Senior Design Proposal, 2015-2016
(J.C. Ordonez, J.V.C. Vargas, Aug 18, 2015)

1. **Project Title:** Design and development of an automated continuous harvesting system for microalgae photobioreactors

2. **Submitting Organization and Company:** FSU and UFPR

3. **Liaison Engineer Information**:

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4. Project summary

This project will focus on the design and the development of a continuous harvesting system for microalgae photobioreactors. An Arduino microcontroller will be programmed, calibrated, and used to automate a microalgae harvesting system. Additionally, a biomass separator and extractor will be developed, integrated, and also will interface with the Arduino microcontroller. This will entail the design and/or usage of a novel pump and should enable batch, semi-continuous, and continuous microalgae culture collection. Initial advances will be implemented at laboratory scale and after the successful small scale prototyping the entire automated photobioreactor system will be scaled up. The end product will consist of a photobioreactor system that will grow microalgae cultures, sample the cultures using pumps, analyze the microalgae concentration, collect microalgae when it has reached a desirable concentration, separate the water medium from the solid biomass using flocculation, extract the biomass, and then recycle the clarified water back to the process medium. This project has the potential to yield a fully automated and continuous harvesting photobioreactor with the capability of clarifying water or effluents, generating valuable biomass, and offers a viable avenue for emission recyling.

5. Introduction

Currently 80% of the world's energy demand is fulfilled by fossil fuels (Zechen 2012). Recent studies indicate that fossil fuels are being consumed at a rate 10^5 times higher than they are being produced in nature (G. Satyanarayana et al, 2011). This demand for energy will quickly supercede the world's supply of fossil fuels and will inevitable lead to an energy source transition. It is therefore prudent and desirable to begin to invest in, research, and development other more sustainable avenues for viable energy production. One high potential alternative is microalgae photobioreactors.

These photobioreactors cultivate microalgae utilizing the autotrophic characteristics of the algae and then produce solid biomass, clarify the medium the algae is grown in, remediate emissions, and can produce hydrogen and other biogases (G. Satyanarayana et al, 2011). This process possesses the capability of being autonomous, sustainable, environmentally friendly, and produces biomass which can be used as a feedstock, fertilizer, coloring agent, chemical production, and a material source with which to generate biodiesel.

Within the photobioreactors, the microalgae cultivation and growth is governed by a time dependent curve which dictates the microalgal lifecycle. On this curve there is a a point where the growth rate of the algae culture is a maximum. In order to optimize the cultivation and harvesting of microalgae, it is possible to maintain algae growth at this peak point in its life cycle. A specialized harvesting system could then continuously collect the microalgae. A continuous supply of cultivated microalgae requires a continuous way of separating the biomass from the medium and extracting said biomass. This is usually done through flocculation which is a process which separates the algae from it's aqueus medium. Traditionally, flocculation is performed by using a centrifuge or by a adding a chemical flocculant and waiting for the flocculated algae to settle. Additionally, there are methods which rely wholly on non chemical bio flocculation.

The challenge within this project is to design and construct a fully automated microalgae growth and harvesting plant. This is achieved using the primary components of a smart control system that can decide when to start harvesting, stop harvesting, and to add growth medium etc., and a developed biomass separator and extractor. This separator and extractor will be designed in such a way that allows the biomass to be extracted from the medium and the medium to be recycled back for further use. This will be a sustainable fully automous system with high potential for environmental recyclability and as an energy source generator.

6. Most Important Project Objectives:

General objective:
Design and development of an automated photobioreactor microalgae continuous harvesting system

Specific objectives:
From the major challenges listed in the previous section, this study selected the following objectives to be pursued by this project in order to achieve the general objective:

- Utilize Arduino microcontroller to fully automate microalgal biomass production process
- Design and integrate a biomass separator to extract solid biomass
- Design and implement a method, process, or technology to facilitate continuous flocculation
- Scale up prototyped bioreactor design to full size

6. Design/Result Expectations:
    - Design, construct, and implement operational units.Provide enough experimental data to test operation evaluate implementation of the designed units.
    - Provide mechanical drawings of the entire system and designed components.Write an invention disclosure (FSU team) to be submitted to the USPTO by the OTT/FSU and a patent request (Brazilian team) to be submitted to the Brazilian INPI, for an automated continuous harvesting/novel flocculator/biomass separator photobioreactor system developed by the 2014/2015 team.

7. Prototype(if required) Expectations:
    - It should be fully automated.
    - Should enable continuous culture collection.
    - It should be low-cost, sustainable, and efficient.
    - It should be for long term outdoor use.
    - It should be scaled.
    - It should be a completely functional system process.

8. Estimated Costs of Hardware, or Items Provided by Sponsor: Approx. $3000

9. New Technology Requirements: Novel microalgae culture flocculator (separator) and biomass extraction system

10. Special Information: N/A

Considerations for team selection:
The team would benefit from a member with knowledge or interest in automatic control and sustainable energy. If teaming with other college departments, a chemical or industrial engineering student would be beneficial.

References:

[1] G. Satyanarayana, A. B. Mariano, and J. V. C. Vargas. 2011. A review on microalgae, a versatile source for sustainable energy and materials. *International Journal of Energy Research* **35: 291–311.**

[2] Yusuf, Christie. 2007. Biodiesel from Microalgae. *Biotechnology Advances* **25: 294 - 306.**

[3] Zechen Wu, Yi Zhu, Weiya Huang, Chengwu Zhang, Tao Li, Yuanming Zhang, and Aifen Li. 2012. Evaluation of flocculation induced by pH increase for harvesting microalgae and reuse of flocculated medium. *Biosource Technology* **110: 496 - 502.**

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