DESIGN AND DESIGN IDEAS FOR HIGHLY INTERACTIVE DIGITAL SPACES

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A hundred ways to cook an egg

Scrambled Eggs, Egg on Toast or Boiled Eggs, all these dishes are more often than not made in a kitchen with an egg. Yet they differ in taste and texture. Made by a bunch of differing appliances and cooking ware as well as larger appliances like a stove or oven. All organized in different drawers and cupboards combined with multiple spices, hopefully to be easily accessible to the cook. So, that said cook has the most ease to get access to those appliances while also being able to check on the food. This of course requires that all the necessary utensils and machinery are well sorted to the understanding of the cook as to be easily found as well as take up the space in the room efficiently, so the cook can easily move between and access the necessary appliances for cooking.

In the game Cooking Simulator the player can take over the role of the chef in a restaurant. Having access to all kinds of cooking utensils and grills, fryers as well as ovens to be used in conundrum with 140 different ingredients to create dishes with all kinds of recipes and utensils. For this the insert of the player, also from here on referred to as the player avatar, in the game needs to navigate a kitchen seen in restaurants.[1]

(Big Cheese Studio: untitled (screenshot of game). https://cdn.akamai.steamstatic.com/steam/apps/641320/ss_57dbadff3491ec272ee82715cac500d7 820d9a9b.jpg?t=1707910177, found on: https://store.steampowered.com/app/641320/Cooking_Simulator/ (last visited 18.5.2024))

which for the purpose of serving customers also has larger allocated floorspace and a higher amount of the aforementioned cooking utensils in comparison to the usual family kitchen. So just like in a real restaurant kitchen the layout is important to efficiently and effectively know where everything is located as well as get there

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[1] Cooking Simulator, Big Cheese Studio, PlayStation 4; xCloud; Xbox One; Windows; Linux; Mac OS, Big Cheese Studio, PlayWay S.A, Poland, 2019.

in a timely manner without too much disruption. The layout then also needs to facilitate the creation of large amounts of food as well as the delivery to the customer in the restaurant. The game has chosen to follow the design philosophy of an island style kitchen to address the previously defined layout requirements. Island style kitchens are defined by having an island, in the case of cooking simulator the preparation area, in the centre of the room as well as the walls also being covered with cooking equipment. For cooking simulator this is where all the different preparation and cooking areas are. The ingredients are in an indented corner of a room separated into a freezer, for food that would appear to be easily perishable, and a bunch of shelfs some filled with plastic containers to hold fruits and vegetables as well as some more dishes and bottles of wine and oil as well as spices some in the form of small gardening plants mounted to the wall. The game promotes a workflow of getting the assignment of which foods should be created which is on the central area screen. Then they pick out the ingredients they need before putting them in the island area or some other space and start cooking and prepping the food before furnishing the dish and sending it to the customer. Navigating around that space as well as multitasking to increase efficiency for an overall output increase of food is a challenge. The game offers the player incentives by giving the player rewards that increase their efficiency by allowing the player to move faster or remove failure states like touching hot things or breaking plates. The island design helps to overcome the challenges of food service by always having the island in sight which is where the orders and receipts are displayed in cooking simulator. So, information is always only one look away. The island also provides ample floor space to move around in. So, the player avatar does not easily bump into things and potentially break them. The island can be used as a preparation area to prepare the food before cooking but also as the service area where the food gets furnished before which is largely left up for the player to decide. Giving some modularity to the cooking approach as well as giving the Player the option to put things at a location where their personal workflow is optimised the best.[2]

The appeal of Cooking Simulator is to fulfil the players fantasy of being able to cook whatever they want while given them a digital space that looks similar to a professional kitchen to mimic all the fun and challenge a person can experience while cooking with no meaningful repercussions. Therefor the game strikes an odd balance. The island kitchen is made for a team of people to be part of the cooking process. Different people preparing, cooking, serving and cleaning. Food often being handed off to another person. The wide-open walking areas facilitate the movement of people without said people bumping into each other. But since Cooking Simulator is a single player game these benefits largely don't apply. Leaving the design choice more so to communicate the feeling of being in a restaurant kitchen then being the ideal design choice for the occupation. Of course, the game also profits of being just a simulator. An important part of kitchen design is cleanliness often being facilitated by a dedicated cleaning area near the door to the customers so dirty dishes can be immediately cleaned and then put

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[2] Cooking Simulator, Big Cheese Studio, PlayStation 4; xCloud; Xbox One; Windows; Linux; Mac OS, Big Cheese Studio, PlayWay S.A, Poland, 2019.

back to be used. In cooking simulator, the door to the customer and the sink are on opposite sides of the room creating a lot of potential conflict points, where they could run into each other with coworkers on the way. But in the game the player has access to infinite dishes so the reusing of them is of no importance and since the game focuses the player on cooking the tasks surrounding cooking, like cleaning, are glanced over. This also leads to the fact that an entire side of the wall is basically unusable cooking space with just some tables and a computer to track the player's progress and give out tasks and rewards accordingly. There is also the fact that there is a lot of technological to help the player. While not impossible to have in kitchens, kitchens are often fairly greasy places as well as people having food residue on their hands, that can be left on those appliances. Creating the need that these appliances are thoroughly cleaned and maintained. This is also part of the reason why managerial appliances are usually not found in the kitchen. Of course, the game is about being in the kitchen and cooking food and not about managing a restaurant. So, from a game design perspective the managerial equipment being in the kitchen makes sense. Moreover, since it wants to simulate a restaurant style kitchen but leaves the player avatar alone in that kitchen it hinders the player avatar to have the best access to all appliances, ingredients and machinery. Since the space is spread farther apart then it needs to for one player for the sake of simulation. The optimal size for a one-person restaurant might just be a regular food stand instead. On the other side the big size and all the appliances can communicate a feeling of grandeur and professionalism that the player can immerse themselves into. Potentially giving way to a mindset that allows the player to put their all into the digital food creations. [3]

But how would a game creator act if they wanted to create the most effective way for food to be made in their game, instead of having a focus on simulation and immersion. How would they create a space where a player has all the things necessary to cook without needing to move throughout the kitchen to get to all the things they need. Moreso having all the things easily in reach.

Talking about games

This Thesis will focus on the designed composition of spaces interwoven with lots of opportunity to interact with the space or things in the space in video games. The goal of this Thesis is to show, discuss and suggest ideas for optimised space usage for places in games with loads of meaningful interactivity to optimize the experience of the player. However, to properly archive the goal of this Thesis, it is helpful as a starting point to exhibit the stated focus of the Thesis in more detail. An appropriate definition of space from the Mariam Webster Dictionary in terms of this Thesis would be "an extent set apart or available".[4] For example, a kitchen room would be a space that is an extent of an average house set apart by most often walls, floor, ceiling and a door. Of course it is rather vague like most official

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[3] Cooking Simulator, Big Cheese Studio, PlayStation 4; xCloud; Xbox One; Windows; Linux; Mac OS, Big Cheese Studio, PlayWay S.A, Poland, 2019.

[4] Merriam-Webster.com Dictionary: Space.

https://www.merriam-webster.com/dictionary/space. (last visited 16.5.2024).

definitions. For this Thesis we will also add to the definition of space, that the player experiences something referred to as a "sense of place".[5] While a whole Thesis topic on its own, this Thesis only requires a rudimentary and partial understanding of the concept. Being that the more set apart the space is, the more defined it feels and therefore gives off a stronger sense of place. This makes a room being encased from everywhere feel like a more defined space while a public plaza feels like a defined space and a forest or meadow that lacks encasement feeling like an undefined space since there is no extent that is being set apart. With defined objects in space also increasing the feeling of a sense of space, like an obelisk making the place feel more unique and defined. It is also important to mention that the space projected by games and the space usually experienced by people are different. With lots of effort being put towards how to make sense of a spatial ideas in games with other peoples' previous analysis and ideas about space. And while unendingly fascinating for the stated goal of this Thesis the important conclusion is that digital space in games is a representation of non-digital space or the space human beings exist in.[6] Lastly, there is something that pertaining for this Thesis will be called reach, which is more in line with the Mariam Webster Dictionary definition of space. This reach surrounds the players avatar and anything in reach can be interacted with while anything out of reach lacks the ability of interaction. To go with the previously established kitchen example while having a knife and a potato, wanting to cut in the same kitchen space, one would have trouble to do so if a person's arm is not long enough to reach both the potato and knife at the same time. Most games mimic this idea giving the player avatar a general and mostly arbitrary amount of reach.

The most appropriate definition of Interactivity in the Mariam Webster Dictionary is "involving the actions or input of a user".[7] Basically, if a person does something involving something else it is interactive. Though since we are focusing on interactivity in a more narrowed environment: Interactivity, for the purpose of this Thesis, is the player's controllable puppet inside the game world, which was already referenced as "player avatar", performing an action that triggers a reaction by another object in the game world. Since this is a rather abstract definition an example in the line of our previous kitchen example would be playing with a puppet inside a puppet sized kitchen. using the puppet like a marionette with strings to stretch out the puppet's hand to reach for a small puppet sized knife that has some duct tape on it. The knife's "reaction" to being touched is then to stick to the puppet's hand. Furthermore, to clarify the understanding of an object in terms of this Thesis, an object is closely aligned to the understanding of object-based

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[5] Conlan, Nicole; Slaughter, Jason: Designing Urban Places that Don't Suck (a sense of place), 2023, Video, 10:47 min.

https://www.youtube.com/watch?v=AOc8ASeHYNw (last visited 16.5.2024).

[6] Günzel, Stephan: What Do They Represent?. Computer Games as Spatial Concepts. In: Espen Aarseth; Stephan Günzel: Ludotopia. Spaces, Places and Territories in Computer Games. Eds.

transcript Verlag, Bielefeld, 2019, pp. 13-40.

[7] Merriam-Webster.com Dictionary: Interactive.

https://www.merriam-webster.com/dictionary/interactive (last visited 16.5.2024).

coding instead of what would be a more conventional understanding of an object. In object-based coding everything that is portrayed is an object with code dictating how it should exist. This is important since clickable things in most software like Microsoft Excel or Microsoft Word could potentially not be perceived as objects but for the definitions of this Thesis are definitely objects.[8] [9]

To finish the exploration of the goal of this Thesis, talking about the idea of the composition aspect in design as the focus of this Thesis would be in order. This is here to imply that there is a possibility of better space usage at the same time as a higher game play purpose to the game objects the players avatar can interact with. To show why this is important in one of the comedic shorts of Thomas 'TomSka' Ridgewell he enters a room that is filled with tiny needles that float in the air and if a person walks through the room, they are going to get stabbed by a bunch of tiny needles.[10] This of course would probably be the most interactive use of space. It presumably could work in certain games, but it would lack a higher purpose in a game, probably only being good at blocking off a space. Therefore, this Thesis will focus more on interactable objects that serve a higher gameplay function making the player want to interact with said objects. To give a non-digital example, a kitchen serving the higher function of creating a meal. The word composition in this Thesis is also used to broaden the scope of this Thesis since it intends to talk about both how game makers could create better spaces in their games. As well as how to design objects that the player can use to create a space. Since games of the latter variety tend to suffer the most from spaces a bit too out of reach for player avatars.

Underutilised Spaces

Since as mentioned before digital spaces are mere representations of non-digital spaces there are some areas in games that are easier to make interactable then the non-digital space they represent. While a ceiling in a non-digital space is mostly empty except for light sources, duo to the fact that people with a variety of heights should be able to pass through and might have trouble reaching areas on the ceiling as well as the ceiling being the floor of the room above leaving trouble of attachments, like screws, reaching through the floor. This however can all be ignored in a digital space where all player avatars can have the same height and reach as well as not needing to obey physics of non-digital spaces. Leaving lots of potential room for games to place interactable game objects on the ceiling like a small bookshelf or a hatch that can be climbed out of to enter a room above saving space on stairs since the player avatar can be incredibly strong and just lift themselves up without hassle. Something similar can also be accomplished with the floor. While most entries to an attic are a fake floor that can be transformed

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[8] Microsoft Excel, Microsoft Corporation, Windows; macOS; Windows Phone; iOS; Android, Microsoft Corporation 1985.

[9] Microsoft Word, Microsoft Corporation, Windows; macOS; Windows Phone; iOS; Android, Microsoft Corporation, 1983.

[10] Ridgewell, Thomas: Needles (feat. Jack and Dean), 2022, Video, 2:07 min.

https://www.youtube.com/watch?v=3I3LCyLY_m0 (last visited 16.5.2024).

into an entry way, the concept of a fake floor could be used to have, for example sliding doors where the player could store things like clothes or just regular boxes that can be taken out of the floor. While a real hassle to make functional while also not ruining the back of a person in non-digital space, digital space in combination with the player avatar can make these ideas easily feasible. Finally walls, while walls should not be messed with in a non-digital space giving the fact that they give places their structural integrity, structural integrity is less of a concern in digital spaces allowing all kinds of ideas like having drawers or shelfs inside of walls. This could also be used to have smalls holes in the walls that could allow a river to flow through a room. Of course, another opportunity could be filling rooms with things usually problematic to fit inside rooms like previously discussed elements of nature or hammocks or an energy beam going through the room for mysterious purposes. As long as a designer can envision it, it is feasible to create in a digital space.

Abstraction

The most fitting Mariam Webster definition of something that is abstract is "disassociated from any specific instance".[11] Though this definition appears still rather unintuitive as most broad concepts are. While abstraction is an often-encountered concept it is in the opinion of this Thesis easier to comprehend with an example. From the perspective of a child an ice cream truck provides ice cream in exchange for currency. Of course, an ice cream truck is more like a merchant that buys from other merchants to sell goods to people that desire those goods at a higher price they purchased. While both descriptions are in a sense true the hypothetical perspective of the child leaves out the mechanics and boils it down to the interaction of currency for ice cream since that is what is most relevant to the child and also fits the definition of "disassociated from any specific instance". Which can also be why a child might not understand that the ice cream truck can run out of ice cream since its idea of the ice cream truck could be built on this single understanding. With the example it might become clear that most games are abstraction. Chess for example being an abstract representation of a battle. Or in the game Minecraft having nature represented in the form of a bunch of cubes. Most forms of play could probably be categorized as an abstraction of something.[12]

However, this exploration of abstraction has not yet shown any capabilities for better space usage. For this it is vital to understand that games are inherently abstract from everyday experiences. A video game's programming does not change if the player recognizes things. As an example, Minecraft's mechanics would not change if all the blocks were just a solid colour.[13] The only thing that would change is the ease of understanding the player has when playing the game. So, for a kitchen in a game with the most optimal space usage, the ideal plan might be to just shrink every interactive object and putting it close to the player's

[11] Merriam-Webster.com Dictionary: Abstract.

https://www.merriam-webster.com/dictionary/abstract (16.5.2024).

[12] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

[13] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

avatar. Though this will probably have its own consequences making it harder and more frustrating to interact with the now small objects.

So, to continue with the idea of abstraction for this Thesis, abstraction manifests in two ways. The first one has to do with the fact that all parts in games are abstract, though to a different degree depending on how strong their association is to the existence they are an abstract from. An example being would be a conversation with another human while talking to them face to face might be the baseline, a conversation over the phone might be an abstract and a letter might be an even stronger abstraction of the concept of a conversation. The other way is that a game object can be an abstraction of another game object. For example, in Minecraft if the player holds mouse button one and looks at a tree the player avatar will usually start interacting in a perceived destructive manner with the tree game object which is more commonly referred to as "punching" the tree and transforming or "breaking" it. After a block game object that was part of the tree has been "broken" it will create a new game object that is a smaller rotating part of the block game object that once belonged to the tree which has been "broken" that can be collected by the player avatar.[14] Talking about game objects with a weaker association a common idea is a heads-up display or user interface. An adequate description for both of these is an embrace of a software look by having information shown in a way more typical to software like Microsoft Excel existing as a layer that is seen before the actual game best imagined like a cardboard cutout in front of the monitor.[15] In Minecraft for example the player can see in his heads up display his health and hunger bar as well as what object he is currently holding if any at all. The heads-up display can also be disabled so it is easy to show what is a heads-up display with the game.[16]

(Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition))

The difference between a heads-up display and a user interface is that a heads-up display is information projected onto the screen with less options for the player to interact, while a user interface is more akin to a software window. A software window is a part of the screen that is taken up by the software to interact with mostly via the cursor. So, a user interface would be a something of a software window in a software window. To follow with the established example of Minecraft a user interface would be opening something like the inventory. The inventory

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[14] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

[15] Microsoft Excel, Microsoft Corporation, Windows; macOS; Windows Phone; iOS; Android, Microsoft Corporation 1985.

[16] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

being an abstract system that associates itself with the idea of carrying stuff around. However, as a user interface it mimics a shelf. A person might usually differentiate things they are carrying in bags or pocket by touch. For most games however differentiating by touch is not feasible. So, they work with a storage solution that gives the most visual clarity. A special kind of shelf with horizontal and vertical bars where each space serves as a form of pedestal for another game object. In the game Minecraft if said inventory is opened by pressing a key there can be another abstraction in form of an image of the wood that was broken in the previous example.[17]

(Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition))

Since the inventory is a user interface the cursor can be used to move the wood around and put it in another part of the shelf. To help the reader with some words most often associated with this an empty shelf space is most often referred to as a slot. This user interface however has another purpose there are empty shelf spaces with drawings on them. this is supposed to represent clothing. While a game may have difficulty portraying putting on clothes it can abstract it by having a game object symbolizing pants and if they go into the designated shelf slot for pants the player avatar will wear those pants. Similarly to the right of those pants slots are shelf spaces with an arrow pointing to the right, this is an association with the idea of portraying how a person could use their hands to make something out of things they carry around. By putting in game objects the user interface is

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[17] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

allowing the player to transform said game objects, that were put into the slots, into another game object. This Thesis, for the sake of terminology, will refer to game objects that are interactable with the user interface as items.[18]

With this rather long-winded explanation of heads up displays and user interfaces done and how they can be used explored, this Thesis is at a point where it can give an example of the previously mentioned strength of association. in Cooking Simulator to cook a steak. The steak needs to be put in a pan that is being heated in which it will slowly cook. It then needs to be taken out of the pan by either grabbing it with a kitchen utensil or putting it on a plate since most of the time it is too hot to be held by the "bare hands" of the player avatar. While in Minecraft when cooking a steak, the steak item just needs to be put in the user interface of the oven game object, that is opened by interacting with the oven. If the oven user interface is also provided with an item labelled as fuel, it will start the cooking process and give the player avatar a cooked steak item that can be put in their inventory. Cooking Simulator with its process has a stronger association with the conventional experience of cooking a steak outside of the digital realm while Minecraft has a more childlike and less associated understanding of cooking with the idea that cooking will result in cooked food provided the necessary ingredients.

With abstraction in terms of this Thesis being established and hopefully understood it is time to have a more thorough exploration of how abstraction can be used for better space usage. If a digital space is hard to navigate because of the size of interactable game objects abstraction can be used to exchange larger game objects with smaller ones that have a similar association. For example, a microwave oven and an oven are different in size and usage scenarios but if their only purpose in a game is to be a game object associated with heating something both represent the process. Similarly, if ice cream is an important part of the game, it might be easier to fit a game object whose purpose it is to dispense ice cream that looks more like a miniature fridge, then a game object, whose looks are closer associated with an ice cream truck. However, like with almost everything it is a trade-off. While an oven can have different designs and is not largely specific to any time period it fits into more scenarios than a microwave oven, which only fits into a very narrow time period. With the mini fridge and ice cream truck example, it is an issue of perception. A player is more likely to think that an ice cream truck is a vendor so there for the ice cream truck gives ice cream in exchange for possibly another game object or another thing the player avatar can trade. While a mini fridge is more widely perceived as a storage container which the player avatar can just freely take game objects out off but with a limited quantity on ice cream. As a finishing aspect of this idea since larger objects take up more space they are more often perceived as having more importance, else why would these game objects be that big, they are also more easily spotted. Which of course is an important design consideration. Since these objects work in the abstract if the player avatar exists in a digital world different to the non-digital world the player inhibits, it is helpful for objects of interaction to reflect this. As an example, in a magical world a stove could have design elements that might read as magical. Like books with

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[18] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

spells or some symbols looking like incantations. Design properties in a world in the far future could have some weird form of technology embedded into it. Like a machine that just 3D prints the food for the player instead of cooking or preparing it.

Another case of Abstraction with strong disassociation is storage. A good number of games have a bunch of collectable items that are important in usage with interactable objects. With games having different approaches to handling them, a game like Warframe uses a user interface as inventory. An inventory being, as established, a term that refers to an abstraction of pockets or empty space that a person could fill to have things on their person. The Inventory of Warframe has no limit on game objects, so the player is free to endlessly collect whatever they find. This works for Warframe since the player collects items passively while playing the game or when actively searching for materials usually gains them by engaging the gameplay loop of shooting things. But more importantly those collectables are usually items with their only use, being requirements of quantity to create Weapons and other game objects the player uses. Though to navigate the Inventory the player has the option to search items by a name the game gives them in the inventory.[19] A game like Minecraft has more interactable game objects. While still using a user interface as inventory, the inventory in Minecraft is limited so only a certain number of items and game objects abstracted as items can be carried around. This allows players to have an easier overview of their items in their inventory which can help with the specific items that can be interacted with to result in creating a game object in the digital space. This limit also reinforces the idea of using the game objects in Minecraft to create a place for the player to stay. Since many game objects can only fulfil their function when placed into the digital space of Minecraft as well as the inventory space being limited. So if the player wants to store more items, they need another storage solution. A chest is a game object that can, usually like an inventory, also hold items which also can be moved in the layer of the user interface allowing players to store items outside of their inventory. If the player has placed down one game object that can only be interacted with when placed down, they are also more likely to place down other game objects with the same predisposition creating an interactive space. Minecraft while having a strong component of building your own space also has a strong component of gathering resources and exploration. To enhance both of these aspects the inventory is limited but the player avatar can carry a lot of things while not losing perspective of what they are holding with the abstract idea of stacking.[20] In a conventional understanding of the term stacking is to put something on something else. In the abstract idea in the world of games. If the player has 2 items in the user interface layer that both represent the same kind of game object for visual clarity the player can stack them on top of each other and indicate that the player now has 2 of these items by having the game object of the user interface layer and then a small number next to it indicating how many of this type of item I have.

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[19] Warframe, Digital Extremes, Windows; PlayStation 4; Xbox One; Nintendo Switch;
PlayStation 5; Xbox Series X/S; iOS, Digital Extremes, 2013.
[20] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

(left: Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition))
(right: Genshin Impact, miHoYo, Windows; iOS; Android; PlayStation 4; PlayStation 5, HoYoverse, 2020)

Most games follow the abstract idea of stacking while in Warframe the same type of game object can be stacked indefinitely [21] in Minecraft a game object can most of the time only be stacked up to 64 times before a new empty shelf space or slot needs to be used. This reinforces the need for a player to return to their created space to store all the game objects they have been gathering. While functional it also inflicts a burden on the created interactive space. Since players will gather more and more items that need to be properly stored. Duo to the fact that items cannot be stacked indefinitely and the sheer amount of collectable game objects in Minecraft the need for space to store these items grows. Also, the player will spend more and more time putting items away in their designated space or any storage container space as well as taking more time to pick out the items that the player needs or wants. Making the player play less and perform more maintenance work in the game to continue having fun. [22]

Of course, there are some games that have come up with ideas for this phenomenon. In the game Terraria the player has access to a button in the user interface layer to automatically store game objects in storage container game objects. The player is also able to interact with game objects while having the user interface layer open while also being able to have a storage container user interface open in the user interface layer. Allowing access to items in both the inventory and storage container as well as still being able to move around. [23]

A game like Cooking Simulator with other focuses in game play and less use for a user interface and a lack of inventory, deals with its storage situation with its high amounts of ingredients in an interesting way. Basically, each ingredient gets an abstract stored representation of it. Most meats are present in a refrigerator. Herbs are shown as the plants they grow from. Most other ingredients are represented as a large amount in a box. Now in the game these abstract representations of ingredients do not work as storage but more as game objects that creates the portrayed ingredient or vendors creating the game object for a price. However, it

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[21] Warframe, Digital Extremes, Windows; PlayStation 4; Xbox One; Nintendo Switch; PlayStation 5; Xbox Series X/S; iOS, Digital Extremes, 2013.

[22] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).
[23] Terraria, Re-Logic, Windows; MacOS; Linux, Re-Logic; 505 Games, 2011.

could also be an interpretation that these abstract representations for ingredients are just storage containers that can hold an infinite amount of one type of game object.[24]

A similar idea for storage exists in the game Skyrim. Skyrim has a user interface in the form of an inventory that is more akin to a list then a shelf. Since this list can be expanded with new items indefinitely the limiting factor of this inventory is the weight every game object is labelled with. In Skyrim the player avatar is only able to carry a certain amount of weight units from items. However, every storage container in Skyrim can carry a practically unlimited amount of weight so the player could dump all the game objects they do not need into a single storage container. The downsides being that even with a self-sorting alphabetical list in the case of Skyrim, the player can take a really long time going through it all to find an item they need. Also, a sufficiently filled storage container can decrease the performance of the game when opened. Making it practically a necessity for the player to properly sort their inventory game objects. Or be troubled with the aforementioned problems.[25]

Then there is also the weird approach of Minecraft itself. Since Minecraft has game objects that when placed can interact with items in the inventory layer of storage containers. Allowing the player to set up structures of game objects that allow the player to put all undesired items onto a single place, most likely a storage container, and then let the structure sort all those items into other multiples of storage containers more easily understandable to the player. These structures can also be built with game objects that transform other game objects as part of the structure. Allowing items to be transformed and then sorted. Removing a need to interact with those special game objects on a user interface layer. However, those structures still occupy a lot of space in Minecraft making it still necessary for the player avatar to navigate through a larger than optimal space by walking around to pick out items. Also building those structures is an ability in itself, with most players being unable to create them, without consulting resources and instructions outside of the game. Limiting the accessibility of this method.[26]

Another idea to a storage solution can be found in user made modifications to games with storage game objects taking up a large amount of space. An example being the Magic Storage modification for Terraria.[27] For this Thesis these game objects will be coined wonder machines. Wonder machines when interacted with give the player a powerful user interface, being an access point to all storage containers which allows the player to store all their unwanted game objects without needing to go to different storage containers. Similarly, this allows the player also

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[24] Cooking Simulator, Big Cheese Studio, PlayStation 4; xCloud; Xbox One; Windows; Linux; Mac OS, Big Cheese Studio, PlayWay S.A, Poland, 2019.

[25] The Elder Scrolls V: Skyrim, Bethesda Game Studios, Windows; PlayStation 3; Xbox 360, Bethesda Softworks, United States of America, 2011.

[26] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

[27] Spriting: Magic Storage.

https://github.com/blushiemagic/MagicStorage (last visited 17.5.2024).

to access and take all kinds of game objects in every storage container. For ease of access these game objects can be sorted by label or found with a search for other identifiable characters, most likely the name identification given to it by the game. Of course, wonder machines are also capable to emulate all game objects that can transform items when interacted with. Giving the player access to all items that are in storage as well as all possible transformation of items in a singular user interface.

Of course, to safe on space in general, the game can also consolidate on game objects with the ability to transform items like the mentioned wonder machine. A great example from the non-digital world would be a Thermomix and its proclaimed ability to do most of the work of other kitchen utensils in a simple singular device. While an analysis of the capabilities of a Thermomix is outside the scope of this Thesis combining interactable game objects saves the player time by navigating a larger user interface that transforms different items. Instead of needing to navigate a space with many different interactable game objects that can only transform a limited amount of distinct items.

Furthermore, Warframe, as an example, gives the player something similar to a wonder machine that can be accessed via a user interface when pressing a button. Since all collected game objects are in the inventory of the player avatar the aforementioned user interface gives the player access to all game objects that transform game objects themselves with a user interface. Making the Warframe inventory a wonder machine. And a one stop shop for all needs of transforming items.[28]

With this revelation the Thesis has now found a way to optimize the abstraction of a conventionally navigable space into the space that is a window of software inside the window of another software in the form of a game. Basically, everything can be reached and interacted with if it is just a user interface which is closely resembling how software like Microsoft Excel or Microsoft Word is structured. Having everything abstracted and ready to be pressed. Every interactable object just a few clicks away and achieved with utmost speed. In the opinion of this Thesis a standard of space usage achievable by any contemporary game. Though the Thesis also believes that software like Microsoft Word and Microsoft Excel does not excel as a basis for a game. For all the use cases of a user interface or heads up display in games. It is always a layer of separation between the player and the digital space of the game. Potentially hindering the Player to be immersed in the game.[29] [30]

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[28] Warframe, Digital Extremes, Windows; PlayStation 4; Xbox One; Nintendo Switch; PlayStation 5; Xbox Series X/S; iOS, Digital Extremes, 2013.

[29] Microsoft Excel, Microsoft Corporation, Windows; macOS; Windows Phone; iOS; Android, Microsoft Corporation 1985.

[30] Microsoft Word, Microsoft Corporation, Windows; macOS; Windows Phone; iOS; Android, Microsoft Corporation, 1983.

As an example, the game Hydroneer lets the player carry around game objects for digging as well as large quantities of valuable stone game objects to sell or transform. However instead of being picked up and carried in a user interface in the form of an inventory, the player avatar carries them in a game object with the association of a bucket or a game object with the association to a vehicle. This of course makes navigating the space together with game objects of interest more tedious but keeps the player more connected to the player avatar in the digital space. Duo to the fact that the player cannot open a user interface there is never a layer of user interface between the player and the player avatar. Strengthening the connection and immersion between player and player avatar.[31]

Multidimensionality and non-Euclidean Spaces

If the previous chapters substance was centered around the tools and ideas of a more effective usage of digital space. This chapter features the tools and ideas of achieving more digital space in reach of the player avatar. To understand how it is even possible to get more digital space in reach of the player avatar. It is a helpful to introduce dimensions in mathematical terms. Mathematically non digital space can be defined as a three-dimensional space since almost all things in non-digital space have height width and depth, each adjective describing a dimension of the space. The mathematical terms for height would be the y-axis for width it would be the x-axis and depth would be the z-axis.
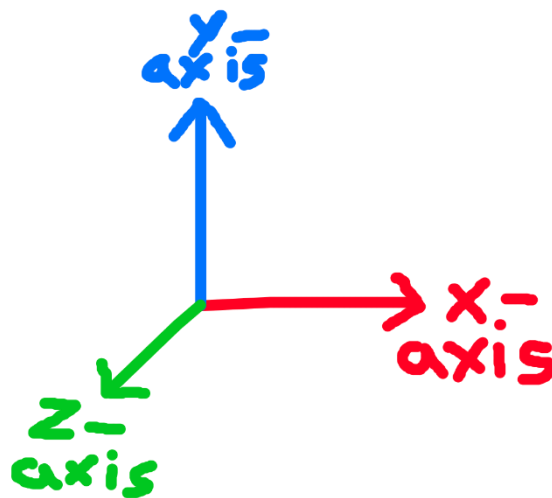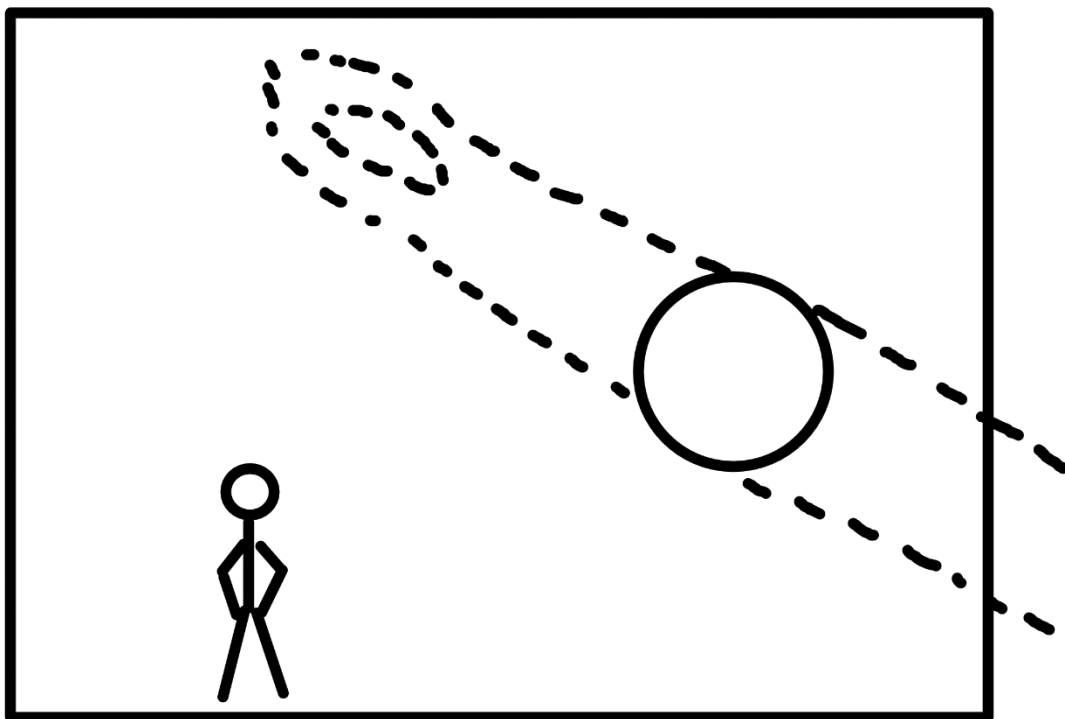

(created by author for Thesis)

Coming back to Multidimensionality in context for this Thesis refers to the idea of adding more mathematical dimensions to the mostly prevalent three-dimensional spaces of video games. A four-dimensional space offers more space than a three-dimensional space for game objects to be placed in, however since the fourth dimension is rather incomprehensible for most people, it might be difficult to visualize since it invites thinking about something beyond the common understanding of the space people usually inhabit. So, to give an example of how to think about the idea of a higher dimension it helps to think of the perception

[31] Hydroneer, Foulball Hangover, GeForce Now; Windows, Foulball Hangover, 2020.

from a two-dimensional space of a three-dimensional object. An approximation of the second dimension might be a piece of paper with a drawing on it. Since it has height and width but barely any depth. Now to imagine there was a person in the form of a drawing. because this person exists in the second dimension, they would only be able to perceive things also existing in the layer off the paper but nothing beyond the confinement of the paper. So, if the paper would be pierced by a three-dimensional object like a needle the person on the paper, only being able to perceive things on the layer of the paper, would only perceive the part of the needle that is intersecting with the paper at the moment. It would look like a circle increasing in size when the needle penetrates the paper before the circle gets smaller and disappears as the needle has passed through the entirety of the paper.

(created by author for Thesis)

This mental model is helpful for imagining how four-dimensional objects that are intersecting with our three-dimensional plane, would look like three dimensional objects that can face in and out of existence. However, if the player and player avatar are bound to interact with a four-dimensional object on its interference point with the third dimension then it is difficult to a level of impossibility to manipulate the game objects in a meaningful way. This means that even though the player avatar would interact with the fourth dimensional object it could only be manipulated in the limited confines of a three-dimensional space. The game 4D Toys has fourth dimensional objects collide with other fourth dimensional objects to move them in fourth dimensional space or by having a four-dimensional force like artificial gravity.[32] To understand why that happens the example of a bowling ball might help. If a bowling ball would roll in a perfect line basically only moving along

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[32] 4D Toys, mtb design works, inc., Windows, mtb design works, inc., 2017.

a two-dimensional axis the pin balls being hit would still move in all sorts of different directions. Meaning that a four-dimensional room could be created that has more interact able game objects that only appear into the player avatar's perception of three-dimensional space when the player avatar collides into four-dimensional game objects. Though for the Thesis the assumption is made that designing a space in the fourth dimension that interacts that precisely with physics might be only possible for the very dedicated. The other idea for a four-dimensional space might be similar to playing with 4D Toys. With the difference being that all objects are important to interact with and to find the important game object for the occasion, the player avatar smashes game objects around the room until the fourth dimensional game object in question is found.

However, those ideas still lack the ability for the player avatar to meaningfully interact with the fourth dimension. Since just like the paper person lacks the ability to perceive the third dimension, games lack the ability to let the screen portray a fourth dimensional space with the same quality as a portrayal of a three-, two- or one-dimensional space. Since then, games tried to work around that restriction. To explain how most games let the player interact with a fourth dimensional space, it is helpful to give an example in more conventionally understandable terms. The first dimension is basically a line. We can imagine morse code as an example of a one-dimensional object since it is only points and lines when written down not needing to possess any height. An approximation of the first dimension would be a slit between our fingers. With this slit the reader of this Thesis can simulate a perception of a two-dimensional space from a one-dimensional perspective by trying to read this text with only the perspective of the slit between their fingers hovering over the text. This method of reading is certainly slower and more strenuous than reading the text normally, but it allows a meaningful interaction with a higher dimension by moving along the axis of the higher dimension. Metaphorically speaking a space can be a "window" to a dimension higher than the dimension of the space. The idea now becomes to shift the window along the axis of a dimension above the third dimension. This idea can be seen in four-dimensional games as either a slider to be moved or keys that make the player avatar move along a higher dimensional axis. Of course, the "window" of four-dimensional space can also be manipulated by being rotated. Rotation also being archived by the use of input devices. Though this Thesis lacks the ability to explain in examples how rotation in fourth dimensional space works so it will instead be explained in mathematical terms. A plane is kind of like a paper that extends without end. A plane can be mathematically constructed with two-dimensional axis. A plane always has an axis perpendicular to it around which it can rotate. A three-dimensional space has three planes so it can rotate around three axis. A four-dimensional space has six planes meaning it can rotate around six axis. Though according to the Creator of 4D Golf in his developer log, two of these axis roll and make them undesirable for video games. Since the human perceives in the form of a plane, a plane rolling would describe the rotation of the perspective and can be achieved by the reader resting their head on their shoulders. Since rolling most

often does not shift the perspective in a game play relevant way it is often not implemented as an axis that can be controlled by the player. [33]

However most four-dimensional games as well as the four-dimensional game Miner 4D, which is the game most relevant game for this Thesis only manipulate their "window" in a singular way. So, it is not necessary for a game to be able to navigate fourth dimensional space in every way possible to make the usage of a four-dimensional space meaningful. Miner 4D is inspired by Minecraft with a similar block-based world however compared to Minecraft by simply rotating a "window" in four-dimensional space Miner 4D is able to have more than double the amount of interactable game objects in potential reach of the player avatar. While higher dimensions definitely show promise by adding more space that can be used for interactable game objects.[34] [35] This Thesis also might stand as a convincing argument in its attempts of explanation why most of these games that use a fourth dimensional space are usually passion projects and the games are few in number. Though this Thesis also encourages everyone that feels like their game needs an amount of room only satiated by a fifth dimensional space to try.

To highlight some of the more lower concept problems. Since the player at most sees a "window" to the game technically interactable objects that are not in the current "window" of the game are out of reach since the player lacks the ability to interact with them since they are not visible on screen. While usually still being able to save the player more time in finding the objects to interact with then trying to walk around in a space where everything is slightly out of reach. It comes at an opportunity cost where the player without aids needs to memorise the places of the things they need to interact with. Hampering accessibility and a potential time cost when the player wants to interact with something that is not visible in their window.

Lastly on the topic of four-dimensional games, there has been interesting ideas of signalling where 4 dimensional objects are while they are not intersecting with the game space. Miner 4D basically gives an outline that can be seen no matter what the players current "window" is.[36] While Golf 4D projects the four-dimensional objects into the perspective.[37] To explain this idea, it helps to remember the example with the paper person and say that the paper space is now being penetrated by a thorn. A thorn has the tendency to be thicker on one end then the other so the paper person would like to know how big the intersection of the thorn and the approximation of the second dimension in form of the paper could be so

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[33] CodeParade: So I Guess I'm Making a 4D Game Now… - 4D Golf Devlog #1, 2022, Video, 4:50 min.

https://www.youtube.com/watch?v=by8eAnez0i8 (last visited 17.5.2024).

[34] Mashpoe: I Made Minecraft, but it's 4D, 2022, Video, 13:47 min.

https://www.youtube.com/watch?v=u8LMyWcKL_c (last visited 17.5.2024).

[35] 4D Miner, Mashpoe, Windows, Mashpoe, 2022.

[36] 4D Miner, Mashpoe, Windows, Mashpoe, 2022.

[37] 4D Golf, CodeParade, Windows; macOS; Linux, CodeParade, 2024.

when the paper moves along the three-dimensional axis the paper person does not bump into the thorn. For this we shine a light on the thorn perpendicular to the paper of the paper person this allows the paper person to see the shadow of the thorn and be aware of the area where they could bump into a thorn.

A more common approach with multidimensionality is to have another three-dimensional space. The most common example would be Minecraft's Nether Dimension. Which is a separate space that the player's avatar can access by walking through a portal. This has the advantage over the previously mentioned higher dimensions that it is a lot easier to visualize and execute as well as for the player to understand and utilize. While still giving the advantage of a substantial increase of space in reach. Though while those other Dimensions exist in games, they are usually not optimized for quickly switching between them. With the aforementioned Nether Dimension taking a bit to load in, while entry also is halted until an animation has finished playing.[38] It appears that most games use other three-dimensional spaces for different environments to invite the player exploring or offering a challenge for the player instead of the idea for better space usage in highly interactive spaces. With the biggest notable example for space usage being the large storage weapon space in the movie Matrix, that the protagonists use to gear up.[39] Therefor this Thesis encourages the idea of multi-dimensional kitchens with the luxury of a walk-in freezer as an ice dimension while all the heat for cooking is supplied by a dimension with active volcanism. Or a library space for all the books written in a game that barely anybody reads. The options for great spaces are limited only by the imagination of the designers.

The last way of putting more space in space is through non-euclidean spaces. The definition of non-euclidean according to the Mariam Webster Dictionary is "not assuming or in accordance with all the postulates of Euclid's Elements".[40] The postulates of Euclid are the truths assumed by Euclid when talking about planar geometry. However, the postulates are not inherently important for this Thesis since most spaces that break with the understanding of how spaces operate conventionally, can be described as non-euclidean. Non-euclidean spaces have a great starting point though with the non-euclidean geometry called Elliptic geometry and Hyperbolic geometry. These defined forms of geometry differentiate themselves from Euclidean geometry by not being planar. Elliptic geometry has geometry that curves in on itself which can lead to the point where it connects with itself while Hyperbolic geometry curves away from itself meaning that there is more space than expected for the amount of distance to the center.[41] These types of geometry are represented in the game Hyperbolica. With Hyperbolic geometry

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[38] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

[39] The Matrix, Wachowski, Lana; Wachowski, Lilly. US, 1999, TC: 01:35:19-01:35:46.

[40] Merriam-Webster.com Dictionary: Non-euclidean.

https://www.merriam-webster.com/dictionary/non-euclidean. (last visited 17.5.2024).

[41] CodeParade: Non-Euclidean Geometry Explained – Hyperbolica Devlog #1, 2020, Video, 10:53 min.

https://www.youtube.com/watch?v=zQo_S3yNa2w (last visited 17.5.2024).

as floor space with the player avatar in the center having an increased amount of space to interact with while a complete Elliptic geometry floorplan would allow for further reach since most things are in view. Though the effort portrayed for this effect in the developer log of Hyperbolica makes it appear that doing so might take more effort than previously established ideas. [42] [43]

Though the understanding of what non-Euclidean spaces can be, has also been formed by influential games such as Antichamber. Antichamber having winding corridors that turn in on themselves and moving closer or behind object changing the location of the player.[44] While games like Superliminal interact more with non-euclidean space by having game objects be influenced by the non-euclidean space via perspective and change accordingly.[45] These ideas can also be rather successfully translated to a space with loads of interactable game objects. The corridors going into themselves could be used as a replacement for a hallway of storage containers or for the big amount of equipment for cooking. Or by having simply more space to work with by having rooms overlap themselves on the floor plan. While size adjusted to perspective allows an easy way for the player to readjust the size of the interactive game objects. Non-Euclidean spaces also allow changes in size by walking through a specific space [46], which could be used to a similar effect with the previously suggested dimension hopping basically giving access to another space surrounded by interactable game objects to do stuff with. An example being a more immersive way to use a user interface. Some ideas for non-Euclidean spaces this Thesis proposes would be a hallway with a wall that is always in reach but can never be run into so something interactable that is always needed could be placed there.

Interaction

So, this Thesis already covered how to make best use of a space as well as putting more space in space so the last segment will focus on the reach of the player avatar. Reach as established being the space surrounding the player avatar that lets the player avatar interact with all the objects inside of that space. As well as game objects also being used for interaction. The reach of the player avatar is usually set to a reasonable degree of distance. So, the player avatar cannot interact with game objects being multiple miles away simply because they are visible. However, there is technically no need to prevent such a situation. If the game space requires loads of interactable game objects to be handled in fast succession it would make sense to increase the reach of the player avatar for such

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[42] CodeParade: Rendering Hyperbolic Spaces – Hyperbolica Devlog #3, 2020, Video, 6:03 min.

https://www.youtube.com/watch?v=pXWRYpdYc7Q (last visited 17.5.2024).

[43] Hyperbolica, CodeParade, Windows; macOS; Linux, CodeParade, 2022.

[44] Antichamber, Demruth, Windows; Mac OS X; Linux, Demruth, 2013.

[45] Superliminal, Pillow Castle Games, Windows; macOS; Linux; Switch; PlayStation 4; Xbox One; Playstation 5; Xbox Series X/S, Pillow Castle Games, 2019.

[46] CodeParade: Non-Euclidean Worlds Engine, 2018, Video, 5:14 min.

https://www.youtube.com/watch?v=kEB11PQ9Eo8 (last visited 17.5.2024).

a scenario. Though even with extended reach the player avatar is limited to game objects that are shown to the player on the part of the screen that the game occupies. With a lot of game objects to be interacted with cluttering a space it will be harder for the player to select the game object they want to interact with. For a situation like that the player avatar could access more of his reach if the game had only the outlines for game objects rendered allowing the player to interact with a game object though another game object since the game object whose outline was clicked is the only one that reacts to the interaction. A less dramatic version of this is giving certain game objects priority to be interacted with. The game Genshin Impact uses a different idea for handling a big amount of game objects that are in reach of the player by using a heads-up display in the form of a list to show all the game objects that can be interacted with and displaying a selected option. This selection can be moved around with input devices, the default being the mouse wheel, and the player can then interact with the selected game object and does not need to bother with the other ones.[47]

With Reach being a core part of this Thesis there are luckily other ways to enhance it. For example, enhancing it with the idea of effective reach. In most games the player avatar is not stationary. So, when a game object is out of reach the player avatar can just simply walk up to it and interact with it. However similarly to an object just out of reach for a person if the player avatar feels slow to move the player will spend more time having nothing better to do then to wait for the player avatar to get into the reach of the game object they want to interact with and probably upsetting them every time they have to spend time moving there. This can turn especially frustrating when the interactable game objects that are of most interest to the player are rather far apart. This could be for reasons of game play, aesthetic or because of focused placed on other parts of the game making process. The frustration the player experiences can be alleviated by making the player avatar more than adequately fast. As well as making sure the player avatar accelerates fast enough. The speed is also beneficial when trying to interact with special game objects since the player will have an easier time relocating the player avatar when the player avatar is adequately fast. Of course, a speed too high could make the player feel like they are not in control and collide with things they did not intend to collide with. Though a good number of games already lets the player toggle between a walking and running speed of the player avatar and it appears to be a rarely used feature for the utility it could bring. However, it could also be problematic if there are game play specific reasons for the speed of the player avatar. Potentially so the player avatar takes time to reach opposition that harasses the player avatar from distance outside of the player avatar's reach or to make gameplay where the challenge is derived from precise movement more palatable. Or to add suspense when the player avatar runs away from something.

Though the speed the player avatar can travel is not necessarily bound to the movement speed of the player avatar for example the player could make the player avatar use a game object that moves the player avatar this could be

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[47] Genshin Impact, miHoYo, Windows; iOS; Android; PlayStation 4; PlayStation 5, HoYoverse, 2020.

something akin to a grapple gun that drags the player along to the place they shot. Or a better means of transportation like the bicycle in the different Pokémon games.[48] Having game objects that the player avatar can be pulled towards like in Genshin Impact is also an option to reduce time between important interactable game objects.[49]

If there is a desire to have the player avatar to reach further only in certain situations, that can also be archived by game objects. For example, the game could hand the player avatar a long stick which allows the player to poke game objects representing potentially people, which allows the player to interact with them. Game objects representing guns could also be used to further the reach of interaction. Maybe if the player avatar shoots a target dummy, the game could play an animation to initiate a conversation with the game object that represents the owner of those target dummies.

Most game objects themselves can also be interacted with along sides another game object. For example, if a player avatar has a potato the player can interact with it by throwing it into a pot or using a knife to cut it. Giving game objects multiple reactions to being interacted with. With this, one can cut down on interactable game objects by having game objects that would interact with other game objects. While the potato is an object that can be interacted with it can also be an object the player interacts with by putting it in an oven or pan. Giving multiple functions. In the game Terraria the player avatar for example can only interact with wires when holding a special game object. These wires can then also interact with other game objects like a teleporter, a game object that is able to move the player large distances. [50]

The best example for a thing that opens up multiple kinds of different interactions would be a modern pocket phone when it needs to be available everywhere or a personal computation device when the action should be tied to a room. Therefor game objects imitating those devices give a designer a lot of power with the interactions the player can take with those devices.

Games in the Second Dimension

there are two major differences that games that are played in a two-dimensional space have to the assumed average game played in a three-dimensional space. The first major difference is the inverse of a point this Thesis has previously made towards games in higher dimensional space. While games in higher dimensional space have the ability to put more interactive game objects in the reach of the player. A game that is played in a two-dimensional space has less space to put objects. So, issues regarding space management for interactive game objects are more pronounced. On the other hand, games that play in a two-dimensional space

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[48] Pokémon, Game Freak, Game Boy; Game Boy Color; Game Boy Advance; Nintendo DS; Nintendo 3DS; Nintendo Switch, The Pokémon Company, 1996.

[49] Genshin Impact, miHoYo, Windows; iOS; Android; PlayStation 4; PlayStation 5, HoYoverse, 2020.

[50] Terraria, Re-Logic, Windows; MacOS; Linux, Re-Logic; 505 Games, 2011.

have a strong tendency to give the player unparalleled vision of the space. This unparalleled vision of the space is explained by the negligible amount of game objects overlapping or being in front each other from the perspective of the camera. To explain this a bit, vision of an object is obstructed if there is no line of sight between a point of optical input, either a camera for a game or an eye for a person. The camera in a good amount of the games with a two-dimensional space is perpendicular towards the plane that makes up the game world. Since it is perpendicular, therefor on an axis that is not relevant for most of the two-dimensional game worlds, game objects tend not to overlap between each other on that axis. Though most two-dimensional game spaces do not adhere strictly to a mathematical understanding of a two-dimensional space, more so an understanding of it as a space with a marginal amount of depth, similar to a simple ant farm, having a little dirt between glass so the ants can dig but the ant enthusiasts can watch the ant structures. Most of the time there will be a game object covering an entire two-dimensional space on its own onto which there is another two-dimensional space with most of the interactive game objects placed in front of. This two-dimensional space that is filled completely with a singular game object probably exists because it gives the illusion of depth as well as communicating an identity to the entirety of the game space, like a sky or a cave, and of course because software operating in a window need to have something in that window even if it is just a black void because the pixel has no information which colour it should be. Meanwhile the layer in front of it is as previously mentioned filled with interactable game objects that in most cases come in the two varieties of solid and nonsolid. The Thesis choose these terms since the solid game objects can be walked on by the player avatar and cannot be passed by the player avatar as well as inhibiting the reach of the player avatar. While the nonsolid ones are potentially still able to be interacted with but do not obstruct the player avatar's movement, which of course also allows the player avatar to obstruct the view of the nonsolid game object. There is also a game object type more common to two-dimensional games while also being fairly special in the sense that it has a semi solid property. The easiest way to understand it would be with an idea of a door. In a three-dimensional space understanding, a door opens sideways or into the direction of depth. Because in a strictly two-dimensional space there is no depth the only viable door is a trap door, alternatively described as a door that moves along the same axis the interacting party moves. Which also prompts a fun thought experiment with how a door would look like that can carry weight, like a pillar for a structure, while also still being able to open or how shelter would look like if the most viable option is to have the entrance at the ceiling as well as which lifeforms would evolve from that. Coming back to the Thesis doors in most two-dimensional games act as a semi solid where they have a solid or closed state and with an interaction become a nonsolid or opened state. A different manifestation of this is something that will be called a "platform" for the purpose of this Thesis, since there are not many game objects that have the combination of attributes. Most of the time these platforms can be traversed by the player horizontally with a notable exception. Basically, making them nonsolid when moved horizontally as well as being nonsolid when moving through it vertically unless the player avatar is completely above it, then it behaves like a solid that the

player avatar can stand on. The player avatar can also treat them as non-solids with a button combination and fall through it and the platforms will never inhibit the reach of the player. While in this description it appears rather mechanically complex in the player experience it is something that can be jumped onto and dropped down from. It is also present in successful games like Terraria or the Smash Bros series of games. These platforms are practical for covering vertical space which is vital in these games. For Terraria to move the player avatars reach vertically for easy access to interactable game objects while the Smash Bros series uses Platforms for the player to have the ability to keep their opponent in their reach vertically. The aforementioned notable exception for Platforms acting solid when the Player Avatar moves horizontally is a diagonal arrangement of platforms portrayed as stairs. If the diagonal arrangement is connected to a solid surface in games like Terraria the player avatar treats it as a solid that they still can fall through while also moving horizontally and vertically up or down depending on the direction these portrayed stairs take. Of course, not all stairs do fall under this definition. The Thesis at this time wants to point out, that in the space we inhabit we might carve stairs into mountains or create them to go down into a basement. The stairs that the player avatar can fall through more so represent the idea of stairs in a lived-in space that allows the choice of navigation beyond just walking up the stairs or just past them. Which is why they need to be semi solid for their purpose. As well as giving the player the choice if the player avatar treats them as solids or non-solids. Making platforms and their derivatives an interactive game object that helps the player avatar navigate space. Though reaching only meaningful levels of interaction when the aspects of the game that are designed to be fun involve space traversal or when a platform functionality is combined with a game object the player wants to interact with for other gameplay reason. An example combined game object might be a bookshelf to read books from or to jump and stand on top of. [51] [52]

Of course, not all two-dimensional adjacent games choose their game space as a plane of width and height. Games like Rimworld or Factorio have their game space as a plane of width and depth with an implied height. A chess board basically. And like a chess board the game places game objects "on top" of that metaphorical chess board which is why this Thesis calls it two dimensional adjacent, because it implies the existence of a third dimension while fundamentally still being a plane that is viewed from a perpendicular position. This of course makes use of previously discussed concepts like platforms redundant since there is no gravity forcing the player avatar vertically downwards. While game objects obstructing other game objects becomes reintroduced as a downside, duo to the reason that the most common adopted perspectives imply ideas of three-dimensionality which can only be evoked in a two-dimensional space by introducing overlaps. Rimworld for example having a new player unfriendly experience in this aspect with a hardly visible layer of roof game objects that are also normally unseen through regular game play but can have consequential gameplay effects, like said roof game

[51] Terraria, Re-Logic, Windows; MacOS; Linux, Re-Logic; 505 Games, 2011.

[52] Super Smash Bros., HAL Laboratory; Sora Ltd.; BANDAI NAMCO Studios Inc., Nintendo 64; Nintendo GameCube; Wii; Nintendo 3DS; Wii U; Nintendo Switch, Nintendo, 1999.

objects collapsing onto important different game objects. Though these kinds of games have also experimented with fascinating storage solutions in conjuncture with their interactive spaces. Most of these storage solutions have to do with the fact of a different gameplay focus. Games like Starbound and Terraria are exploration adventure games with a player avatar focus and a sandbox that encourages self-expression through artistic construction. Games like Stardew Valley Rimworld and Factorio however focus their gameplay loop on an economical land use which unifies them by giving the player a "bird's eye" perspective. Stardew Valley lets the player use digital land for digital agriculture. With the produce game objects being able to be sold to later acquire other useful game objects, or they can be gifted to increase the social standard of the player avatar in the game. Factorio as a more industrial coated game lets the player develope the land with game objects, inspired by heavy industry, that can either extract other game objects of transform game objects, while also having a strong focus on automation. This is of special interest for this Thesis since the space with loads of interactivity can be displaced. With automation negating the need for player interaction, which can lead to a consolidation of interactivity to a specific space and using transportation game objects to increase traversal speed, which in turn makes the space the player avatar can easily interact with larger. Factorio however still uses a user interface for storage, while Rimworld has a more unconventional method for storage. Rimworld itself does not let the player interact with dense spaces through a player avatar. Instead, the player controls the timetable of multiple digital actors that perform tasks in the game space. Though the focus of the player is tilted towards optimising the space footprint and interaction spaces for the digital actors since the task productivity of these digital actors is most of the time determined by how effectively they can get to the interaction spaces for tasks and additionally for some tasks the distance to stored materials that are required for tasks. Those stored materials in this case are represented by game objects being put into digital structures functionally similar to warehouses, with every stored material game object never being abstracted into a storage container, leading to an impactful cost for storage as game objects are just laid on the floor. So denser interactive spaces in Rimworld are there for defined by minimizing traversing time for digital actors to different interaction spaces. [53] [54] [55] [56] [57]

So, with all this mentioned two-dimensional games can employ previously stated ideas for space optimisation with relative ease, even ideas involving multidimensionality by hoping to alternative universes. Dwarf Fortress for example allows the player to look at multiple two-dimensional layers to create an understanding of three-dimensional space with each layer being a two-

[53] RimWorld, Ludeon Studios, Windows; macOS; Linux, Ludeon Studios, 2018.

[54] Factorio, Wube Software, Windows; macOS; Linux; Nintendo Switch, Wube Software, 2020.

[55] Starbound, Chucklefish, Windows; macOS; Linux, Chucklefish, 2016.

[56] Terraria, Re-Logic, Windows; macOS; Linux, Re-Logic; 505 Games, 2011.

[57] Stardew Valley, ConcernedApe, Android; iOS; Windows; macOS; Linux; Nintendo Switch; PlayStation 4; PlayStation Vita; Xbox One, ConcernedApe; Chucklefish, 2016.

dimensional view at a certain height.[58] The Key characteristic of two-dimensional spaces in games is the ability of the player to have almost all game objects in sight which cuts out memorisation of interactable game objects in a higher dimensional interactive space. Since all of the game objects in reach of the avatar are also in sight of the player. The flip side of the characteristics is also that there is less space to put game objects into. Meaning that it will take more effort and ideas to keep all the interactive game objects in reach of the player avatar, lacking an entire dimension of possible design optimisation. Alternatively living with the consequences of the player avatar needing to move around to get to the interactive game objects.

Virtual Reality and Augmented Reality

Augmented Reality in the realm of games is a display projected over the non-digital world, most often found on phones or dedicated hardware systems like the Apple Vision Pro.[59] Augmented Reality also is the base of Pokémon Go,[60] a game adequately described as having been a phenomenon at one point[61]. Augmented Reality thrives on its unique level of interaction with the environment. The most successful endeavours in the field, create a digital space that uses the non-digital space as a starting point and building on it.[62] The digital space is then conveyed to the player through the device of choice of the player. Though most Augmented Reality Games thrive on adding interactivity to spaces with some having an interesting focus on exploring non digital spaces that gain added interactivity through the game. Giving the players reasons to explore their surroundings or view them from a different lens. Exploration based Augmented Reality games however have recently experienced a culling because of a once in a generation pandemic, which rendered the core gameplay loop hard to execute. With the highest profile shut down being Minecraft Earth.[63] Of course there are still Augmented Reality games, however Augmented Reality games that let the player redecorate their own living space, that benefit from the well-designed spaces provided by inhabiting non digital spaces designed for humans to inhabit as well as profiting from the more immersive experience provided by using the player as the anchor for the player avatar, seem to be rather sparse. Though Augmented Reality could serve as an option to easily add decorations to the room for the

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[58] Dwarf Fortress, Bay 12 Games, macOS; Linux; Windows; GeForce Now, Kitfox Games, 2006

[59] Apple Inc.: Apple Vision Pro.

https://www.apple.com/apple-vision-pro/ (last visited 18.5.2024).

[60] Pokémon GO, Niantic, Android; iOS, The Pokémon Company; Nintendo, 2016.

[61] Duffy, Connor: What is social media phenomenon Pokémon Go?.

https://www.abc.net.au/news/2016-07-11/what-is-pokemon-go/7587346 (last visited 18.5.2024).

[62] Roos, Long: Top 21 Augmented Reality Games, The Next Evolution of Mobile Gaming is now available on IOS & Android.

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[63] Mojang Staff: MINECRAFT EARTH COMING TO AN END, Let's give it a proper send-off.

https://www.minecraft.net/de-de/article/minecraft-earth-coming-end (last visited 18.5.2024).

player or add extra interactivity and functionality to the spaces the player already inhabits.

Virtual Reality on the other hand is the focus on complete immersion of the player and while Alternate Reality fuses the avatar and the player character through a technological interface. Virtual Reality is linking the player avatar and the player on more points meaning it is a more complete fusion between the two. Fusion in this context refers to the player avatar receiving inputs by the player over actions mimicking the actions taken by the player like grabbing things. Furthermore the visual inputs in the player avatar are also following the eyes or visual input of the player. Basically, making the avatar an extension of the player more so than a puppet being controlled by the player. The most noticeable part where the fusion falls short is physical restraint of movement experienced either by the player or player avatar. Which arrives from the fact that the Virtual Reality space is not fused with the non-digital space of the player. This shows when the player avatar is unable to exit a specific space like the boxing ring in games like Creed: Rise to Glory [64] while the player might have more non-digital space beyond the digital space of the game that the player could physically move to which disrupts the feeling of fusion. Of course, the opposite is also true with players trying to navigate the digital space while accidently crashing into the limitations of their non-digital space. This also comes with some oddities that can be uniquely concerning for Virtual Reality games. In a game that is not set in Virtual Reality, the designer can control the height of the space and the height of the player avatar while in Virtual Reality games the difference is depending on height of the player. Another attribute to be thoughtful of is that looking up for the player engages their neck muscles in contrary to games not set in Virtual Reality, that use a simple twitch upwards to the input device. Having the player's neck muscles engaged for prolonged interaction periods can be uncomfortable and therefore a sub optimal design choice. Of course, there is also benefit since in Virtual Reality Interaction is no longer tied to game objects visually present to the player avatar. As well as having double the interaction possibilities with 2 controllers for the player allowing for more possibilities to do interactions simultaneously. Though while there is almost no struggle with most handheld game objects, game objects in the form of structures can cause an avatar and player to disconnect with the consequences that either the player phases through game objects or the player can move their head while the avatar cannot, or the player has problems navigating a structure because of complications with the non-digital space. This is most often the case with Virtual Reality shooters, like Hot Dogs, Horseshoes & Hand Grenades [65] since they benefit from leaning around corners and can spook the player into sudden movement without awareness of the non-digital space.

To proceed to the topic of combining previous design ideas in combination with Virtual Reality and Augmented Reality. The main Advantage of both of these ways to experience game is their natural high immersion. This Immersion is created by

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[64] Creed: Rise of Glory, Survios, Windows; PlayStation 4; PlayStation VR; Oculus Quest; PlayStation 5; PlayStation VR2, Survios, 2018.
[65] Hot Dogs, Horseshoes & Hand Grenades, RUST LTD., Windows, RUST LTD., 2016.

how close the experience of the player avatar and player can be shared. Creating as previously mentioned the unique experience that Virtual Reality offers. Having what the player avatar sees and what the player avatar can interact with, no longer tied to one another. Since its a translation of physical space to digital space the player and their avatar become a coupled being and therefor a player's movement can move the avatar allowing a more natural feel of shifting the player avatar's perspective. Basically, no longer using the centre of the screen or a broad area around the player avatar to select things to interact with, instead using the hand controllers that are coupled to the player avatar to interact with game objects. Also, most often increasing the connection points which players use to interact from 1 to 2 allowing skilled players to have more opportunity to interact. This also leaves the opportunity open to add more connection points the player can use for interaction maybe having a player character with 4 hand game objects that are controlled by 2 players. Though this also changes the space the player can use for interaction from a spherical shape around the player avatar into a cylindrical shape for the player avatar which is cantered around the player's torso, since the player and player avatar are somewhat linked. This will also engage the player more letting the players use their knees to pick things up for example or cover small distances while moving around. On the other side the player will have slightly more trouble controlling the player avatar for prolonged periods of time, because the player avatar and player are linked the player's body is also being fatigued with the neck being already a previous point of concern. In addition, while the player can go to their knees it is probably not a great idea to rely on this action in the game, so the game is less physically demanding and game objects more designed to be at arm's length of the player then in what the player can reasonably grasp. Furthermore, as mentioned the height of the player avatar is usually not set. While the developer can assume a happy medium for their interaction space it is probably not a bad idea to take into consideration how the people with exceptional heights deal with these situations or just assume that those people will have adjusted their height with their device if at all possible. This leads to the idea that many design ideas of interaction are applicable to virtual reality and the only troublesome area might be Multidimensionality where concepts should be checked for their nauseating potential. Augmented Reality has a weirder way of interaction. Since a lot of augmented reality games uses a phone as a platform so the entire touch screen is the space the player uses to interact while also being the lens the player sees the game with or in terms of the game the camera game object. Of course, there are different platforms like the Apple Vision Pro.[66] But the phones as a platform are also a big share of the market.[67] With phones comes also limitations mostly from the performance and battery life of the hardware as well as considerations how interactive the space could be since interacting with the phone also blocks of part of the screen and therefor part of the interactive space. Also,

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[66] Apple Inc.: Apple Vision Pro.

https://www.apple.com/apple-vision-pro/ (last visited 18.5.2024).

[67] Wijman, Tom: Newzoo's year in review: the 2023 global games market in numbers.

https://newzoo.com/resources/blog/video-games-in-2023-the-year-in-numbers (last visited 18.5.2024).

game objects have to be a certain size to be visible as well as being able to be pressed without issue with a human finger. Of course, the benefit of the platform phone is that it is the most accessible way to create a more immersive space that the player can walk around in making it ideal for Augmented Reality games that use the space of the non-digital world to build on top off. Their adherence to build on already established space makes Multidimensionality hard to implement and the medium seems to function best with ideas of abstraction using user interfaces to give the player the best possibility to interact while not needing to always obstruct the screen.

Conclusion

this Thesis discussed different ideas and concepts to create better interactable spaces and their possible implementation. Some of the examples even included modifications made to games by the fanbases of said game. So, if these discussed ideas are not revolutionary in nature, then why do we tend to see similar solutions or lack of solutions for the problems the player can run into, in this Thesis.

This probably has to do with how spaces with lots of interactive game objects are approached during game development. It is most of the time not a feature that is inherently designed as part of the game and the important gameplay experience, more so the metaphorical dirty dishes that are created by other features that were focused on by game development, that now need to be cleaned up. This is not inherently a bad thing. In the opinion of this Thesis a game should focus on its fun gameplay aspects to make it the best product it can be while minimising things that could take away from the enjoyment of the player.

The questions then remaining are can there be made time in development for the ideas the Thesis suggests or else can a well created dense interaction space be a fun addition to the gameplay. The Thesis believes that these ideas can be added time efficiently if the game is built around the aforementioned ideas. Since most of these ideas revolve around a system implemented into the game like an inventory system or a rendering system for dimensions higher then a third dimension. In the opinion of this Thesis, it is easier to build systems first and then develop games on top of these systems then trying to slot a system in afterwards when most things are built and hope that something like a system that interacts with multiple facets of the game is not causing trouble with those facets of the game. This Thesis also believes that with the system in place the system can also be modified to help the vision of the game and that for an example an inventory system should be modified during development to adjust to the vision of the game. Therefor the Thesis believes that it should be possible with somebody putting in effort for the idea of better interactive spaces to be included in games.

Now if the question is if interactive spaces could be a fun addition to the gameplay the answer this Thesis finds is less straightforward since a lot of players derive their fun from different things evident by all the different types of games and how

players interact with them. Cooking Simulator could be an example of an interactive space that is fun since the fun is derived from interacting with the space to its fullest potential be it achieving mastery over the space representing a kitchen or using fire game objects to burn it all to a crisp.[68] Virtual Reality games with their gameplay making the player feel like they are in the digital space of the game with restrictive elements to the player's movement also lend themselves to interactive spaces. With a game space that has a lot of interactive things surrounding the player avatar fitting easily into the restrictions of Virtual Reality and being enhanced by the benefits of virtual reality. Of course, these examples have interactive spaces at their core of the gameplay, so a player who likes these ideas for games is probably inclined to think that interactive spaces are fun. So could games with interactive spaces as a necessity from other parts of the game be fun. In Minecraft building interactive spaces encourages the player to build in the digital space. The larger the required amount of storage game objects the larger the digital footprint being taken up in the digital space the more the player is invited to build. Though storage can grow bigger than the space the player avatar can reasonably interact with and without specialist knowledge the interactive space cannot be decreased in size by the player which makes it reach the point of tedium in the eyes of the Thesis.[69] Beyond Minecraft the only ideas to progress beyond the point of tedium is an idea of avoidance a wonder machine that bundles interactive game objects together avoiding the idea of making the interactable space fun by making it brutally efficient to spend the least amount of time in those spaces and let the player return to the parts of the game that they could be considered more fun. However, the Thesis believes that an interactive space can offer a moment of closure for other parts of the game. For example, after overcoming a challenge in the game one of the rewards could be the expenditure of the interactive space giving access to a new interactive item as a decoration. Another way could be by giving the player more creative ownership of the digital space letting them rearrange the space and having loads of game objects with interactive elements to decorate the space with. Similar how humans adjust the non-digital spaces they inhabit. The Thesis hopes that these ideas would lead to a more fun secondary interactive space in games.

Now with the discussion of the previous topics concluded the Thesis ideal purpose was to inspire the reader and communicate ideas about interactive spaces. So hopefully if this Thesis falls short of its ideals the current reader still found something in this Thesis.

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[69] Minecraft, Mojang Studios, Windows; MacOS; Linux, Mojang Studios, 2011 (Java Edition).

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