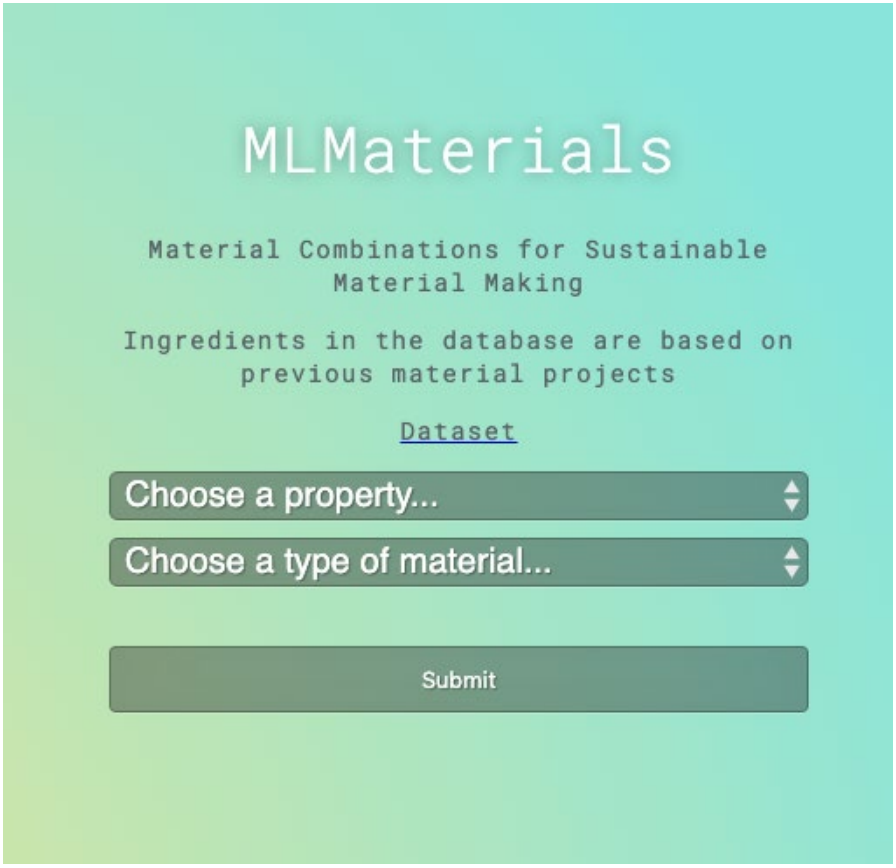


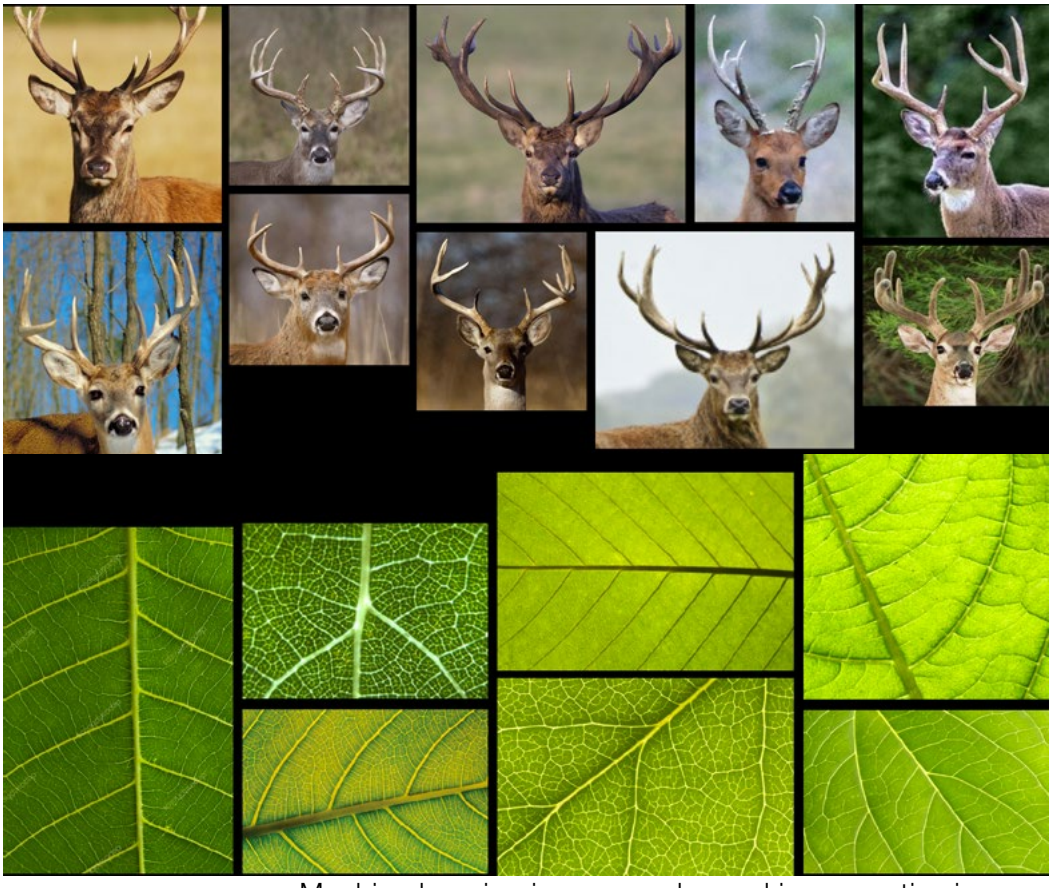
Masters of Craft:
Programming - Machine Learning
: Research

Janet Choi

Machine Learning

Machine Learning is a trend and common keyword that shown in products and services. Some people criticize machine learning is not accurate because it is possible to have bias, which is affected by how people select and handle the datasets. However, accuracy could be enhanced by combination of better training models, more instances for training and unsupervised training.

Because of the my interests of topics, supervised training will be used as datasets will be created by myself. Machine learning is applicable in many industries because of its ability to handle data, including numbers, images, videos, text and sound.



Machine learning is commonly used in generative images

Engage with Expert

Dr. Daniel Polani - University of Hertfordshire

Dr. Polani is a professor from the School of Computer Science, University of Hertfordshire. His works focused on Artificial Intelligence: finding out the ways of problem-solving from natural intelligence and behaviors of animals.

Machine Learning Used in Medicine

He shared an article from Nature, which is “How artificial intelligence is changing drug discovery”, focused on how machine learning could be a method to enhance the efficiency and effectiveness on the process of discovering new drugs. For example, Pfizer uses IBM Watsons System; it is believed that machine learning would be beneficial for lowering costs and saving time. Although my project is not related to drug or medical industry, the concept of to my project aim.

The incentive of my project is to connect machine learning to material futures. But in what ways? It is about the sustainability inside the project, rather than the material of the project. The material is a medium to show the concept, yet how the whole system can be operated to bring the material be sustainable in different aspects is the most essential part.

Machine Learning Bias: Suggestions

Dr. Polani suggested that using datasets required careful analysis and thorough understanding of the data, for it could be the cause of machine learning bias, which would lead to inaccurate results. However, concerning my project, it is impossible to use unsupervised learning as I cannot initialize a character for the model. He advised that I should give more instances for the model to find out the possible results. The more the examples, The more accurate the results.

Originally, I only have 40 examples from MA Material Futures catalogue and Radical Matter; Later on, I kept on looking for related projects from books, online portfolios and videos. The on-going dataset consists of 80 projects.

Engage with Community

Participating in Hackathon

Start from Basics

Pedro Mendonca is a mentor at Hack Brunel, a hackathon organized by University of Brunel, and he is a software engineer as well. Since I have no experience in software development, I was puzzled to learn Python and machine learning in a short period of time, and more importantly, I need to create a project that can advocate my aim.

Before this project, I tried to learn JavaScript for web development but I was hindered in the learning journey. He told me to stay focus on learning the basics of Python, for Python is a minimal language for beginners. I need to understand the logic of the programming language before I learn from project-based tutorials. Although I did not have enough time to learn thoroughly in Python, the practices of typing codes - think about the solution, refer to documentation, look for references and find out suggestions on Stack-flow helped me to develop my programming skills in the future.

Python Model to Production

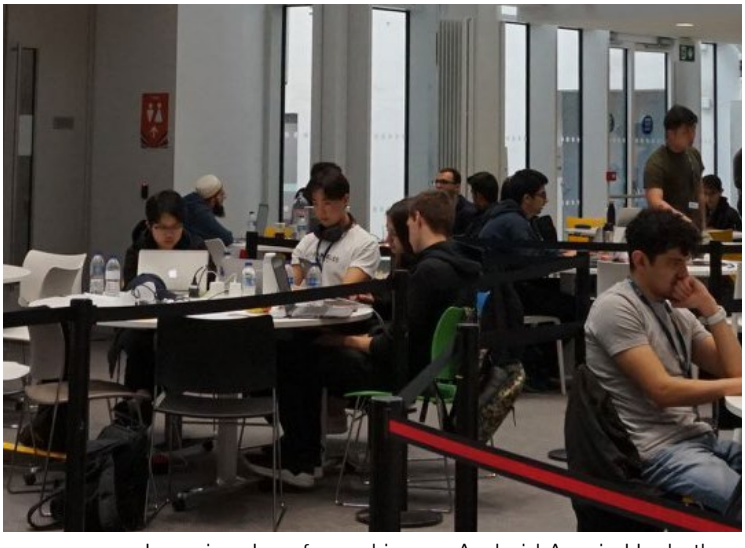
Although comparing to C++ or C, Python is not the fastest language, my priority is to learn machine learning efficiently, so I chose Python for my ML project. However, I need to think about how the library can be used in the future, which implies an issue of sustainability.

As a result, I joined a workshop of Flask and API. Flask is a web framework that can deploy python scripts to be implemented as a web application. It is used in my final example - a web app.

Visions on Programming

In the hackathons, I discussed my project with students from BSc Computer Science, Kings College London. They shared that how they learn programming and suggested that I should learn C++ and Java if I want to continue my project to another extent. Learning C++ would be very challenging, yet it can train up my logical thinking, which would be beneficial for me to think in different perspectives for not only this project, but also other upcoming projects.

Learning Using API, JSON and Flask with Python



Learning Java for making an Android App in Hackathon

Engage with Community

Reaching out: Workshops and Talks

In order to understand the application of machine learning, other than online resources, I attended different talks and workshops related to machine learning and also its frameworks.

Art & Visuals

In the “Machine visions: an exploration of art, AI and creativity” Talk, I was inspired by the works by Anna Ridler and Alex Graves, who are an artist and a research scientist respectively.

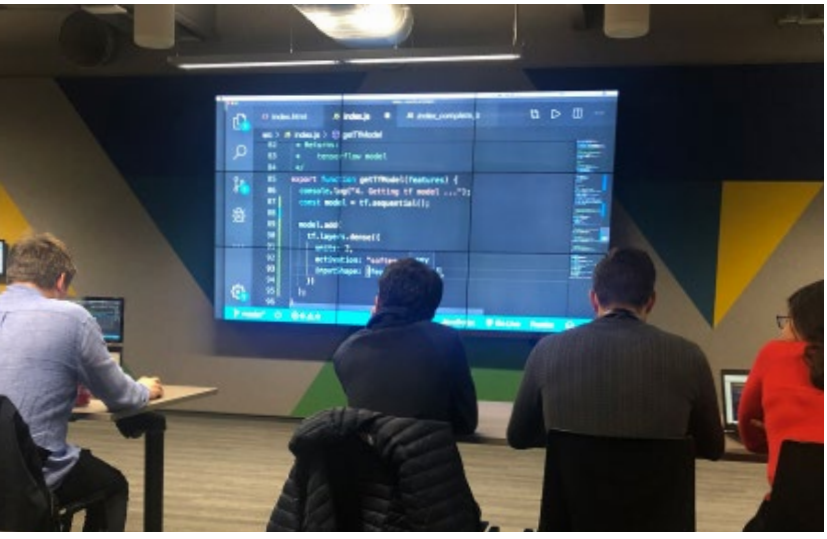
Anna shared her idea development of the Tulip project. She made her own database of more than a thousand of tulip pictures, so as to build up a machine learning model to show the blooming flower. The use of machine learning in this project is a medium to show the ironical side of block-chain, which leads me to rethink how I can provoke the meaning in my project.

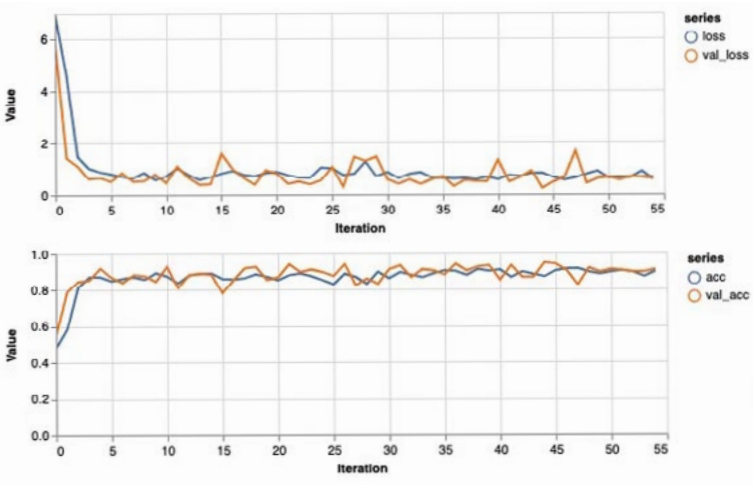
Classification

Other than talks, I also went to workshops. One of them talked about how to create a machine learning model with the use of Tensorflow.js and logistic regression, where we can use a dataset to find out the probability of a real or fake Instagram profile. In this session, I realized that creating a new training model from scratch would be very challenging. Therefore, I began to look for similar algorithm to my project background as a material library. Therefore, I found out association rule training and Apriori algorithm to learn.

Commercial & Data Analysis

In Pytorch London talk, the research scientist from Monzo was invited to share their new research on the language model for customer services. He talked about the classification approach for suggesting solutions for customers’ inquiries. Sometimes, old training models only analyzed the keywords, so it is possible to misunderstand the actual needs of the customer. Therefore, the team changed the approach - using separate classifier models, and compare the results, so that the accuracy can be improved.

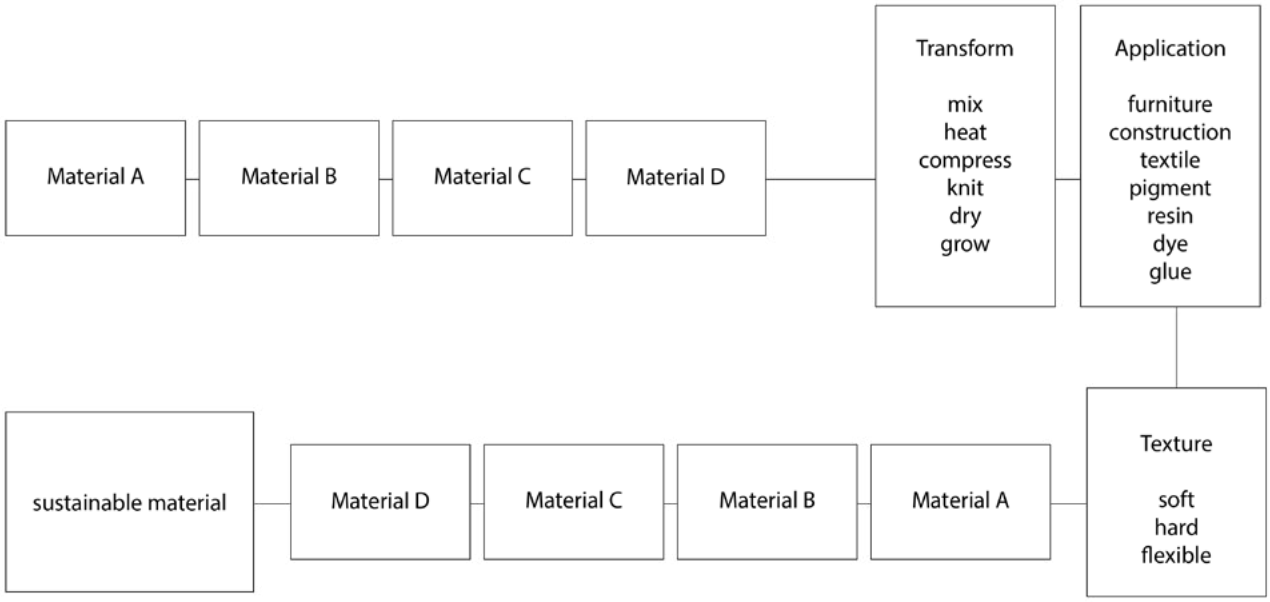




Learning Tensorflow.js for classification model

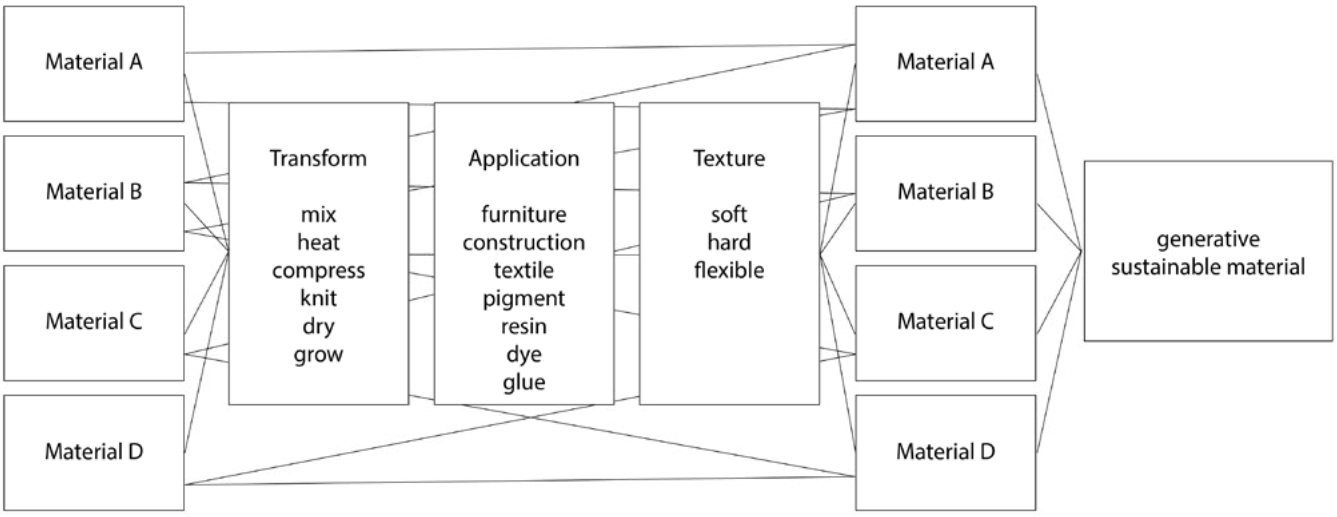
Program Work-flow version 1

Problem:
- lack of algorithm and classification model
- need to construct the relationship between features



Program Work-flow version 2

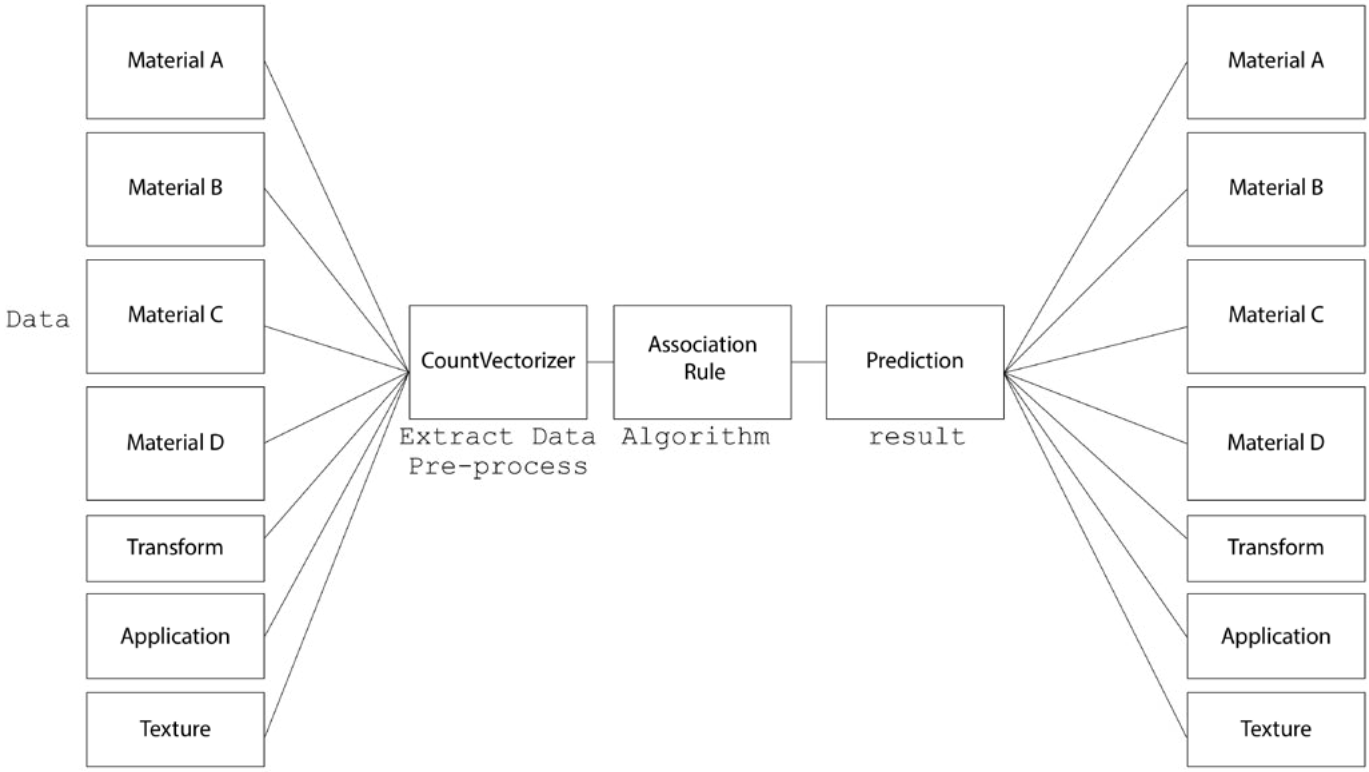
Problem:
- neural network is advanced
- the content of this library is not suitable for
  natural language Processing (NLP)



Program Work-flow Final Version

- Association Rule Learning
- suggest related combination according to materials, applications, textures and keywords
- Algorithm: Apriori Algorithm / Cosine Similarity

Further Development:
- generative model: combine different ingredients



Supervised Learning

with Association Rule Learning

Machine Learning is available in many types of language, but python is the most commonly used language with Tensorflow, a popular Machine Learning Framework.

These frameworks provide a rich support to create complex models for training and analyzing the data for further development. Other than Tensorflow and Pytorch, it is possible to look for solutions in other operation systems, such as Swift for iOS and MacOS with the use of CoreML and CreateML, which are the initial machine learning frameworks for building applications which are compatible for mobile devices and desktop software.

Cosine Similarity

This model is used in the project according to the models and examples that were originally created for recommendation engines.

According to “A Novel Modified Apriori Approach for Web Document Clustering”, although it is not flawless, it is used in different industries extensively, such as recommendation engine. It calculates the divergence between 2 elements. In commercial practice, companies utilize this algorithm to incorporate with other data, such as other users’ favourites, to enhance the effectiveness of the recommendation.

Apriori Algorithm

As a further development, I will concern Apriori Algorithm as an alternative for my project because of its utilize sequencing methodology in item sets. According to “An Empirical Study of Document
Similarity and Term Extraction Using Apache Spark”, it is used to determine which individual item and group of items appear frequently, so this is also similar to the conditions used in the library for generate possible combinations of materials.

Example:

Distinguished {algae, animal, bioresin, chemical, dust, food, fungi, glass, glycerine, human, insect, metal, mineral, oil, paper, plant}

=> {algae, glycerine, water}

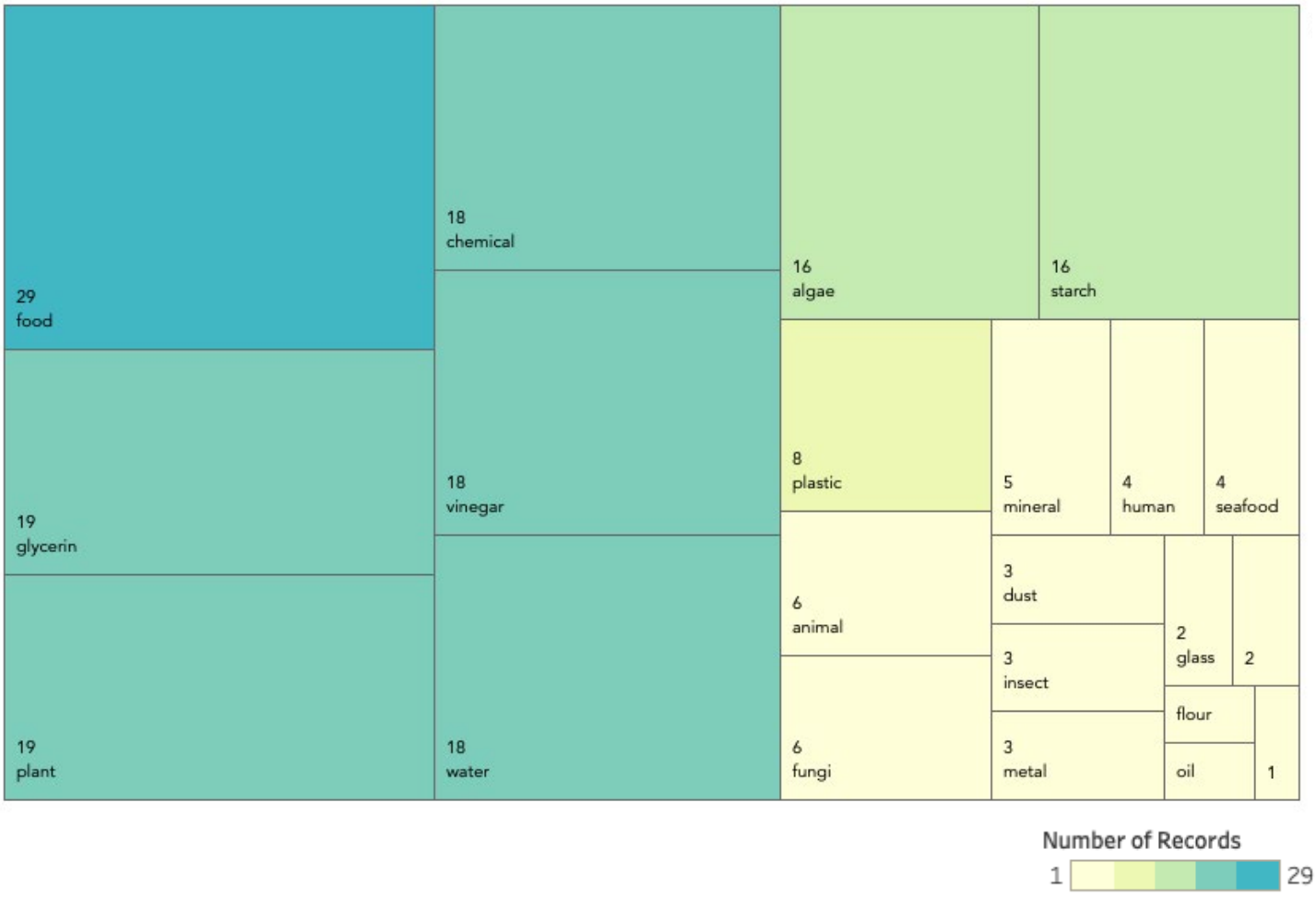
Support(algae)

=(Number of combinations involved algae)/ (Total number of projects)

=14/80=0.175

Data Analysis

visualizing the data



Frequent Combination of Materials

main waste/leftover (e.g. food)
+
collagen (e.g. crustacean in seafood)
OR
thickening agent (e.g. glycerin)
+
humectant (e.g. oil)
+
acid (e.g. vinegar)

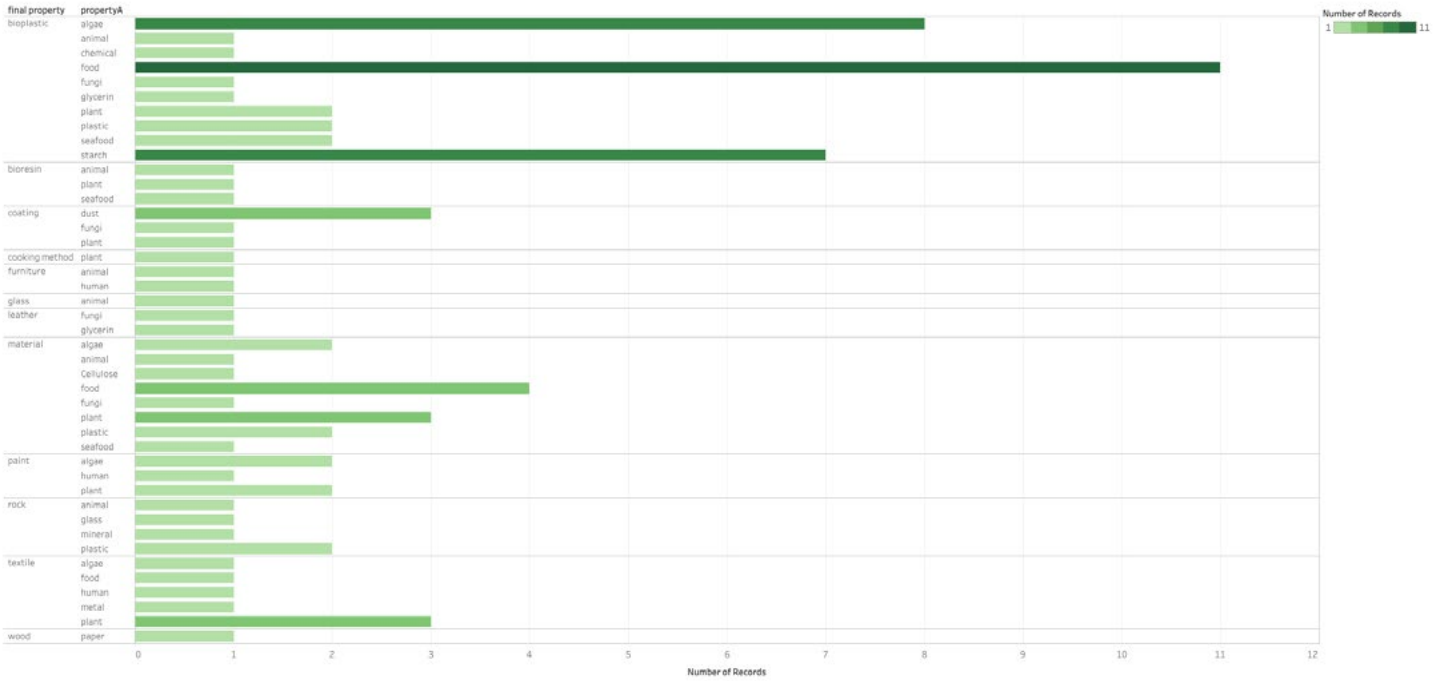
While preparing the dataset, I found that the data of sustainable materials shown some stories behind.

Types of Ingredients

Through observing from the combination of material, it is quite obvious that the sustainable materials projects utilize ingredients together - main waste/ leftover (e.g. food), thickening agent (e.g. glycerin), humectant (e.g. oil), acid (e.g. vinegar) and collagen (e.g. crustacean in seafood).

As a result, as a further development, I will change the categorization of ingredient according to the use, rather than the type.

Data Analysis
visualizing the data



Ingredients to Properties

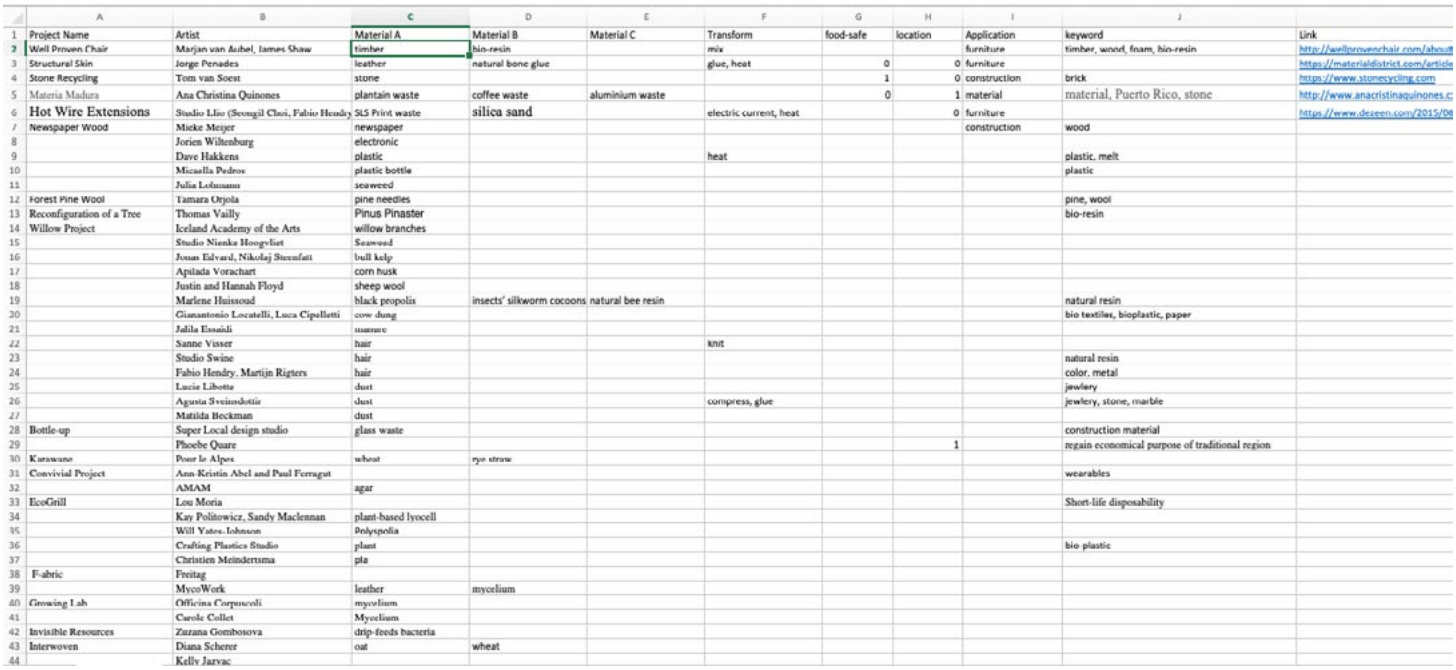
Algae, glycerin and starch are widely used as a thickening agent. These ingredients are tended to result in bioplastic, for their elasticity and transparency in materiality.

In the session of bioplastic, it's ironic to see plastic as the ingredient for the material making. Even though it aims to reuse the plastic wastes, it is critical to think how this kind of material can be sustainable in other than a conceptual way.

Because of the fiber, plants are inclined to produce textile according to their natural structure, which could be strong and endurable.

Process

Prepare Data for Extraction



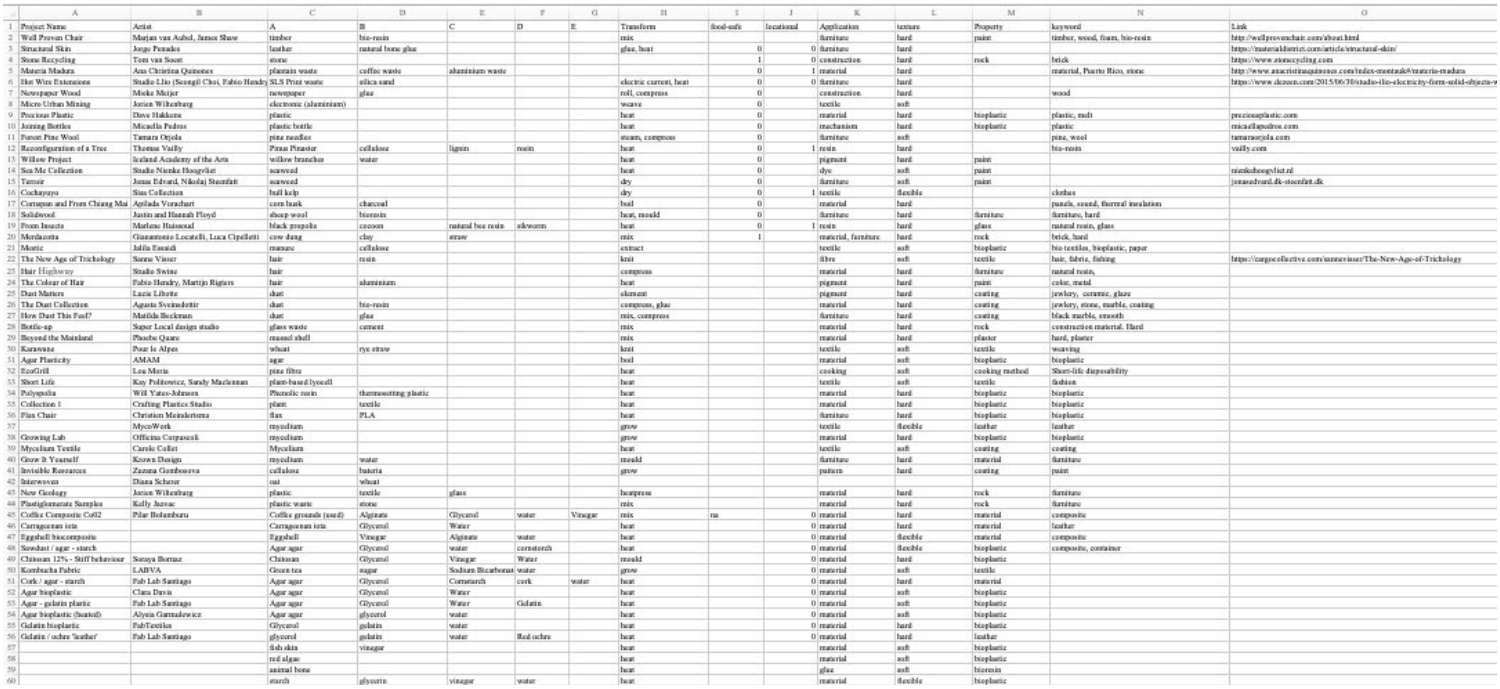
	A	B	C	D	E	F	G	H	I	J	Link
1	Project Name	Artist	Material A	Material B	Material C	Transform	food-safe	location	Application	keyword	Link
2	Well Proven Chair	Marjan van Aubel, James Shaw	timber	bio-resin		mix			furniture	timber, wood, foam, bio-resin	http://wellprovenchair.com/about
3	Structural Skin	Jorge Penades	leather	natural bone glue		glue, heat	0	0	furniture		https://materialdistrict.com/article
4	Stone Recycling	Tom van Soest	stone				1	0	construction	brick	https://www.stonecycling.com
5	Materia Madura	Ana Christina Quinones	plantain waste	coffee waste	aluminium waste		0	1	material	material, Puerto Rico, stone	http://www.anacristinaquinones.c
6	Hot Wire Extensions	Studio Lilo (Seongil Choi, Fabio Hendry	SLS Print waste	silica sand		electric current, heat		0	furniture		https://www.dezeen.com/2015/08
7	Newspaper Wood	Mieke Meijer	newspaper						construction	wood	
8		Jorien Wiltenburg	electronic								
9		Dave Hakkens	plastic			heat				plastic, melt	
10		Micaella Pedros	plastic bottle							plastic	
11		Julia Lohmann	seaweed								
12	Forest Pine Wool	Tamara Orjola	pine needles							pine, wool	
13	Reconfiguration of a Tree	Thomas Vailly	Pinus Pinaster							bio-resin	
14	Willow Project	Iceland Academy of the Arts	willow branches								
15		Studio Nienke Hoogvliet	Seaweed								
16		Jonas Edvard, Nikolaj Steenfatt	bull kelp								
17		Apilada Vorachart	corn husk								
18		Justin and Hannah Floyd	sheep wool								
19		Marlene Huissoud	black propolis	insects' silkworm cocoons	natural bee resin					natural resin	
20		Gianantonio Locatelli, Luca Cipelletti	cow dung							bio textiles, bioplastic, paper	
21		Julila Essaidi	manure								
22		Sanne Visser	hair			knit					
23		Studio Swine	hair							natural resin	
24		Fabio Hendry, Martijn Rigters	hair							color, metal	
25		Lucie Libotte	dust							jewlery	
26		Agusta Sveinsdottir	dust			compress, glue				jewlery, stone, marble	
27		Matilda Beckman	dust								
28	Bottle-up	Super Local design studio	glass waste							construction material	
29		Phoebe Quare						1		regain economical purpose of traditional region	
30	Karawane	Pour le Alpes	wheat	rye straw							
31	Convivial Project	Ann-Kristin Abel and Paul Ferragut								wearables	
32		AMAM	agar								
33	EcoGrill	Lou Moria								Short-life disposability	
34		Kay Politowicz, Sandy Maclennan	plant-based lyocell								
35		Will Yates-Johnson	Polyspelia								
36		Crafting Plastics Studio	plant							bio plastic	
37		Christien Meindertsma	pla								
38	Fabric	Freitag									
39		MycoWork	leather	mycelium							
40	Growing Lab	Officina Corpuscoli	mycelium								
41		Carole Collet	Mycelium								
42	Invisible Resources	Zuzana Gombosova	drip-feeds bacteria								
43	Interwoven	Diana Scherer	oat	wheat							
44		Kelly Jazvac									

Dataset version 1

It only had about 40 examples in the dataset. The data was collected from MAMF catalogue and ***Radical Matter: Rethinking Materials for a Sustainable Future***, a book by Caroline Till and Kate Franklin. The categories are mainly determined by the information available from the work description and further research online.

Process

Prepare Data for Extraction



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Project Name	Artist	A	B	C	D	E	Transform	food-safe	locational	Application	texture	Property	keyword	Link
2	Well Proven Chair	Marjan van Aubel, James Shaw	timber	bio-resin				mix			furniture	hard	paint	timber, wood, foam, bio-resin	http://wellprovenchair.com/about.html
3	Structural Skin	Jorge Penadés	leather	natural bone glue				glue, heat	0	0	furniture	hard			https://materialdistrict.com/article/structural-skin/
4	Stone Recycling	Tom van Soest	stone						1	0	construction	hard	rock	brick	https://www.stonecycling.com
5	Materia Madera	Ana Christina Quinones	plantain waste	coffee waste	aluminium waste				0	1	material	hard		material, Puerto Rico, stone	http://www.anachristinaquinones.com/index-montaje8/materia-madera
6	Hot Wire Extensions	Studio Lilo (Seongil Choi, Fabio Hendy)	SLS Print waste	silica sand				electric current, heat	0	0	furniture	hard			https://www.dezeen.com/2015/06/30/studio-lilo-electricity-form-solid-objects-v
7	Newspaper Wood	Mieke Meijer	newspaper	glue				roll, compress	0		construction	hard		wood	
8	Micro Urban Mining	Jorian Wilmelburg	electronic (aluminium)					weave	0		textile	soft			
9	Precious Plastic	Dave Hakkens	plastic					heat	0		material	hard	bioplastic	plastic, melt	preciousplastic.com
10	Joining Bottles	Micaella Pedros	plastic bottle					heat	0		mechanism	hard	bioplastic	plastic	micaellapedros.com
11	Forest Pine Wool	Tamara Orjola	pine needles					steam, compress	0		furniture	soft		pine, wool	tamaraorjola.com
12	Reconfiguration of a Tree	Thomas Vailly	Pinus Pinaster	cellulose	lignin	resin		heat	0	1	resin	hard		bio-resin	vailly.com
13	Willow Project	Iceland Academy of the Arts	willow branches	water				heat	0		pigment	hard	paint		
14	Sea Me Collection	Studio Nienke Hoogvliet	seaweed					heat	0		dye	soft	paint		nienkehoogvliet.nl
15	Tarmor	Jonas Edvard, Nikolaj Steenfatt	seaweed					dry	0		furniture	soft	paint		jonasedvard.dk-steenfatt.dk
16	Cochayuyo	Sina Collection	bull kelp					dry	0	1	textile	flexible		clothes	
17	Corruption and From Chiang Mai	Apilada Vorachart	corn husk	charcoal				boil	0		material	hard		panels, sound, thermal insulation	
18	Solidwool	Justin and Hannah Floyd	sheep wool	bioresin				heat, mould	0		furniture	hard	furniture	furniture, hard	
19	From Insects	Marlene Huissoud	black propolis	cocoon	natural bee resin	silkworm		heat	0	1	resin	hard	glass	natural resin, glass	
20	Mordacotta	Gianantonio Locatelli, Luca Cipelletti	cow dung	clay	straw			mix	1		material, furniture	hard	rock	brick, hard	
21	Mortic	Jalila Essaidi	manure	cellulose				extract			textile	soft	bioplastic	bio-textiles, bioplastic, paper	
22	The New Age of Trichology	Sanne Visser	hair	resin				knit			fibre	soft	textile	hair, fabric, fishing	https://cargocollective.com/sannevisser/The-New-Age-of-Trichology
23	Hair Highway	Studio Swine	hair					compress			material	hard	furniture	natural resin,	
24	The Colour of Hair	Fabio Hendry, Martijn Rigters	hair	aluminium				heat			pigment	hard	paint	color, metal	
25	Dust Matters	Lucie Libotte	dust					element			pigment	hard	coating	jewlery, ceramic, glaze	
26	The Dust Collection	Agusta Sveinsdottir	dust	bio-resin				compress, glue			material	hard	coating	jewlery, stone, marble, coating	
27	How Dust This Feel?	Matilda Beckman	dust	glue				mix, compress			furniture	hard	coating	black marble, smooth	
28	Bottle-up	Super Local design studio	glass waste	cement				mix			material	hard	rock	construction material. Hard	
29	Beyond the Mainland	Phoebe Quaro	mussel shell					mix			material	hard	planter	hard, planter	
30	Karawane	Pour le Alpes	wheat	rye straw				knit			textile	soft	textile	weaving	
31	Agar Plasticity	AMAM	agar					boil			material	soft	bioplastic	bioplastic	
32	EcoGrill	Lou Morin	pine fibre					heat			cooking	soft	cooking method	Short-life disposability	
33	Short Life	Kay Politowicz, Sandy Maclennan	plant-based lyocell					heat			textile	soft	textile	fashion	
34	Polypsolin	Will Yates-Johnson	Phenolic resin	thermosetting plastic				heat			material	hard	bioplastic	bioplastic	
35	Collection 1	Crafting Plastics Studio	plant	textile				heat			material	hard	bioplastic	bioplastic	
36	Flax Chair	Christien Meindertsma	flax	PLA				heat			furniture	hard	bioplastic	bioplastic	
37		MycoWerk	mycelium					grow			textile	flexible	leather	leather	
38	Growing Lab	Officina Corpuscoli	mycelium					grow			material	hard	bioplastic	bioplastic	
39	Mycelium Textile	Carole Collet	Mycelium					heat			textile	soft	coating	coating	
40	Grow It Yourself	Known Design	mycelium	water				mould			furniture	hard	material	furniture	
41	Invisible Resources	Zanura Gumbsova	cellulose	bakteria				grow			pattern	hard	coating	paint	
42	Interwoven	Diana Scherer	oat	wheat											
43	New Geology	Jorian Wilmelburg	plastic	textile	glass			heatpress			material	hard	rock	furniture	
44	Plastiglomerate Samples	Kelly Jazvac	plastic waste	stone				mix			material	hard	rock	furniture	
45	Coffee Composite Co02	Pilar Bolumburu	Coffee grounds (used)	Alginate	Glycerol	water	Vinegar	mix	na	0	material	hard	material	composite	
46	Carrageenan iota		Carrageenan iota	Glycerol	Water			heat		0	material	hard	material	leather	
47	Eggshell biocomposite		Eggshell	Vinegar	Alginate	water		heat		0	material	flexible	material	composite	
48	Sawdust / agar - starch		Agar agar	Glycerol	water	cornstarch		heat		0	material	flexible	bioplastic	composite, container	
49	Chitosan 12% - Stiff behaviour	Sonaya Borraz	Chitosan	Glycerol	Vinegar	Water		mould		0	material	hard	bioplastic		
50	Kombucha Fabric	LABVA	Green tea	sugar	Sodium Bicarbonate	water		grow		0	material	soft	textile		
51	Cork / agar - starch	Pab Lab Santiago	Agar agar	Glycerol	Cornstarch	cork	water	heat		0	material	hard	material		
52	Agar bioplastic	Clara Davis	Agar agar	Glycerol	Water			heat		0	material	soft	bioplastic		
53	Agar - gelatin plastic	Pab Lab Santiago	Agar agar	Glycerol	Water	Gelatin		heat		0	material	soft	bioplastic		
54	Agar bioplastic (heated)	Alyein Garmadewee	Agar agar	glycerol	water			heat		0	material	soft	bioplastic		
55	Gelatin bioplastic	PabTextiles	Glycerol	gelatin	water			heat		0	material	hard	bioplastic		
56	Gelatin / ochre 'leather'	Pab Lab Santiago	glycerol	gelatin	water	Red ochre		heat		0	material	hard	leather		
57			fish skin	vinegar				heat			material	soft	bioplastic		
58			red algae					heat			material	soft	bioplastic		
59			animal bone					heat			glue	soft	bioresin		
60			starch	glycerin	vinegar	water		heat			material	flexible	bioplastic		

Dataset version 2 : add examples

After discussion with the expert, I added more examples so as to enhance the accuracy. Each material entry allows 5 ingredients. For the section of “food-safe” and “location”, it has difficulty to confirm the food safety and locational availability of ingredients, so many of them are not filled in. As I found that “link” may not be useful, so I started to leave it blank.

Process

Prepare Data for Extraction

A	B	C	D	E	Transform	Application	texture	Property
timber	bio-resin				mix	furniture	hard	paint
leather	natural bone glue				heat	furniture	hard	material
stone					mix	construction	hard	rock
plantain waste	coffee waste	aluminium waste			mix	material	hard	material
SLS Print waste	silica sand				electric current,	furniture	hard	material
newspaper	glue				roll, compress	construction	hard	wood
electronic (aluminium)					weave	textile	soft	textile
plastic					heat	material	hard	bioplastic
plastic bottle					heat	mechanism	hard	bioplastic
pine needles					compress	furniture	soft	textle
Pinus Pinaster	cellulose	lignin	rosin		heat	resin	hard	material
willow branches	water				heat	pigment	hard	paint
seaweed					heat	dye	soft	paint
seaweed					dry	furniture	soft	paint
bull kelp					dry	textile	flexible	textile
corn husk	charcoal				boil	material	hard	material
sheep wool	bioresin				heat	furniture	hard	furniture
black propolis	cocoon	natural bee resin	sikworm		heat	resin	hard	glass
cow dung	clay	straw			mix	material, furnit	hard	rock
manure	cellulose				extract	textile	soft	bioplastic
hair	resin				knit	fibre	soft	textile
hair					compress	material	hard	furniture
hair	aluminium				heat	pigment	hard	paint
dust					element	pigment	hard	coating
dust	bio-resin				compress,	material	hard	coating
dust	glue				compress	furniture	hard	coating
glass waste	cement				mix	material	hard	rock
mussel shell					mix	material	hard	plaster
wheat	rye straw				knit	textile	soft	textile
agar					boil	material	soft	bioplastic
pine fibre					heat	cooking	soft	cooking method
plant-based lyocell					heat	textile	soft	textile
Phenolic resin	thermosetting plastic				heat	material	hard	bioplastic
plant	textile				heat	material	hard	bioplastic
flax	PLA				heat	furniture	hard	bioplastic
mycelium					grow	textile	flexible	leather
mycelium					grow	material	hard	bioplastic
Mycelium					heat	textile	soft	coating
mycelium	water				mould	furniture	hard	material
cellulose	bateria				grow	pattern	hard	coating
oat	wheat							
plastic	textile	glass			heatpress	material	hard	rock
plastic waste	stone				mix	material	hard	rock
Coffee grounds (used)	Alginate	Glycerol	water	Vinegar	mix	material	hard	material
Carrageenan iota	Glycerol	Water			heat	material	hard	material
Eggshell	Vinegar	Alginate	water		heat	material	flexible	material
Agar agar	Glycerol	water	cornstorch		heat	material	flexible	bioplastic
Chitosan	Glycerol	Vinegar	Water		mould	material	hard	bioplastic
Green tea	sugar	Sodium Bicarbonate	water		grow	material	soft	textile
Agar agar	Glycerol	Cornstarch	cork	water	heat	material	hard	material
Agar agar	Glycerol	Water			heat	material	soft	bioplastic
Agar agar	Glycerol	Water	Gelatin		heat	material	soft	bioplastic
Agar agar	glycerol	water			heat	material	soft	bioplastic
Glycerol	gelatin	water			heat	material	hard	bioplastic
glycerol	gelatin	water	Red ochre		heat	material	hard	leather

Dataset version 3: trim data field

I preprocessed the unused data, such as “link”, “food-safe” and “location”, so it was more convenient for me to import and use the data in with the machine learning program in python.

Process

Prepare Data for Extraction

material a	material b	material c	material d	material e	transform	application	texture	property
timber	bio-resin				mix	furniture	hard	paint
leather	natural bone glue				heat	furniture	hard	material
stone					mix	construction	hard	rock
plantain waste	aluminium waste	coffee			mix	material	hard	material
sls print waste	silica sand				heat	furniture	hard	material
newspaper	glue				compress	construction	hard	wood
electronic (aluminium)					knit	textile	soft	textile
plastic					heat	material	hard	bioplastic
plastic bottle					heat	mechanism	hard	bioplastic
pine needles					compress	furniture	soft	textile
pinus pinaster	cellulose	lignin	rosin		heat	resin	hard	material
willow branches	water				heat	pigment	hard	paint
seaweed					heat	dye	soft	paint
seaweed					dry	furniture	soft	paint
bull kelp					dry	textile	flexible	textile
corn husk	charcoal				heat	material	hard	material
sheep wool	bioresin				heat	furniture	hard	furniture
black propolis	cocoon	natural bee resin	sikworm		heat	resin	hard	glass
cow dung	clay	straw			mix	material	hard	rock
manure	cellulose				grow	textile	soft	bioplastic
hair	resin				knit	fibre	soft	textile
hair					compress	material	hard	furniture
hair	aluminium				heat	pigment	hard	paint
dust					grow	pigment	hard	coating
dust	bio-resin				compress	material	hard	coating
dust	glue				compress	furniture	hard	coating
glass waste	cement				mix	material	hard	rock
mussel shell					mix	material	hard	material
wheat	rye straw				knit	textile	soft	textile
agar					heat	material	soft	bioplastic
pine fibre					heat	cooking	soft	cooking method
plant-based lyocell					heat	textile	soft	textile
phenolic resin	thermosetting plastic				heat	material	hard	bioplastic
plant	textile				heat	material	hard	bioplastic
flax	pla				heat	furniture	hard	bioplastic
mycelium					grow	textile	flexible	leather
mycelium					grow	material	hard	bioplastic
mycelium					heat	textile	soft	coating
mycelium	water				grow	furniture	hard	material
cellulose	bateria				grow	pattern	hard	coating
oat	wheat				mix	material	hard	material
plastic	textile	glass			compress	furniture	hard	rock
plastic waste	stone				mix	furniture	hard	rock
coffee ground	alginate	glycerol	water	vinegar	mix	material	hard	material
carrageenan iota	glycerin	water			heat	material	hard	material
eggshell	vinegar	alginate	water		heat	material	flexible	material
agar agar	glycerin	water	starch		heat	material	flexible	bioplastic
chitosan	glycerin	vinegar	water		grow	material	hard	bioplastic
green tea	sugar	sodium bicarbonate	water		grow	material	soft	textile
agar agar	glycerin	cornstarch	cork	water	heat	material	hard	material
agar agar	glycerin	water			heat	material	soft	bioplastic
agar agar	glycerin	water	gelatin		heat	material	soft	bioplastic
agar agar	glycerin	water			heat	material	soft	bioplastic
glycerol	gelatin	water			heat	material	hard	bioplastic
glycerol	gelatin	water	red ochre		heat	material	hard	leather
fish skin	vinegar				heat	material	soft	bioplastic
red algae					heat	material	soft	bioplastic
animal bone					heat	glue	soft	bioresin
starch	glycerin	vinegar	water		heat	material	flexible	bioplastic
starch	glycerin	vinegar	oil	water	heat	material	flexible	bioplastic
banana peel	vinegar	honey			heat	material	soft	bioplastic
orange peel	starch	sodium bicarbonate	lemon juice	vinegar	heat	material	hard	bioplastic
coffee ground	starch	sodium bicarbonate	vinegar	lemon juice	heat	material	hard	bioplastic
watermelon peel	starch	honey	lemon juice		heat	material	soft	bioplastic
banana peel	glycerin	vinegar	baking soda		heat	material	hard	bioplastic
tea waste	starch	vinegar	honey		heat	material	hard	bioplastic
grapes peel	starch	lemon juice	honey		heat	material	hard	bioplastic
coffee ground	starch	vinegar	glycerol	gelatin	heat	material	hard	bioplastic
nut shell	coffee ground	agar	glycerol	agar	heat	material	hard	bioplastic
starch	glycerin	vinegar			heat	material	flexible	bioplastic
starch	oil	water			heat	material	soft	bioplastic
starch	vinegar	glycerine	agar		heat	material	hard	bioplastic
starch	flour	vinegar	glycerol	wax	heat	material	hard	bioplastic
fish					heat	glue	soft	bioresin
pine pitch					heat	glue	soft	bioresin
starch	glycerin	vinegar	water		heat	material	soft	bioplastic
plastic					heat	material	hard	material
grape	glycerin	agar agar			heat	material	hard	bioplastic
nutshell	mycelium	flour			heat	material	hard	material

Dataset version 4 : simplify, rename, more examples

When the data was processed for data analysis, the name of some ingredients need to be changed as the same: “glycerine” and “glycerol” to “glycerin”; although glycerol and glycerin have a distinction, it provides clearer information for the data analysis.

Process

Prepare Data for Extraction

propertyA	materialA	propertyB	materialB	propertyC	materialC	propertyD	propertyD	transform	application	texture	final property
plant	timber	bioresin	bioresin					mix	furniture	hard	paint
animal	leather	bioresin	natural bone glue					heat	furniture	hard	material
mineral	stone	plastic	plastic					mix	construction	hard	rock
plant	plantain waste	metal	aluminium waste	food	coffee			mix	material	hard	material
plastic	sls print waste	chemical	silica sand					heat	furniture	hard	material
paper	newspaper	chemical	glue					compress	construction	hard	wood
metal	electronic (aluminium)							knit	textile	soft	textile
plastic	plastic							heat	material	hard	bioplastic
plastic	plastic bottle							heat	mechanism	hard	bioplastic
plant	pine needles							compress	furniture	soft	textile
plant	pinus pinaster	chemical	cellulose	algae	lignin	plant	rosin	heat	resin	hard	material
plant	willow branches	water	water					heat	pigment	hard	paint
algae	seaweed							heat	dye	soft	paint
algae	seaweed							dry	furniture	soft	paint
algae	bull kelp							dry	textile	flexible	textile
plant	corn husk	plant	charcoal					heat	material	hard	material
animal	sheep wool	bioresin	bioresin					heat	furniture	hard	furniture
animal	black propolis	insect	cocoon	insect	natural bee resin	insect	sikworm	heat	resin	hard	glass
animal	cow dung	mineral	clay	plant	straw			mix	material	hard	rock
human	manure	chemical	cellulose					grow	textile	soft	bioplastic
human	hair	chemical	resin					knit	textile	soft	textile
human	hair							compress	material	hard	furniture
human	hair	metal	aluminium					heat	pigment	hard	paint
dust	dust							grow	pigment	hard	coating
dust	dust	bioresin	bio-resin					compress	material	hard	coating
dust	dust	chemical	glue					compress	furniture	hard	coating
glass	glass waste	mineral	cement					mix	material	hard	rock
seafood	mussel shell							mix	material	hard	material
plant	wheat	plant	rye straw					knit	textile	soft	textile
algae	agar							heat	material	soft	bioplastic
plant	pine fibre							heat	textile	soft	cooking method
plant	plant-based lyocell							heat	textile	soft	textile
chemical	phenolic resin	plastic	thermosetting plastic					heat	material	hard	bioplastic
plant	plant	textile	textile					heat	material	hard	bioplastic
plant	flax	starch	pla					heat	furniture	hard	bioplastic
fungi	mycelium							grow	textile	flexible	leather
fungi	mycelium							grow	material	hard	bioplastic
fungi	mycelium							heat	textile	soft	coating
fungi	mycelium	water	water					grow	furniture	hard	material
plant	cellulose	fungi	bacteria					grow	pattern	hard	coating
food	oat	plant	wheat					mix	composite	hard	material
plastic	plastic	textile	textile	glass	glass			compress	furniture	hard	rock
plastic	plastic waste	mineral	stone					mix	furniture	hard	rock
food	coffee ground	vinegar	vinegar	glycerin	glycerin	water	water	mix	composite	hard	material
algae	carrageenan iota	glycerin	glycerin	water	water			heat	composite	hard	material
food	eggshell	vinegar	vinegar	chemical	alginate	water	water	heat	composite	flexible	material
algae	agar agar	glycerin	glycerin	water	water	starch	starch	heat	bioplastic	flexible	bioplastic
seafood	chitosan	glycerin	glycerin	vinegar	vinegar	water	water	grow	bioplastic	hard	bioplastic
food	green tea	food	sugar	chemical	sodium bicarbonate	water	water	grow	textile	soft	textile
algae	agar agar	glycerin	glycerin	starch	starch	plant	cork	heat	composite	hard	material
algae	agar agar	glycerin	glycerin	water	water			heat	bioplastic	soft	bioplastic
algae	agar agar	glycerin	glycerin	food	gelatin	water	water	heat	bioplastic	soft	bioplastic
algae	agar agar	glycerin	glycerin	water	water			heat	material	soft	bioplastic
glycerin	glycerin	food	gelatin	water	water			heat	bioplastic	hard	bioplastic
glycerin	glycerin	food	gelatin	water	water	mineral	red ochre	heat	textile	hard	leather
seafood	fish skin	vinegar	vinegar					heat	material	soft	bioplastic
algae	red algae							heat	bioplastic	soft	bioplastic
animal	animal bone							heat	glue	soft	bioresin
starch	starch	glycerin	glycerin	vinegar	vinegar	water	water	heat	bioplastic	flexible	bioplastic
starch	starch	glycerin	glycerin	vinegar	vinegar	oil	oil	heat	bioplastic	flexible	bioplastic
food	banana peel	vinegar	vinegar	food	honey			heat	bioplastic	soft	bioplastic
food	orange peel	starch	starch	chemical	sodium bicarbonate	vinegar	lemon juice	heat	bioplastic	hard	bioplastic
food	coffee ground	starch	starch	chemical	sodium bicarbonate	vinegar	vinegar	heat	bioplastic	hard	bioplastic
food	watermelon peel	starch	starch	food	honey	vinegar	lemon juice	heat	bioplastic	soft	bioplastic
food	banana peel	glycerin	glycerin	vinegar	vinegar	chemical	baking soda	heat	bioplastic	hard	bioplastic
food	tea waste	starch	starch	vinegar	vinegar	food	honey	heat	bioplastic	hard	bioplastic
food	grapes peel	starch	starch	vinegar	lemon juice	food	honey	heat	bioplastic	hard	bioplastic
food	coffee ground	starch	starch	vinegar	vinegar	glycerin	glycerin	heat	bioplastic	hard	bioplastic
food	nutshell	food	coffee ground	algae	agar	glycerin	glycerin	heat	bioplastic	hard	bioplastic
starch	starch	glycerin	glycerin	vinegar	vinegar			heat	bioplastic	flexible	bioplastic
starch	starch	food	oil	water	water			heat	bioplastic	soft	bioplastic
starch	starch	vinegar	vinegar	glycerin	glycerin	algae	agar	heat	bioplastic	hard	bioplastic
starch	starch	chemical	flour	vinegar	vinegar	glycerin	glycerin	heat	bioplastic	hard	bioplastic
seafood	fish							heat	glue	soft	bioresin
plant	pine pitch							heat	glue	soft	bioresin
starch	starch	glycerin	glycerin	vinegar	vinegar	water	water	heat	bioplastic	soft	bioplastic
plastic	plastic							heat	composite	hard	material
food	grape	glycerin	glycerin	algae	agar agar			heat	bioplastic	hard	bioplastic
food	nutshell	fungi	mycelium	chemical	flour			heat	composite	hard	material

Dataset version 5 : type of ingredient, more examples

In the data analysis, a problem of inadequate data is difficult to show the kinds of ingredients used in the projects. Therefore, I added in the fields of “property a / b / c” which refers to the type of ingredient.

Process

Prepare Data for Extraction

index	title	artist	propertyA	materialA	propertyB	materialB	propertyC	materialC	propertyD	materialD	transform	application	texture	final property	keyword	link
1	Well Proven Chair	Marjan van Aubel James Shaw	plant	timber	bioresin	bioresin					mix	furniture	hard	paint	timber wood foam furniture chair rough	http://wellprovenchair.com/about.html
2	Structural Skin	Jorge Penades	animal	leather	bioresin	natural bone glue					heat	furniture	hard	material	wood furniture chair table	https://materialdistrict.com/article/structural-skin/
3	Stone Recycling	Tom van Soest	mineral	stone	plastic	plastic					mix	construction	hard	rock	brick commercial tile multi-functional	https://www.stonecycling.com
4	Materia Madura	Ana Christina Qui s	plant	plantain waste	metal	aluminium waste	food	coffee			mix	material	hard	material	material Puerto Rico stone location-based coffee metal	http://www.anacristinaqui s.com/index-montaukf/materia-madura
5	Hot Wire Extensions	Studio Ilio Seongil Choi Fabio Hendry	plastic	sls print waste	chemical	silica sand					heat	furniture	hard	material	3d-print plastic sls pla mineral structure art	https://www.dezeen.com/2015/06/30/studio-ilio-electricity-form-solid-objects-
6	Newspaper Wood	Mieke Meijer	paper	newspaper	chemical	glue					compress	construction	hard	wood	wood glue furniture construction commercial tile	https://miekemeijer.com/newspaperwood
7	Micro Urban Mining	Jorien Wiltenburg	metal	electronic (aluminium)							knit	textile	soft	textile	electronics metal knit weave textile metallic	http://jorienwiltenburg.nl/work19.html
8	Precious Plastic	Dave Hakkens	plastic	plastic							heat	material	hard	bioplastic	plastic melt heat heatpress machine blend shred	https://preciousplastic.com/
9	Joining Bottles	Micaella Pedros	plastic	plastic bottle							heat	mechanism	hard	bioplastic	joint plastic bottle furniture wood mechanic	https://micaellapedros.com/
10	Forest Pine Wool	Tamara Orjola	plant	pine needles							compress	furniture	soft	textile	pine wool carpet soft hard multi-functional furniture chair heatpress	http://tamaraorjola.com/
11	Reconfiguration of a Tree	Thomas Vailly	plant	pinus pinaster	chemical	cellulose	algae	lignin	plant	rosin	heat	resin	hard	material	bio-resin bowl mug mould	http://studiothomasvailly.com/
12	Willow Project	Iceland Academy of the Arts	plant	willow branches	water	water					heat	pigment	hard	paint	willow plant	https://www.dezeen.com/2016/03/18/iceland-academy-arts-product-design-st
13	Sea Me Collection	Studio Nienke Hoogvliet	algae	seaweed							heat	dye	soft	paint	seaweed algae translucent soft textile chair weave	https://www.nienkehoogvliet.nl/
14	Terroir	Jonas Edvard Nikolaj Steenfatt	algae	seaweed							dry	furniture	soft	paint	seaweed composite chair rough furniture hard	https://jonasedvard.dk/work/terroir/
15	Cochayuyo	Sisa Collection	algae	bull kelp							dry	textile	flexible	textile	clothing textile hard	https://www.sisacollection.com/cochayuyo
16	Cornspan and From Chiang Mai	Apilada Vorachart	plant	corn husk	plant	charcoal					heat	material	hard	material	panel sound thermal insulation music	https://materialdistrict.com/material/cornspan/
17	Solidwool	Justin and Hannah Floyd	animal	sheep wool	bioresin	bioresin					heat	furniture	hard	furniture	furniture hard	https://www.solidwool.com/about
18	From Insects	Marlene Huissoud	animal	black propolis	insect	cocoon	insect	natural bee resin	insect	silkworm	heat	resin	hard	glass	natural bio-resin glass clay	https://www.marlene-huissoud.com/from-insects-product/
19	Merdacotta	Gianantonio Locatelli Luca Cipelletti	animal	cow dung	mineral	clay	plant	straw			mix	material	hard	rock	brick hard furniture installation	http://www.thisisthemuseum.org/about/
20	Mestic	Jalila Essaidi	animal	manure	chemical	cellulose					grow	textile	soft	bioplastic	biotextiles bioplastic paper textile cellulose-derivatives	https://jalilaessaidi.com/cowmanure/
21	The New Age of Trichology	Sanne Visser	human	hair	chemical	resin					knit	textile	soft	textile	hair fabric fishing textile net	https://cargocollective.com/sannevisser/The-New-Age-of-Trichology
22	Hair Highway	Studio Swine	human	hair							compress	material	hard	furniture	natural resin bioplastic amber translucent aesthetics art	https://www.studioswine.com/work/hair-highway/
23	The Colour of Hair	Fabio Hendry Martijn Rigters	human	hair	metal	aluminium					heat	pigment	hard	paint	color metal black pigment coating	https://www.martijnrigters.com/the-colour-of-hair-objects
24	Dust Matters	Lucie Libotte	dust	dust							grow	pigment	hard	coating	jewlery ceramic glaze	http://lucielibotte.com/
25	The Dust Collection	Agusta Sveinsdottir	dust	dust	bioresin	bio-resin					compress	material	hard	coating	jewlery stone marble coating small rough	https://www.domusweb.it/en/news/2014/05/23/agusta_sveinsdottir_dust.htm
26	How Dust This Feel?	Matilda Beckman	dust	dust	chemical	glue					compress	furniture	hard	coating	black marble smooth construction furniture	https://www.dezeen.com/2015/02/06/matilda-beckman-furniture-made-from-
27	Bottle-up	Super Local design studio	glass	glass waste	mineral	cement					mix	material	hard	rock	construction material hard tile location-oriented East-Africa	https://www.bottle-up.org/
28	Beyond the Mainland	Phoebe Quare	seafood	mussel shell							mix	material	hard	material	hard plaster location-oriented Ireland marine homeware ceramic marine seafood	https://www.dezeen.com/2015/02/06/matilda-beckman-furniture-made-from-
29	Karawane	Pour le Alpes	plant	wheat	plant	rye straw					knit	textile	soft	textile	weave textile tradition knit swiss straw location-oriented	https://www.formandseek.com/karawane
30	Agar Plasticity	AMAM	algae	agar							heat	material	soft	bioplastic	bioplastic translucent solid homeware hard disposability biodegradable translucent	https://www.a-ma-m.com/agarplasticity
31	EcoGrill	Lou Moria	plant	pine fibre							heat	textile	soft	cooking method	temporary outdoor cooking grill utensil	https://www.loumoria.com/tracing-paper-c1app
32	Short Life	Kay Politowicz Sandy Maclennan	plant	plant-based lyocell							heat	textile	soft	textile	fashion textile clothing short-life	http://www.tedresearch.net/research/detail/short-life/
33	Polyspoila	Will Yates-Johnson	chemical	phenolic resin	plastic	thermosetting plastic	chemical	calcium carbonate	mineral	wood flour	heat	material	hard	bioplastic	bioplastic reform plastic thermosetting recycle	https://whyi.uk/polyspoila
34	Collection 1	Crafting Plastics Studio	plant	plant	textile	textile					heat	material	hard	bioplastic	bioplastic eyewear glasses compostable durable	https://www.craftingplastics.com/collection-1
35	Flax Chair	Christien Meindertsma	plant	flax	starch	pla					heat	furniture	hard	bioplastic	bioplastic chair furniture hard flax pla	https://christienmeindertsma.com/Flax-Chair
36	MycoWork	MycoWork	fungi	mycelium							grow	textile	flexible	leather	leather grow mycelium biodegradable mushroom	https://www.mycoworks.com/
37	Growing Lab	Officina Corpuscoli	fungi	mycelium							grow	material	soft	bioplastic	bioplastic mycelium fungi achitecture design grow	https://www.corpuscoli.com/projects/the-growing-lab/
38	Mycelium Textile	Carole Collet	fungi	mycelium							heat	textile	soft	coating	textile pattern mycelium grow	https://www.domusweb.it/en/design/gallery/2019/04/01/carole-collet-myceliu
39	Grow It Yourself	Krown Design	fungi	mycelium	water	water					grow	furniture	hard	material	lamp homeware mycelium mushroom grow	https://www.krown-design.com/product-category/grow-it-yourself/?product_v
40	Invisible Resources	Zuzana Gombosova	plant	cellulose	fungi	bacteria					grow	pattern	hard	coating	paint bacterial cellulose pigment grow	https://www.frameweb.com/news/invisible-resources-by-zuzana-gombosova
41	Interwoven	Diana Scherer	food	oat	plant	wheat					mix	composite	hard	material	grow plant carpet pattern textile clothing rough root rootsystem	http://dianascherer.nl/
42	New Geology	Jorien Wiltenburg	plastic	plastic	textile	textile	glass	glass	metal	steel	compress	furniture	hard	rock	furniture recycle marble rough	http://jorienwiltenburg.nl/work14.html
43	Plastiglomerate Samples	Kelly Jazvac	plastic	plastic waste	mineral	stone					mix	furniture	hard	rock	art sculpture waste environment history grow	http://www.kellyjazvac.com/Stones/Stones.html
44	Coffee Composite CoO2	Pilar Bolumburu	food	coffee ground	vinegar	vinegar	glycerin	glycerin	water	water	mix	composite	hard	material	composite bowl mug mould hard homeware rough	https://materiom.org/recipe/171
45	Carrageenan iota	Zoë Powell	algae	carrageenan iota	glycerin	glycerin	water	water			heat	composite	hard	material	leather soft translucent	https://materiom.org/recipe/120
46	Eggshell biocomposite	María José Besoain Alejandro Weiss LAB	food	eggshell	vinegar	vinegar	chemical	alginate	water	water	heat	composite	flexible	material	composite hard solid	https://materiom.org/recipe/60
47	Sawdust / agar - starch	Tamara Schwarz	algae	agar agar	glycerin	glycerin	water	water	starch	starch	heat	bioplastic	flexible	bioplastic	composite container cork rough homeware	https://materiom.org/recipe/53
48	Chitosan 12% - Stiff behaviour	Soraya Bornaz	seafood	chitosan	glycerin	glycerin	vinegar	vinegar	water	water	grow	bioplastic	soft	bioplastic	rubber bioplastic soft flexible seafood marine	https://materiom.org/recipe/48
49	Kombucha Fabric	LABVA	food	green tea	food	sugar	chemical	sodium bicarbonate	water	water	grow	textile	soft	textile	soft translucent fermentated origami	https://materiom.org/recipe/42
50	Cork / agar - starch	Fab Lab Santiago	algae	agar agar	glycerin	glycerin	starch	starch	plant	cork	heat	composite	hard	material	cork composite homeware	https://materiom.org/recipe/40
51	Agar bioplastic	Clara Davis	algae	agar agar	glycerin	glycerin	water	water			heat	bioplastic	soft	bioplastic	translucent bioplastic soft flexible	https://clara-davis.com/albums/bioplastic-wax/
52	Agar - gelatin plastic	Fab Lab Santiago	algae	agar agar	glycerin	glycerin	food	gelatin	water	water	heat	bioplastic	soft	bioplastic	translucent bioplastic soft flexible	https://materiom.org/recipe/24
53	Agar bioplastic (heated)	Alysia Garmulewicz	algae	agar agar	glycerin	glycerin	water	water			heat	material	soft	bioplastic	transparent translucent bioplastic flexible	https://materiom.org/recipe/41
54	Gelatin bioplastic	FabTextiles	glycerin	glycerin	food	gelatin	water	water			heat	bioplastic	hard	bioplastic	elastic transparent translucent bioplastic	http://fabtextiles.org/the-secrets-of-bioplastic/
55	Gelatin / ochre 'leather'	Fab Lab Santiago	glycerin	glycerin	food	gelatin	water	water	mineral	red ochre	heat	textile	hard	leather	leather bio-based hard flat	https://materiom.org/recipe/32
56	MarinaTex	Lucy Hughes	seafood	fish skin	vinegar	vinegar					heat	material	soft	bioplastic	bioplastic transparent translucent seafood fish food-waste marine	https://www.dezeen.com/2019/11/15/marinatex-lucy-hughes-james-dyson-aw
57	DIY bioplastics	Lucia Borroni	food	orange peel	starch	starch	chemical	sodium bicarbonate	vinegar	lemon juice	heat	bioplastic	hard	bioplastic	coffee hard homeware rough bowl mug	https://www.youtube.com/watch?v=PrIJjjznwEE
58	DIY bioplastics	Lucia Borroni	food	coffee ground	starch	starch	chemical	sodium bicarbonate	vinegar	vinegar	heat	bioplastic	hard	bioplastic	hard homeware rough bowl	https://www.youtube.com/watch?v=PrIJjjznwEE
59	Bio plastic from watermelon	Ong SK	food	watermelon peel	starch	starch	food	honey	vinegar	lemon juice	heat	bioplastic	soft	bioplastic	flexible soft material	https://www.youtube.com/watch?v=OPIB4JnMAJU
60	Banana bioplastic	Mattia Massetti	food	banana peel	glycerin	glycerin	vinegar	vinegar	chemical	baking soda	heat	bioplastic	hard	bioplastic	hard homeware rough	https://www.youtube.com/watch?v=jelBPntTSW8
61	DIY bioPlastic	Scuola di Ateneo Architettura e Design "	food	tea waste	starch	starch	vinegar	vinegar	food	honey	heat	bioplastic	hard	bioplastic	hard homeware rough flat	https://www.youtube.com/watch?v=Z1gLiSid6OM
62	BIOPLASTIC GRAPES	Sperim Design	food	grapes peel	starch	starch	vinegar	lemon juice	food	honey	heat	bioplastic	hard	bioplastic	hard bowl mug houseware food rough	https://www.youtube.com/watch?v=Gmj2vNWxji
63	Bioplastic Coffee	UNICAM - Course of experimentation of	food	coffee ground	starch	starch	vinegar	vinegar	glycerin	glycerin	heat	bioplastic	hard	bioplastic	coffee hard board game mould food rough	https://www.youtube.com/watch?v=ZwiDH5KTvj0
64	Bioplastic BIO CC	Fabbiana Cimini	food	nut shell	food	coffee ground	algae	agar	glycerin	glycerin	heat	bioplastic	hard	bioplastic	cork hard flat board rough coffee game mould food rough	https://www.youtube.com/watch?v=BaCOXoReNME
65	Make Bioplastic	Science Luxembourg	starch	starch	glycerin	glycerin	vinegar	vinegar			heat	bioplastic	flexible	bioplastic	elastic translucent bioplastic	https://www.youtube.com/watch?v=Cop-QppF1Ik
66	Home Bioplastic		starch	starch	food	oil	water	water			heat	bioplastic	soft	bioplastic	elastic bioplastic	https://www.youtube.com/watch?v=OcqN6-OmiiM
67	Eco-friendly Bioplastics		starch	starch	vinegar	vinegar	glycerin	glycerin	algae	agar	heat	bioplastic	hard	bioplastic	bioplastic biodegarable transparent translucent food wrap	https://www.youtube.com/watch?v=dPheh0hhvto
68	bioplastic soles	Aurora Pelaggi Christian Simone	starch	starch	chemical	coal	vinegar	vinegar	glycerin	glycerin	heat	bioplastic	hard	bioplastic	shoe fashion hard rubber sole	https://www.youtube.com/watch?v=mJ9MxES_Yuw
69	Fish Glue		seafood	fish							heat	glue	soft	bioresin	tool glue bio-resin plant seafood collagen marine	https://www.youtube.com/watch?v=JsnE73Sg3qI
70	Pine Pitch Glue		plant	pine pitch							heat	glue	soft	bioresin	tool glue bio-resin plant	https://www.youtube.com/watch?v=VJtCkuo1rIs
71	Bioplastic Jewelry	Lili Design Ltd	starch	starch	glycerin	glycerin	vinegar	vinegar	water	water	heat	bioplastic	soft	bioplastic	jewelry transparent mould	https://www.youtube.com/watch?v=-7KCIdlr7So
72	Recycle HDPE Plastic	Atomic Shrimp	plastic	plastic							heat	composite	hard	material	plastic heatpress hdpe recycle flat tile	https://www.youtube.com/watch?v=W_XUJwfNdLw
73	Grape pomace / agar	LABVA	food	grape	glycerin	glycerin	algae	agar agar			heat	bioplastic	hard	bioplastic	dry hard translucent material	https://materiom.org/recipe/36
74	Walnut shell | mycelium WS01	Laboratorio de Biofabricación FADEU	food	nut shell	fungi	mycelium	chemical	flour			heat	composite	hard	material	composite mug bowl rough solid	https://materiom.org/recipe/33
75	Aqua Shelltic	Kit Sam Lam Bing Yim Secondary School	algae	seaweed	food	egg shell	vinegar	vinegar			heat	bioplastic	flexible	bioplastic	food wrap transparent translucent stretch flexible calcium lactate	http://startupbeat.hkej.com/?p=73612
76	Ari Jónsson	Ari Jónsson	algae	red algae powder	water	water					heat	bioplastic	hard	bioplastic	red algae powder bottle mug bioplastic biodegradable translucent	https://www.dezeen.com/2016/03/20/ari-jonsson-algae-biodegradable-water-l
77	From Peel to Peel	Emma Sicher	food	fruit peel	cellulose	cellulose					mix	bioplastic	hard	bioplastic	fermented microbial cellulose grow bioplastic translucent food package	https://www.dezeen.com/2018/11/13/sustainable-food-packaging-emma-siche
78	Bio Iridescent Sequin	Elissa Brunato	Cellulose	Cellulose							grow	textile	hard	material	grow cellulose shining fashion textile	https://www.dezeen.com/2019/08/02/bio-iridescent-sequin-elissa-brunato-sus
79			algae	red algae							heat	bioplastic	soft	bioplastic	algae transparent translucent bioplastic	
80			animal	animal bone							heat	glue	soft	bioresin	bone glus natural resin bio-resin	
81			starch	starch	glycerin	glycerin	vinegar	vinegar	water	water	heat	bioplastic	flexible	bioplastic	translucent	
82			starch	starch	glycerin	glycerin	vinegar	vinegar	oil	oil	heat	bioplastic	flexible	bioplastic	translucent	
83			food	banana peel	vinegar	vinegar	food	honey			heat	bioplastic	soft	bioplastic	composite soft	

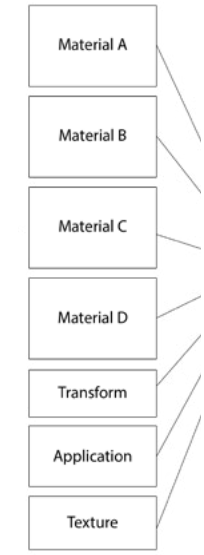
Dataset finalized version : add index and link

In the machine learning program, index is used to call the array of data from the row, so I added a column for “index”. When I need to revise the data, I realized that the links are essential for reference.

Machine Learning: Final Program

Implementing the association rule learning in Python

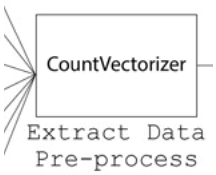
Workflow




```
import pandas as pd
import numpy as np
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.metrics.pairwise import cosine_similarity

df = pd.read_csv("datasets_materials_v29.csv")
```

```
def combine_features(row):
    return row['keyword']+" "+row['texture']+" "+row['application']+" "+row['transform']
#     return row['keyword']+" "+row['application']+" "+row['propertyB']+" "+row['propertyC']
```

1. import the necessary libraries
2. import the data from csv file to the program




```
for feature in features:
    df[feature] = df[feature].fillna('')

df["combined_features"] = df.apply(combine_features,axis=1)
```

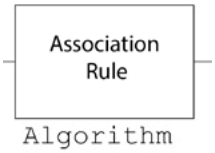
```
cv = CountVectorizer()
count_matrix = cv.fit_transform(df["combined_features"])
```

3. select the features and clean up the dataset
4. pre-process the data by counting the words and calculating the frequency of words

Machine Learning: Final Program

Implementing the association rule learning in Python

Workflow



Algorithm

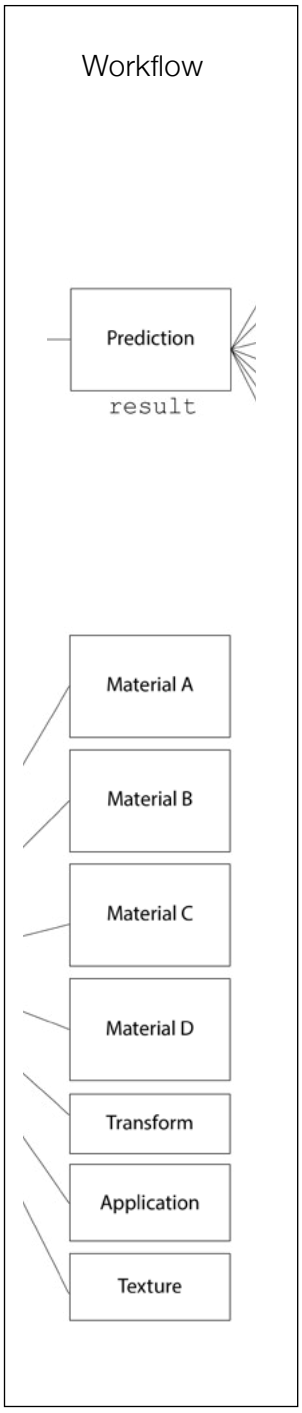
```
cosine_sim = cosine_similarity(count_matrix)
```

```
def get_title_from_index(index):
    return df[df.index == index]["materialA"].values[0]

#get link for reference
def get_home(index):
    return df[df.index == index]["link"].values[0]

def get_index_from_title(title):
    return df[df.application == title]["index"].values[0]

def get_materialB(index):
    return df[df.index == index]["materialB"].values[0]

def get_materialC(index):
    return df[df.index == index]["materialC"].values[0]

def get_materialD(index):
    return df[df.index == index]["materialD"].values[0]

def get_transform(index):
    return df[df.index == index]["transform"].values[0]

def get_texture(index):
    return df[df.index == index]["texture"].values[0]

def get_application(index):
    return df[df.index == index]["application"].values[0]
```

5. call the build-in function of cosine similarity
6. define different functions to get designated results

Machine Learning: Final Program

Implementing the association rule learning in Python




```
picked_title = input("Input your choice of application (construction / furniture /
project_index = get_index_from_title(picked_title)
similar_project = list(enumerate(cosine_sim[project_index])) #similarity
```

7. prompt to ask for input
8. call the function assigned

```
sorted_similar_projects = sorted(similar_project,key=lambda x:x[1],reverse=True)[1:]
print(sorted_similar_projects)
```

```
i=0
print("\nPicked Function: "+picked_title)
print("\nTopyou 5 Possible combinations of materials to {"+picked_title+"} are:\nMaterial A | Material B | Material C | Material D => Tra
for element in sorted_similar_projects:
    print("|| "+get_title_from_index(element[0])+" | "+ get_materialB(element[0])+" | "+get_materialC(element[0])+" | "+get_materialD(ele
    i=i+1
    if i>5:
        break
```

9. calculate the result by using output from cosine similarity
10. get the result

Possible Outcomes

Test with different inputs for desired materials

Mostly, the output is reasonable for looking for material formula based on applications. However, if there are inadequate instances, the result would be unexpected. For example, when “glue” is picked, it prints out instances of resins, which are similar to glue.

```
Picked Function: bioplastic

Topyou 5 Possible combinations of materials to {bioplastic} are:
Material A | Material B | Material C | Material D => Transform [Property]

|| agar agar | glycerin | water |  || => heat  [bioplastic]
|| agar agar | glycerin | gelatin | water|| => heat  [bioplastic]
|| watermelon peel | starch | honey | lemon juice|| => heat  [bioplastic]
|| starch | oil | water |  || => heat  [bioplastic]
|| banana peel  | vinegar | honey |  || => heat  [bioplastic]
|| red algae |   |   |  || => heat  [bioplastic]
```

```
Picked Function: glue

Topyou 5 Possible combinations of materials to {glue} are:
Material A | Material B | Material C | Material D => Transform [Property]

|| fish |   |   |  || => heat  [glue]
|| animal bone |   |   |  || => heat  [glue]
|| pinus pinaster | cellulose | lignin | rosin|| => heat  [resin]
|| black propolis | cocoon | natural bee resin | sikworm|| => heat  [resin]
|| banana peel  | vinegar | honey |  || => heat  [bioplastic]
|| watermelon peel | starch | honey | lemon juice|| => heat  [bioplastic]
```

```
Picked Function: pigment

Topyou 5 Possible combinations of materials to {pigment} are:
Material A | Material B | Material C | Material D => Transform [Property]

|| green tea | sugar | sodium bicarbonate | water|| => grow  [textile]
|| banana peel  | vinegar | honey |  || => heat  [bioplastic]
|| agar agar | glycerin | water |  || => heat  [bioplastic]
|| agar agar | glycerin | gelatin | water|| => heat  [bioplastic]
|| watermelon peel | starch | honey | lemon juice|| => heat  [bioplastic]
|| red algae |   |   |  || => heat  [bioplastic]
```

Possible Outcomes

Test with different inputs for desired materials

```
Picked Function: construction

Top 5 Possible combinations of materials to {construction} are:
Material A | Material B | Material C | Material D => Transform [Property]

|| glass waste | cement |   |  || => mix  [material]
|| cow dung | clay | straw |  || => mix  [material]
|| mussel shell |   |   |  || => mix  [material]
|| dust | bio-resin |   |  || => compress  [material]
|| grape | glycerin | agar agar |  || => heat  [bioplastic]
|| corn husk | charcoal |   |  || => heat  [material]
```

```
Picked Function: furniture

Topyou 5 Possible combinations of materials to {furniture} are:
Material A | Material B | Material C | Material D => Transform [Property]

|| sheep wool | bioresin |   |  || => heat  [furniture]
|| flax | pla |   |  || => heat  [furniture]
|| timber | bioresin |   |  || => mix  [furniture]
|| seaweed |   |   |  || => dry  [furniture]
|| plastic bottle |   |   |  || => heat  [mechanism]
|| plastic | textile | glass | steel|| => compress  [furniture]
```

```
Picked Function: material

Topyou 5 Possible combinations of materials to {material} are:
Material A | Material B | Material C | Material D => Transform [Property]

|| sheep wool | bioresin |   |  || => heat  [furniture]
|| flax | pla |   |  || => heat  [furniture]
|| leather | natural bone glue |   |  || => heat  [furniture]
|| plastic bottle |   |   |  || => heat  [mechanism]
|| plastic |   |   |  || => heat  [material]
|| phenolic resin | thermosetting plastic | calcium carbonate | wood flour||
```

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