Quantum Generators: an Evolution-Enabled Reconfigurable Cell Shape Optimizer for Crop Production.

Poondru Prithvinath Reddy

February 26, 2022

Quantum Generators: An Evolution-enabled Reconfigurable Cell Shape Optimizer for Crop Production.

Poondru Prithvinath Reddy

ABSTRACT

Quantum Generators is a means of achieving mass food production with short production cycles, and when and where required by means of machines rather than land based farming which has serious limitations. The process for agricultural practices for plant growth in different stages is simulated in a machine with a capacity to produce multiple seeds from one seed input using computational models of multiplication (generating multiple copies of kernel in repetition). The crop tissues are collection of living cells and Cell tissues can be shaped to perform effective union and are required to be shaped in such a way that they gather other cells in their environment forming them into new cell tissues with same parameters/capability and subsequently grow into larger crop tissues. In this paper, we present a method to produce living natural tissues of crops that are constructed by acquiring several small and more detailed cells of large crop objects and then form a larger crop structure by combining these small cells. The main goal of this method is to create structures that are identical to the natural structure that are found in the tissues in the crops. Hence the shape of a cell tissue is designed in simulation to perform a specific task i.e. union, using a process of trial and error(an evolutionary algorithm). We present an evolutionary strategy implementation to solve complex shape related synthesis problems in crop body formation by exploiting the possibilities offered by evolutionary process or natural selection and results show that if there's enough of cells of particular type in a chamber/dish, they will start to develop and will compact together.

INTRODUCTION

A **Quantum** (plural quanta) is the minimum amount of any physical entity (physical property) involved in an interaction. On the other hand, **Generators** don't actually create anything instead, they generate quantity prescribed by physical property through multiplication to produce high quality products on a mass scale. The aim of Quantum Generators is to produce multiple seeds from one seed at high seed rate to produce a particular class of food grains from specific class of **seed** on mass scale by means of machine rather than land farming.

The process for agricultural practices include preparation of soil, seed sowing, watering, adding manure and fertilizers, irrigation and harvesting. However, if we create same conditions as soil germination, special watering, fertilizers addition and plant growth in different stages in a machine with a capacity to produce multiple seeds from one seed input using computational models of multiplication(generating multiple copies of kernel in repetition) then we will be closure to achieving mass food production by means of quantum generators(machine generated) rather than traditional land based farming which has very serious limitations such as large space requirements, uncontrolled contaminants, etc. The development of Quantum Generators requires specialized knowledge in many fields including Cell Biology, Nanotechnology, 3D Cellprinting, Computing, Soil germination and initially they may be big occupying significantly large space and subsequently small enough to be placed on roof-tops.

The Quantum Generators help world meet the food needs of a growing population while simultaneously providing opportunities and revenue streams for farmers. This is crucial in order to grow enough food for growing populations without needing to expand farmland into wetlands, forests, or other important natural ecosystems. The Quantum Generators use significantly less space compared to farmland and also results in increased yield per square foot with short production cycles, reduced cost of cultivation besides easing storage and transportation requirements.

In addition, Quantum Generators Could Eliminate Agricultural Losses arising out of Cyclones, Floods, Insects, Pests, Droughts, Poor Harvest, Soil Contamination, Land Degradation, Wild Animals, Hailstorms, etc.

Quantum generators could be used to produce most important *food* crop *like* rice, wheat and maize on a mass scale and on-demand when and where required.

Computers and Smartphones have become part of our lives and Quantum Generators could also become very much part of our routine due to its potential benefits in enhancing food production and generating food on-demand wherever required by bringing critical advanced technologies into the farmland practices.

3D Bioprinting

3D Bioprinting is a form of additive manufacturing that uses cells and other biocompatible materials known as bioinks, to print living structures layer-by-layer which mimic the behavior of natural living systems. Three dimensional bioprinting is the utilization of 3D printing–like techniques to combine cells, growth factors, and biomaterials to fabricate biomedical parts that maximally imitate natural tissue characteristics.

Bioprinting (also known as **3D bioprinting**) is combination of **3D printing** with biomaterials to replicate parts that imitate natural tissues, bones, and blood vessels in the body. It is mainly used in connection with drug research and most recently as cell scaffolds to help repair damaged ligaments and joints. In this paper, we are looking at natural tissues related to food crops like rice, wheat or maize.
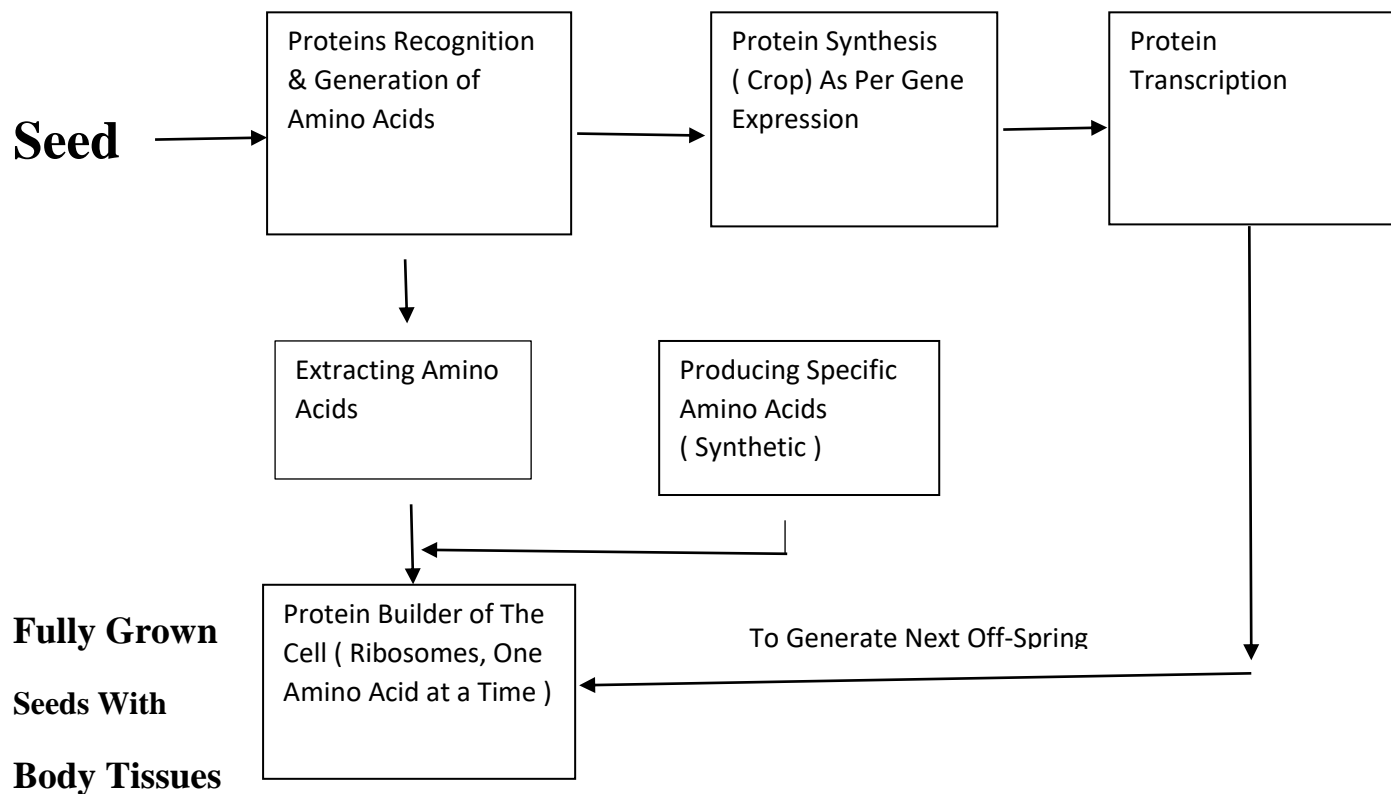

METHODOLOGY

Process Flow Diagram (Fig 1)

```
                  ┌──────────────────┐      ┌──────────────────┐      ┌──────────────┐
                  │ Proteins         │      │ Protein Synthesis│      │ Protein      │
         Seed ──► │ Recognition      │ ──►  │ ( Crop) As Per   │ ──►  │ Transcription│
                  │ & Generation of  │      │ Gene Expression  │      │              │
                  │ Amino Acids      │      │                  │      │              │
                  └────────┬─────────┘      └──────────────────┘      └──────┬───────┘
                           │                                                 │
                           ▼                                                 │
                  ┌──────────────────┐      ┌──────────────────┐             │
                  │ Extracting Amino │      │ Producing        │             │
                  │ Acids            │      │ Specific Amino   │             │
                  │                  │      │ Acids (Synthetic)│             │
                  └────────┬─────────┘      └────────┬─────────┘             │
                           │        ◄────────────────┘                       │
Fully Grown       ┌────────▼─────────┐                                       │
                  │ Protein Builder  │   To Generate Next Off-Spring         │
Seeds With        │ of The Cell      │ ◄─────────────────────────────────────┘
                  │ ( Ribosomes, One │
Body Tissues      │ Amino Acid at a  │
                  │ Time )           │
                  └──────────────────┘
```

Fig 1. Process Flow Diagram of Seed Builder

Protein from input seeds is broken down into individual amino acids which are reassembled by Quantum Generating ribosomes into proteins that Crop cells need to be generated. The information to produce a protein is encoded in the **cell's** DNA. When a protein is produced, a copy of the DNA is made (called mRNA) and this copy is transported to a ribosome.

Protein **synthesis** is the process used by the QG(Quantum Generator) to make proteins. The first step of protein **synthesis** is called Transcription. It occurs in the nucleus. During transcription, mRNA transcribes (copies) DNA.

Body tissues **grow** by increasing the number of cells that make them up. Every **cell** in the crop body contains protein. The basic structure of protein is a chain of amino acids. We need protein in our diet to help human body repair cells and make new ones. Protein is also important for growth and development in children, teens, and pregnant women.

The major steps in protein synthesis are:

- DNA unzips in the nucleus.
- mRNA nucleotides transcribe the complementary DNA message.
- mRNA leaves nucleus and goes to ribosome.
- mRNA attaches to ribosome and first codon is read.
- tRNA brings in proper amino acid from cytoplasm.
- a second tRNA brings in new amino acid.

The journey from gene to **protein** is complex and tightly controlled within each cell. It consists of two major **steps**: transcription and translation. Together, transcription and translation are known as gene expression.

Protein synthesis is the process in which **cells make proteins**. It occurs in two stages: transcription and translation. Transcription is the transfer of genetic instructions in DNA to mRNA in the nucleus. Translation occurs at the ribosome, which consists of rRNA and proteins**.**

Ribosomes are the protein builders or the protein synthesizers of the cell. They are like construction guys who connect one amino acid at a time and build long chains. Ribosomes are special because they are found in both prokaryotes and eukaryotes.

Ribosomes, large complexes of **protein** and ribonucleic acid (RNA), are the cellular organelles responsible for protein synthesis. They receive their "orders" for protein synthesis from the nucleus where the DNA is transcribed into messenger RNA (mRNA).

During the **process** of transcription, the information stored in a gene's DNA is passed to a similar molecule called RNA (ribonucleic acid) in the cell nucleus. A type of RNA called transfer RNA (tRNA) assembles the protein, one amino acid at a time.

Ribosomes are the sites in a **cell** in which **protein** synthesis takes place. Cells have many ribosomes, and the exact number depends on how active a particular cell is in synthesizing proteins. For example, rapidly growing cells usually have a large number of ribosomes.
Amino acids can be produced by breaking down proteins, known as the extraction method. However, the amount of amino acids in the source protein limits the amount of amino acids made. Extraction is not good for

making mass quantities of specific amino acids. So Synthetic Methods of making amino acids is necessary in protein synthesis.

The Quantum Generator contains pre-programmed Protein Synthesizer relevant to specific Crop/Tissue which essentially reassembles ribosomes (Sites in a Cell) into proteins that your crop cells need. The sequence and information to produce a protein is encoded in the synthesizer of Quantum Generator.

Optimization in Cell Synthesis

The ability to make small molecules autonomously and automatically will be fundamental to many applications, including quantum generators. Additionally, automated synthesis requires (in many cases) optimization of reaction yields; following optimization, the best conditions can be fed to the synthesis robot to increase the overall yield. There are different approaches to automated yield optimization, and as optimization of reaction conditions requires live feedback from the robotic system, many different detectors are required to monitor progress of the reactions, including benchtop nuclear magnetic resonance spectroscopy, Raman spectroscopy, UV-Vis spectroscopy, etc. Harvested data are then fed to optimization algorithms to explore often the multidimensional parameter space. The platform could be easily reconfigured to the desired task in a plug-and-play fashion, by attaching different modules to the platform core and Robotic approaches also promise to speed up biological space exploration and realization.

Machine Learning in Biological Space Exploration

Machine learning approaches are fundamental to scientific investigation in many disciplines. In biological studies, many of these methods are widely applicable, we explore how robotics/automation are helping to progress cell synthesis through exploring biological space and beyond. Scientists have begun to embrace the power of machine learning coupled with statistically driven design in their research to predict the performance of synthetic reactions. For our study, the yield of a synthetic reaction can be predicted using **random forest (machine learning algorithm)** in the multidimensional space obtained from robotic automation to map the yield landscape of intricate synthesis following synthesis code allowing improved prediction of high-yielding conditions and replication mechanisms. Meanwhile, our emphasis is on automation of synthesis, and synthesis through automation offers far better efficiency and accuracy. In addition, the machine learning algorithm

explored a wider range of biological space that would need to be performed purely automated way to fast-track synthesis. This brings the development of automation, optimization, and molecular synthesis very close.

In general, this approach allows for faster and more efficient retrosynthetic analysis than any other well-known method. Figure 2 shows a graphical representation of workflow for joining automated retrosynthesis with a synthesis robot and reaction optimization. The retrosynthetic module will generate a valid synthesis of the target that can then be transferred into synthesis code that can be executed in a robotic platform. The optimization module can optimize the whole sequence, getting the feedback from the robot.
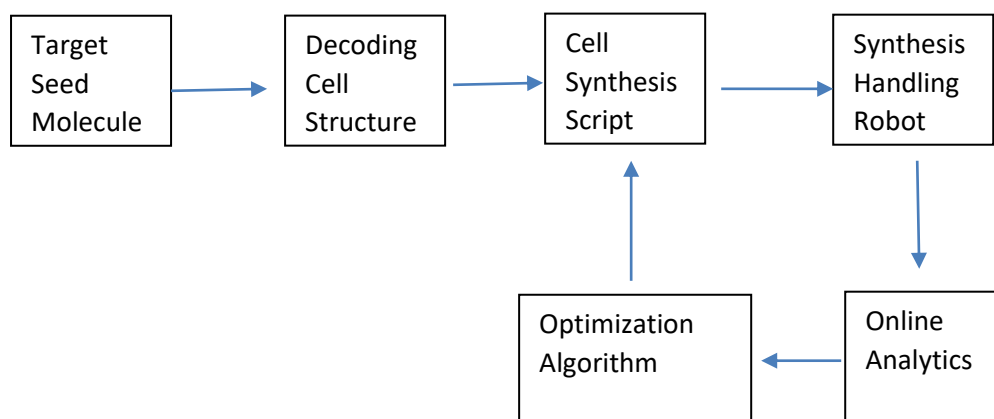

Fig. 2 Architecture of Robotic Synthesis of Crop Cells in a Quantum Generator

The Random Forest is a machine learning algorithm and as the name suggests, "**Random Forest** is a classifier that contains a number of **decision** trees on various subsets of the given dataset and takes the average to improve the predictive accuracy of that dataset. Instead of relying on one **decision tree**, the **random forest** takes the prediction from each decision **tree** and merges them together to get a more accurate and stable prediction.

Protein Synthesis – Synthesis Script

Protein synthesis can be divided broadly into two phases - transcription and translation. During transcription, a section of DNA encoding a protein, known as a gene, is converted into a

template molecule called messenger RNA (mRNA). This conversion is carried out by enzymes in the nucleus of the cell and the mRNA, so converted, is initially produced in a premature form (pre-mRNA) which undergoes post-transcriptional modifications to produce mature mRNA. The mature mRNA is exported from the cell nucleus for translation to occur. During translation, the mRNA is read by ribosomes which use the nucleotide sequence of the mRNA to determine the sequence of amino acids and the specific protein factors required for protein synthesis. The ribosomes catalyze the formation of peptide bonds between the encoded amino acids to form a polypeptide chain.

Following translation the polypeptide chain must fold to form a functional protein; for example, to function as an enzyme the polypeptide chain must fold correctly to produce a functional active site. In order to adopt a functional three-dimensional (3D) shape, the polypeptide chain must first form a series of smaller underlying structures called secondary structures and the polypeptide chain in these secondary structures then folds to produce the overall 3D structure. Once correctly folded, the protein can undergo further maturation through different post-translational modifications which can alter the protein's ability to function, and the protein's ability to interact with other proteins.

A synthesis reaction occurs when two or more reactants combine to form a single product. This type of reaction is represented by the general equation: A + B → AB. An example of a synthesis reaction is the combination of sodium (Na) and chlorine (Cl) to produce sodium chloride (NaCl). The approach for improving protein synthesis using the potential of various species i.e. natural and synthetic extract lies in the mixing of various extracts inside the same reaction platform creating a new cell system with original features. Such hybrid cell systems have been generated by mixing various commonly used extracts together or adding classically used extract for adoption in cell synthesis platforms. The idea supporting such systems lies on each individual cell extract might present specific potentials but also specific drawbacks, mixing two different extracts in a rational way could help compensate individual limitations and combine to achieve the advantages of each system.

In Protein Synthesis, the Script essentially involves:-

1. Each amino acid is attached to a tRNA molecule specific to that amino acid by a high-energy bond and the tRNA is said to be "charged" when the amino acid is attached:

2. The energy of the charged tRNA is converted into a peptide bond linking the amino acid to another one on the ribosome.
3. New amino acids are linked by means of a peptide bond to the growing chain:
4. This process continues until the final amino acid is added. The whole thing works only in the presence of mRNA, ribosomes, several additional protein factors and enzymes.

Genetic Algorithm – Algorithmic Predictions

The efficacy of cell systems i.e. assessing parameters for improving cell synthesis reactions could rely on a considerable number of variables and the amount of work required for exploring variables toward transcription or translation elements in cell systems can be reduced by using Computational Design approaches. Therefore, there is a need to use a learning loop oriented by models generated from Computational Design approaches for optimizing cell protein synthesis reactions and achieving good accuracy in the combinatorial space calculation to be tested. And this requires testing of (i) a combination of genetic designs of few constructs by varying spacers around RBS(Ribosome Binding Sites) and sequences, and (ii) other reaction components (amino acids, glucose, etc.) to an incomplete cell synthesis reaction buffer. By optimizing one variable at a time with a learning algorithm, the designs could managed to reach higher than that of normal increase in protein production in different iterations of execution.

The strategy can be applied for a library of synthetic promoters, Untranslated Regions (UTR) and Ribosome Binding Sites (RBS), at the level of Coding sequence (CDS) and even Translation machinery can be supplemented or adjusted to improve protein synthesis. Further, Reaction buffers can be optimized to infer what composition needs better adjustment per cell preparation and once established a cell protein synthesis protocol, reactions can be optimized for better protein function and desired output.

Mathematical models either stochastic or deterministic can be digitally be evolved to generate optimal synthesis designs that satisfy a particular objective and genetic algorithm is suitable for use to design gene regulatory platforms that exhibit ideal cell synthesis. A genetic algorithm is a metaheuristic inspired by the process of natural selection that

belongs to the larger class of biological evolutionary algorithms. This algorithm reflects the process of natural selection where the fittest individuals are selected for reproduction in order to produce offspring of the next generation. Initially a pool of unique gene designs were required to be generated from basic reactions that satisfy design goal. These design courses were subsequently evolved using numerical simulations to obtain a desired output by repeated rounds of digital mutations and functional screening. These designs could serve as alternatives to consider, model or test during the cell synthesis cycle.
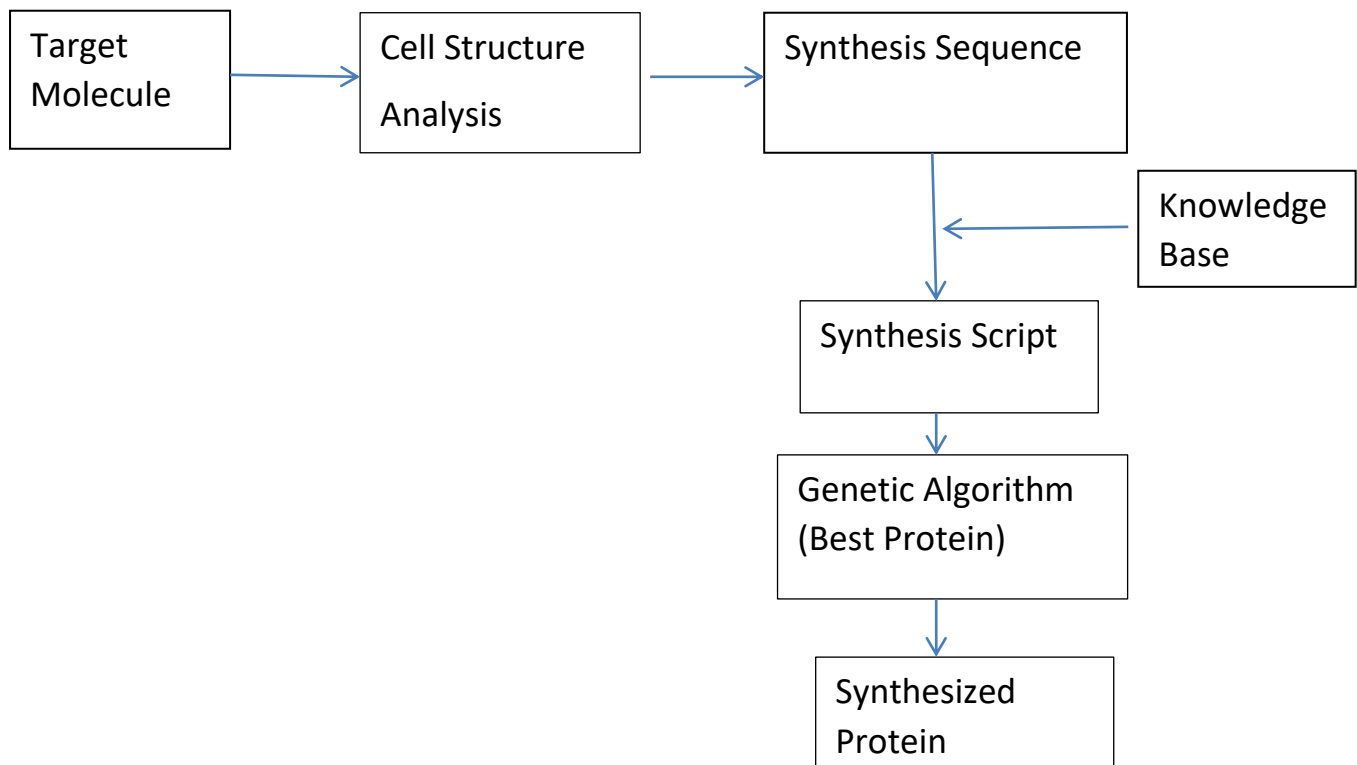
Protein Synthesis Workflow

```
┌──────────┐      ┌──────────────┐      ┌──────────────────┐
│ Target   │ ───> │ Cell Structure│ ───>│ Synthesis Sequence│
│ Molecule │      │ Analysis     │      │                  │
└──────────┘      └──────────────┘      └──────────────────┘
                                                 │
                                                 │        ┌───────────┐
                                                 │    <───│ Knowledge │
                                                 │        │ Base      │
                                                 v        └───────────┘
                                          ┌──────────────┐
                                          │ Synthesis Script│
                                          └──────────────┘
                                                 │
                                                 v
                                          ┌──────────────────┐
                                          │ Genetic Algorithm │
                                          │ (Best Protein)   │
                                          └──────────────────┘
                                                 │
                                                 v
                                          ┌──────────────┐
                                          │ Synthesized  │
                                          │ Protein      │
                                          └──────────────┘
```

Fig. 3 Graphical representation of Protein Synthesis Workflow

An approach to the problem of biological synthesis design and execution, beginning with an abstract representation of the practice of biological synthesis that then gets executed as per the required synthesis programming for its practical realization. Using this foundation to construct closed-loop synthetic procedure in a synthesizer with an

abstraction of biological synthesis, we can generate new crop proteins that may be verified, optimized, and repeated entirely automatically. However, this leads us to test the reactions with different synthetic parameters and conditions.

The synthesis script can be developed using any high-level programming language with automation in combination with machine learning and AI. Additionally, automated synthesis requires(in many cases) optimization of reaction yields, the best conditions can be programmed in a synthesizer to increase the overall yield.

ARCHITECTURE

Cell Shape Engineering

Crop tissues/cells (which are collections of living cells) can be shaped to perform specific tasks. These cells can be programmed/shaped – to blend/ assemble other cells, eventually to form into large crop bodies. The cells required to be shaped in such a way that they gather other cells in their environment forming them into new/ larger cells/tissues with the same capability/structure. And if there's enough of these cell types in a dish/container, they will start to develop and will compact together.

The shape of a cell's body and it's distribution/structure are automatically designed in simulation to perform a specific task, using a process of trial and error(an evolutionary algorithm). Artificial Intelligence has been used to figure out the best shape for the crop tissues/cells.

Using a computational model that simulates the nature of cell and everything of the tissue capability, the process yields the cell shape best suited to ensure the shape of the actual cell tissues into more efficient form suitable to a particular situation/task and accordingly enables cells to compact together in their environment forming them into larger tissues with the same capability.

Evolutionary Algorithm

Evolutionary Algorithms' (EA) constitute a **collection of methods** that originally have been developed to solve combinatorial optimization problems. Nowadays, Evolutionary Algorithms is a subset of Evolutionary Computation that itself is a subfield of Artificial Intelligence / Computational Intelligence.

An evolutionary algorithm (EA) is an algorithm that uses mechanisms inspired by nature and solves problems through processes that emulate the behaviors of living organisms.

The main classes of EA in contemporary usage are (in order of popularity) **genetic algorithms (GAs), evolution strategies (ESs), differential evolution (DE) and estimation of distribution algorithms (EDAs).**

Evolutionary algorithms are based on **concepts of biological evolution**. A 'population' of possible solutions to the problem is first created with each solution being scored using a 'fitness function' that indicates how good they are. The population evolves over time and (hopefully) identifies better solutions. Although genetic algorithms are the most frequently encountered type of evolutionary algorithm, there are other types, such as Evolution Strategy and we have chosen evolution strategy as preferred option as it suits our requirement of cell shape engineering.

Evolution Strategy

In Evolution Strategy, we do not care much about the function and its relationship with the inputs or parameters. Some large population of numbers (parameters of the model) go into the algorithm and it squeeze out one value. We try to find the best set of such numbers which returns good values for our optimization and search problem.

The implementation process is as below:-

1. Randomly generate parameters(population species)
2. Generate a population with different parameter vectors by sampling with Gaussian distribution
3. Evaluate each candidate by running the model and based on the output value evaluate the loss or the objective function by binding it to Evolution Strategy.
4. We then select top/best performing elite parameters and take the mean of these parameters for finding our best parameter so far
5. We then repeat the above process by again generating different parameters by adding Gaussian distribution to our best parameter

obtained so far and repeat the whole process till best solution is found

RESULTS

Based on population of sample candidate solutions, and using visualization library that shows how the accuracy changes across each population. It is observed that after few iterations, on the MNIST dataset, we are able to find good accuracy . However, using higher values for the population of parameters might increase the accuracy. Therefore, evolutionary model as an optimization and shape engineering that mimics the concept of natural evolution / natural selection is encouraging.

CONCLUSION

Quantum Generators (QG) creates new seeds iteratively using the single input seed and the process leads to a phenomenon of generating multiple copies of kernels in repetition. As crop tissues are collection of living cells and are required to compact other cells, eventually to form larger crop tissues and we presented a method to produce natural tissue structures of crops that are designed in simulation to perform a specific task i.e. union, using a process of trial and error(an evolutionary algorithm). We present an evolutionary strategy implementation to solve complex shape related amalgamation problems in crop body formation . by exploiting the possibilities offered by natural selection and results show that if there's enough of cells in a chamber/dish, they will start to develop and will compact together in to a pattern of required architecture or biological blocks.

REFERENCE

1. Poondru Prithvinath Reddy: "**Quantum Generators: Functional Model for the Self-Assembly of Cells from the Structured Compute Units",** Google Scholar

2. Adam Slowik & Halina Kwasnicka: **"Evolutionary algorithms and their applications to engineering problems",** Springer Link