A graph that cannot have multiple edges for two nodes or a looping edge that starts and ends with the same vertex.

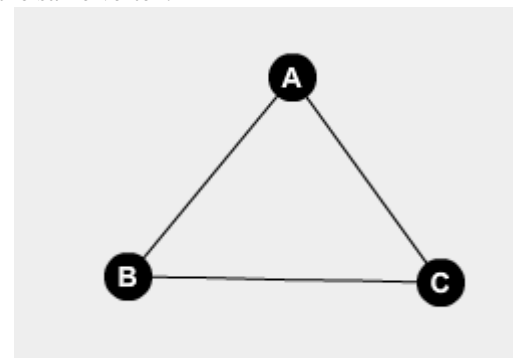


Image 3.1 Simple Graph

Created with [Graph Creator \(nctm.org\)](https://www.graphcreator.net/)

2. Unsimple graph
A graph that have multiple edges for two nodes or looping edges.

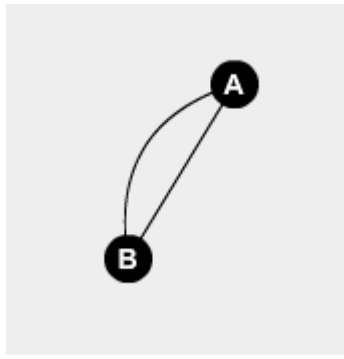


Image 3.1 Unsimple Graph
Created with [Graph Creator \(nctm.org\)](http://nctm.org)

unique and no charm share the exact same effect although some are just a more powerful version of other charms at greater Charm Notch cost.



Image 3.1 All Charms
Source:

<https://hollowknight.fandom.com/wiki/Category:Charms>

Graphs can also be classified according to their edges' direction:

1. Undirected graph

A graph that simply has edges that doesn't have directions. Usually represents relations.

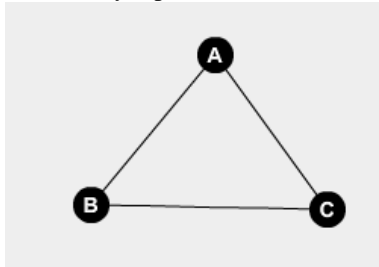


Image 3.1 Undirected Graph
Created with [Graph Creator \(nctm.org\)](http://nctm.org)

There 45 charms in Hollow Knight but only 40 at max can be held at one time due to the fact that some are permanently replaced at some point in the game.

Those counted as unique interaction are those that do not simply amplify an existing effect. For example Fragile Strength, a charm that increases Nail damage, combined with Fury of the Fallen, a Charm that increases damage when critically wounded, will only amplify the damage bonus.

Among all charms these are all that interacts with other charms and grants unique effects:

1. Stalwart Shell – Thorns of Agony

Stalwart Shell is a charm that increases the duration of invincibility when The Knight is hit by an attack and Thorns of Agony lets The Knight grow thorns that hit nearby enemies when hit by an attack but unable to instantly move.

When combined, the moment The Knight unable to attack at thorn state will be reduced but still retain the invincibility bonus.

2. Shaman Stone – Flukeness – Defender's Crest

Shaman Stone increases Spell damage, Flukeness is a charm that transforms a Spell – Shade Soul/Vengeful Spirit – to numerous small creatures that damage enemies, and Defenders Crest creates a constant small cloud around The Knight that damages enemies.

When only Flukeness and Defender's Crest are combined, Shade Soul/Vengeful Spirit will transform into one giant volatile creature that creates a dung cloud that damages overtime when explode. Additionally, when Shaman Stone is equipped, the dung cloud attack frequency is increased.

3. Dashmaster – Sharp Shadow

Dashmaster makes The Knight dash more frequently and allows downward dash and Sharp Shadow makes The Knight able to damage enemies when dashing through them.

When equipped together, Sharp Shadow's damage is increased by 1.5x.

4. Dashmaster – Sprintmaster

Sprintmaster increases The Knight's movement speed by

2. Directed graph

Directed graphs has arrows as their edges. Edges that connects the same vertices may be different depending on the edge's direction. For example A to B and B to A is different.

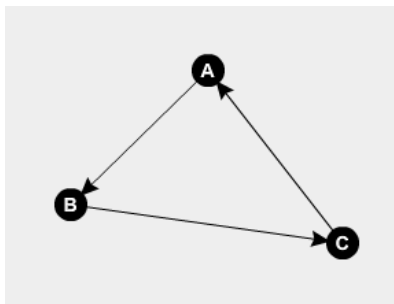


Image 3.1 Directed Graph
Created with [Graph Creator \(nctm.org\)](http://nctm.org)

If all vertices are connected and none are isolated, the graph is called a connected graph. Each vertex can reach another vertex through one or more edges called a path. Additionally, graphs can form a circuit if the path starts and ends with the same vertex. For example, in image 3.1, A-B is a path and A-B-C-A is a circuit.

IV. CHARMS AND THEIR COMBO IN HOLLOW KNIGHT

As Mentioned earlier, charms are accessories that can be equipped to grant the player beneficial effects. All charms are

20%. When Dashmaster is also equipped, Sprintmaster grants 37% bonus speed instead of 20%.

5. Sprintmaster – Weaversong
Weaversong spawns 3 friendly spiders that damages enemies when they hit them. With Sprintmaster equipped, the spiders will jump farther and move faster.
6. Grubsong – Grubberfly’s Elegy
Grubsong will increase The Knight’s Soul when damaged and Grubberfly’s Elegy allows The Knight to launch projectile when doing basic attack when their health is full.

When equipped together, Grubsong’s Soul gain will be increased.

7. Grubsong – Weaversong
When equipped together, the spiders will increase The Knight’s Soul when they hit an enemy.
8. Grubberfly’s Elegy – Fury of the Fallen
Fury of the Fallen increases The Knight’s basic attack damage when critically wounded. When equipped with Grubberfly’s Elegy, the projectile fired from Grubberfly’s Energy bonus also works when critically wounded and increases damage dealt by the projectile.
9. Fury of the Fallen – Glowing Womb – Defender’s Crest
Glowing Womb drains Soul overtime but also spawns an explosive flying little version of The Knight that homes nearby enemies.

When Defender’s Crest is equipped with Glowing Womb, the little Knight’s contact damage will be reduced (unless Fury of the Fallen is active) but in exchange, creates a dung cloud that lingers and deals damage.

10. Baldur Shell – Shape of Unn – Spore Shroom
Baldur Shell makes The Knight immune to damage when healing, Shape of Unn turn The Knight into a slug while healing making The Knight able to move, and Spore Shroom allows The Knight to release gas that damages enemy overtime.

When Baldur Shell and Shape of Unn are equipped together, The Knight will take form of a snail with blue shell and when all three are equipped, The Knight will grow mushrooms on their back as well.

11. Defender’s Crest – Spore Shroom
When both are equipped, Spore Shroom’s damage will be increased and its duration will be increased as well but with less frequency.
12. Quick Focus – Shape of Unn
Quick Focus increases the needed time to heal and when combined with Shape of Unn, the movement speed while healing is increased.
13. Deep Focus – Spore Shroom
Deep Focus increases the amount of health healed but also increases the amount of time to heal. When paired with Spore Shroom, its radius is increased by 35%.
14. Joni’s Blessing – Hiveblood

Joni’s Blessing increases the amount of health The Knight has by 40% by changing it to Lifeblood state, where The Knight cannot normally heal and Hiveblood regenerates the last health lost after 12 seconds of not taking damage.

When paired together, Hiveblood can regenerate Lifeblood health but at twice the duration needed.

15. Dreamshield – Dream Wielder
Dreamshield creates a rotating shield around The Knight that protects against most projectile but will deal basic attack damage then deactivates for a short period of time. Dreamwielder increases Soul gained from Dreamnailing, an action that is used to gain Soul when hitting an enemy with a special Dreamnail.

When used together, Dreamshield will rotate faster and deactivation duration will be reduced.

V. GRAPH REPRESENTATION

The graph that will be used as representation will be a simple undirected graph, meaning that all edges will not have any directions and only one edge is allowed for two of the same vertices. All vertices represent all Charms. The vertices can be connected with other vertex with an edge, in this graph it will represent that both charms interact with each other. Charms that don’t interact with any other charm will have no edge at all, meaning it will be considered an isolated vertex.

According the data in part IV, there are 45 charms but only at maximum of 40 at one time and there are 15 charm interactions which 3 of them involves 3 charms and the rest involves 2 charm.

A vertex will contain 2 types of data, the first being its Charm name, the second is a Boolean where it represents its status whether or not it is currently equipped.

A unique charm interaction effect will occur when a vertex has the status ‘equipped’ and a neighboring vertex also has the status ‘equipped’. For 3 charm interactions, it will search for a circuit. The circuit consists of 3 vertices and edges and if all 3 vertices has the status equipped, then an effect will occur. A rough illustration would be:

- 2-charm interaction: Accepts 2 parameters A and B that is both Charms, then A will search B from its neighboring vertices and if equipped, the effect will happen.
- 3-charm interaction: Accepts 3 parameters A, B and C that is all 3 Charms, then creates a circuit A-B-C-A. While traversing the circuit, it will also check whether they are equipped. If all are equipped, then the effect will happen.

The graph created will have 20 edges; 3 3-charm interactions means 9 edges and 12 2-charm interactions means 12 edges as well.

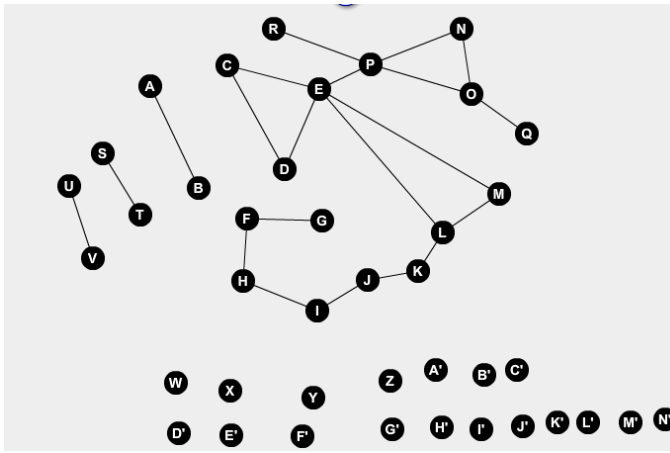


Image 5.1

Created with [Graph Creator \(nctm.org\)](http://nctm.org)

Each vertex corresponds to a certain Charm, that is:

- A: Stalwart Shell
- B: Thorn of Agony
- C: Shaman Stone
- D: Flukenest
- E: Defender's Crest
- F: Dashmaster
- G: Sharp Shadow
- H: Sprintmaster
- I: Weaver Song
- J: Grubsong
- K: Grubberfly's Elegy
- L: Fury of the Fallen
- M: Glowing Womb
- N: Baldur Shell
- O: Shape of Unn
- P: Spore Shroom
- Q: Quick Focus
- R: Deep Focus
- S: Joni's Blessing
- T: Hiveblood
- U: Dreamshield
- V: Dream Wielder

The rest of the Charms from W to N' do not have any interaction with other Charms, therefore they are isolated.

As an example, for 2-charm interaction, let's take Dashmaster – Sprintmaster or G-H. When only both of them are equipped, first F will look at its neighboring vertices, which is G and H. Since G is not equipped, it will not do anything, but H is equipped, so G-H's effect will occur, that is the increased bonus movement speed.

For 3-charm interaction, let's take Defender's Crest – Shaman Stone – Flukenest or E-C-D. Since this is a 3-charm interaction, it will create the circuit E-C-D-E, go through them, and check whether all 3 are equipped or not. If yes, then the effect will occur.

But E-C-D also has a partial effect when only E and D are equipped. This can be solved by counting them as 2-charm interaction and using the same algorithm as the G-H interaction.

VI. CONCLUSION

In conclusion, graph is applicable in many aspects in life. One

of them is in game programming, especially when considering how to apply a feature as an algorithm. If the feature involves relation of one thing and another, it is best to implement them as a graph.

Graph is a theory of representing information as relations where each object is treated as a vertex and their relation is represented as an edge that connects two vertices.

With this understanding of graph application, it is expected that in the future implementing features as graph is more understandable and will be useful.

VII. ACKNOWLEDGMENT

I want to thank God for allowing me to finish this paper assignment on time. I also thank my parents for supporting me always in my high and lows. I thank Mrs. Fariska Zakhralatifa Ruskanda for educating me through college lessons and exercises as well. Hopefully this paper is useful for those needs it and pardon for all mistakes made in this paper.

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PERNYATAAN

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

Bandung, 8 Desember 2020

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