Analyzing systemic evolution of technologies by combining tech mining and semantic TRIZ

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Introduction
The analysis of science & technology advance has been greatly systematized through the use of bibliometric tools and further advanced by the use of Techmining, a combination of text mining tools with the knowledge of technological innovation processes (1). On the other hand, the assessment of the evolution of emerging technologies, its progress and the possible shift to other new technologies continue to be the subject matter of study.
The present work attempts to further throw off some light on the progress or shifts to other new technologies by utilizing a combination of trends analyzed by TechMining jointly with the syntactic and semantic approach of semantic TRIZ, the application of syntactic-semantic tools with the knowledge of the TRIZ methodology and technological innovation processes.
The combination of both approaches, TechMining and semantic TRIZ, can bring fresh insights to the understanding of evolution and shifts in the DSSC technology (2). Semantic TRIZ should also help to identify the hierarchy of main components as well as auxiliary components and the interrelationship among them. Complemented with Techmining, be able to assess their progress in its functions as a way to understand also their state in the S curves and their interrelationship within the system.

Background
The starting point of TRIZ is the analysis of technologies as systems and its progress to a an ideal state where all the benefits with no harm of a technology, is reached (3). The systemic point of view though is of relevant interest 'per se' (4) As Bertalanffy reminds us, to deal with complex sets, or 'systems', one should consider aspects related to their number (quantity, citations, repetition, appearance,..), to their type and to the relations of their constituent elements.

Technologies are systems (3) (4)(5) and in particular, the dye sensitized solar cell is a system with components and interrelations among them, worth to be studied in their effect on the whole system evolution.

In Techmining there is some research using morphology analysis (6) in which the study of a technology takes into account their different parts or constituents, though not analyzing their interactions. Ma et al (7) apply the 'morphology analysis' to the components of the dye sensitized solar cell. The present paper takes profit of said work to update and advance in the cited purpose.

Methodology
The authors have mined thousands of articles, patents and web sites, to understand the trends of the constituent components of DSSCs but also if said components, experiment a shift in their functions, usage and parameters which either consolidate the DSSC system or have a new life for other alternatives which may hinder its original function in the DSSC system. The

knowledge about the interrelations among the DSSC components, should also identify several research challenges and bottlenecks.

According to the experience of the writers, a operational map of a DSSC system is presented in figure 1 based on the knowledge of TRIZ SAO modeling and by reviewing several research papers and recent reviews about DSSC, understanding about its materials and its defects. The DSSC system depicted has been reviewed by the team of Nazeeruddin and Grätzel in Switzerland

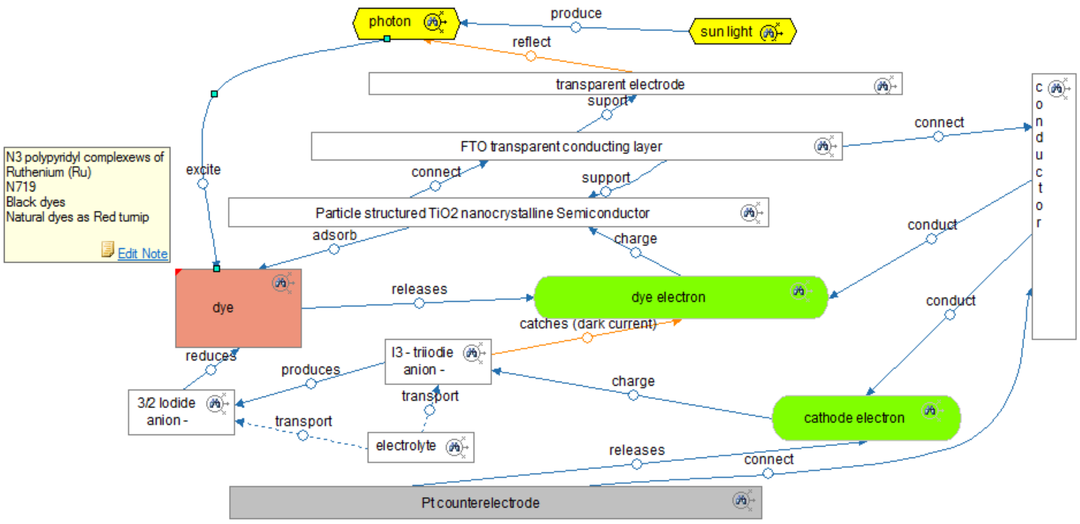
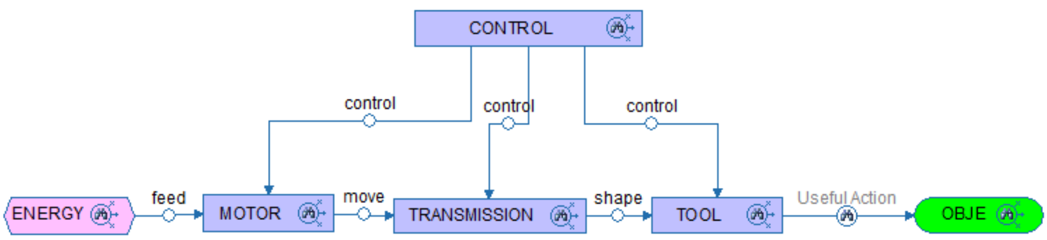


Figure 1

The diagram above represents the system model of a DSSC in where each arrow points from the 'tool' or function donor, to a function receiver or 'object' and represents a function in which the 'tool' changes, controls or maintains some parameter of the 'object'. The blue arrows represent useful functions whereas the red ones are undesirable functions or shortcomings for the current system. The dotted lines are useful functions although with a performance ranking below its satisfactory state (for instance, the electrolyte should transport the anions faster). The boxes are part of our system, the elements pertaining to the system, the hexagons a are elements out of our system, pertaining to the environment of the system, and the ovals are the target of the system, what the system is intended for.

In TRIZ, the concept of an almost complete system has at least a source of energy, a motor, a transmission means, a tool and a control. The tool of the system is directly responsible of changing some parameter of the object of the system. For example, in a machine tool, the tool is the cutter and is the direct responsible for machining the piece. In a photo camera the lenses are the tool shaping the image photons to cast the CCD or formerly the film. See figure 2



According to TRIZ laws of evolution, it is easier to change the parts farther of the object than changing the tool. The more internal, the easier. For instance, in the photo industry, filmmakers camera makers, etc., all except lenses manufacturers were struggling to find a right position in the new digital market. When the tool changes, the principle of the system usually also changes, and this represents a major change in the technology. For instance the lighting industry recently stopped the incandescent wire (the tool producing the photons) in the search for already known fluorescent lamps making some spare time for the coming of the LED's. In these cases, the tool has been changed, carrying also major changes in the industry, but it kept without changes one of the components in contact with the environment as it is the screw thread part. These inter phase components are also less prone to change due to their interconnected nature which at the same time depends on standards and network effects.

Applying such concept to our DSSC system, as a starting point the authors have initiated the analysis on one of the elements of the DSSC system. In particular, the authors started with the counter electrode due to its contribution in the overall efficiency of the DSSC (10)

Figure 2 represents the trend of citation of two major counter electrode types after the analysis of 11.373 articles from 1991 to 2013 ISI WOS following the nine steps of the decision phases and the tech mining process (1) to analyze the state of the art and trends of the components. Also the aggregated values are shown. To define the search strategies, the authors have considered using some previous bibliometric work (7)

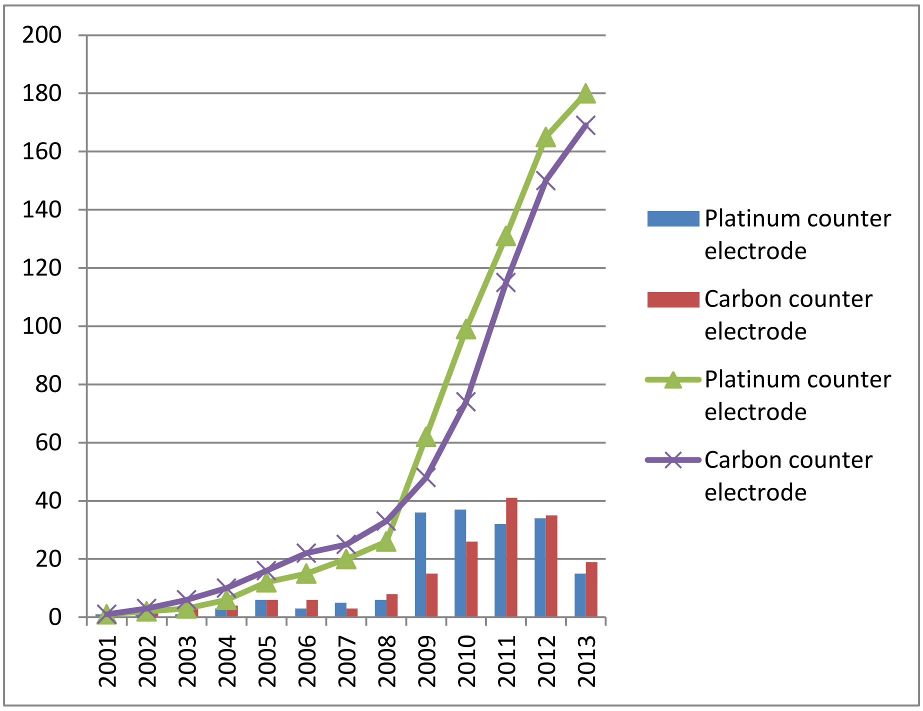


Figure 2

By exploring figure 2 trend, it seems that platinum and carbon are most used as materials for the counter electrode. By using the semantic TRIZ, we have started complementarily to explore the type of electrodes. A first extraction is shown in fig 3 as a way of example. By exploring the components of the DSSC records from full text patents with applicaton date from 1991 to 2013, the material and somehow the manufacturing procedure or the design configuration, are cited, so that a good view of what is really occurring in the development and evolution of the counter electrode component.

65	platinum counter electrode	As shown in the figure, the photosensitized electrode 1 according to the present invention is assembled with a **platinum counter electrode** 51 to form a solar cell device filled with an electrolyte 52 inside.	InN/InP/TiO2 photosensitized electrode	Most relevant	EP-1887592 B1, US-7622397 B2	**Institute of Nuclear Energy Research, Atomic Energy Council**(Lungtan,China
66	nickel counter electrode	There is no particular limitation to the kind of the counter electrode 43 as long as the counter electrode 43 if formed by a conductive substrate. A conductive metal such as titanium, aluminum, and **nickel** can be cited as an **example of the counter electrode** 43. In the counter electrode 43, in order to promote the redox reaction of the electrolytic solution, a catalyst is provided in a surface contacting the electrolytic solution. Examples of the catalyst include platinum, graphite, and an organic polymer. The catalyst is provided on the counter electrode by platinum sputtering, a method of reducing a platinum colloid solution, graphite application, or organic polymer spin coating.	Dye Sensitized Solar Cell	Most relevant	US-20090000661 A1	**YOSHIMOTO, Naoki**(Hitachinaka, Japan
68	carbon counter-electrode	Each element includes a light facing anode comprising nanocrystalline titania, a **carbon counter-electrode** (cathode), which is a porous, catalytic, electrically conducting carbon-based structure bonded together using a titania binder, and separating the anode from the cathode is placed an intermediate...	PHOTOVOLTAIC DYE CELL HAVING AN IMPROVED COUNTER-ELECTRODE	Most relevant	WO-2009027977 A2	**3GSOLAR Ltd.** (Israel);
75	polymer film	Examples of **counter electrodes** which can be used include glass or a **polymer film** on which platinum, carbon, rhodium, ruthenium or the like are vapor-deposited, or conductive fine particles are applied.	Dye-Sensitized Solar Cell	Most relevant	US-20090242027 A1	**Inoue, Teruhisa**(Tokyo, Japan
77	thin Pt layer	The conductive layer and **thin Pt layer** are to be a **counter electrode** of the solar cell.	Dye-sensitized solar cell	Most relevant	US-20090199896 A1	**Oki Semiconductor Co. Ltd.** (Tokyo, Japan)

Figure 3 an extraction of counter electrode materials from 2009 patents (source micropatent)

Another possible step is to explore the functions that the counter electrode is performing and how these functions are evolving in time or which other elements may take the same functions. Understanding of the system may help to understand or recognize some of the current problems, e.g. in (12) there is a clear component conflict in the ‘DSSC electrolyte since a good crosslinking increases stability, but hinders conductivity whereas a less crosslinked electrolyte is less stable but offers a higher conductivity.

The authors think that the course of the research by combining TechMIning and Semantic TRIZ, will bring a better understanding of the challenges and evolutions of the DSSC system.

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