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AUTOMATED CELL CULTIVATION AND ANALYSIS: AN APPROACH FOR A USER INTERFACE DESIGN

WENZEL, Sabine; FISCHER, Robert; NOWACK, Tobias;
STUBENRAUCH, Mike; WITTE, Hartmut
Biomechatronics Group, Institute of Micro- and Nanotechnologies (IMN MacroNano®),
Technische Universität Ilmenau

ABSTRACT

While automation is standard in most industrial and research fields, cell cultivation is still dominated “handling”, manual processes. To improve the situation, our group focusses on the development of a bio-centred, automated cell cultivation tool. Modular design may help to realize a variety of experiments. Cultivation processes are observed and controlled via a graphical user interface. This article describes the systematic approach, the overall specification (with process analyses) and the preliminary results for the prototype of a graphical user interface.

Index Terms – user interface, GUI, automation, cell cultivation, cell analysis

1. INTRODUCTION

Up to now, cell cultivation is dominated by manual processes. Our group focusses on a bio-centred approach with different modules for automated cell cultivation: System for Automated Cell Cultivation and Analysis (SACCA) [1]. The modular design of the SACCA-workbench (see figure 1) helps to realize several variants of experimental setups.

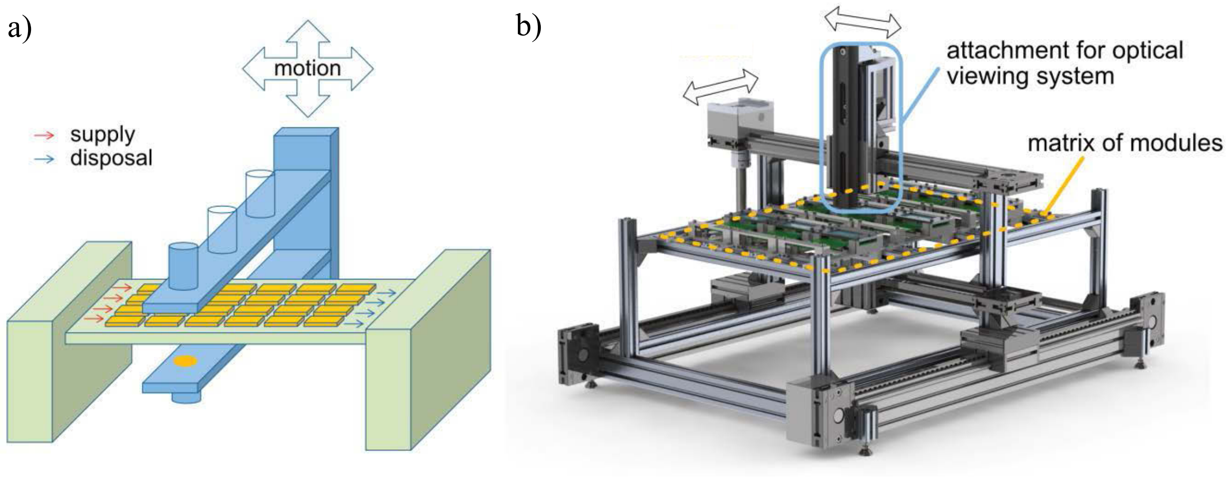

Figure 1: a) Schematic of the SACCA-workbench, green: supply unit (basic module), orange: matrix of spatially fixed cell cultures, blue: mobile optical analysis system; b) CAD-model of the setup

The operator has to interact with the workbench by human machine interfaces. Methods of user experienced design and usability guidelines were used to develop the graphical user interface (GUI). It may be predicted, if the operator cannot interact with the complex system easily, the technology will not be accepted. An early focus on users and their tasks is important to establish a user friendly human machine interaction.

2. APPROACH

To understand the system it is important to define processes and specifications. Thus, an early exchange between experts from different mechatronic domains taking part in the development process was established. Under the aspect of usability, we also included potential users into the first steps of GUI design to conduct first user surveys. The user interface (UI) design is based on the system specifications (developer side; see chapter 3) and the analysis of user experiences. The design process follows VDI 2206 [2] as well as the principles of Usability Engineering [3; 4] and general GUI design principles [5; 6].

3. SYSTEM SPECIFICATION

The first steps of development consist of an activity analysis. Therefore, all devices are defined and the information flows among them are analysed (see figure 2). The cells are observed via distributed sensors inside the modules and optionally by an integrated analytic tool (moving optical system). All processes and actions should be manageable via a touchscreen interface.

The workbench consists of a basic module (a framework for all operating elements) featuring a three-axis positioning system for analysis modules and a matrix of cell cultivation modules (see figure 1 b) with pumps for nutrient supply. Currently, the analysis module is an optical system including image acquisition and processing. The graphical user interface is installed on the server with the master clock and the storage of all experimental data. The GUI will illustrate and help to control different experimental parameters for the complete system. As a "master-of-masters" the server communicates with a network of microcontrollers acting as coordinators for cell cultivation and the basic module, which both in turn interact with microcontrollers executing dedicated system processes like the control of environmental parameters for cell cultivation.

To control the supply infrastructure, physical (e. g. temperature and forces on cells), chemical (e. g. pH and availability of nutrients and gases) as well as biological parameters (e. g. cell-cell- and cell-matrix-interactions) could be monitored and changed. These parameters have a direct impact on cell reactions like differentiation or synthesis of specific metabolites and thus enable the investigation of cellular stimulus-response-mechanisms. The coordinator of cultivation processes configures the pumps and the adjacent modules with default parameters. They are set for an experimental setup by the server but can be changed by the user via the GUI. The coordinator cultivation also collects sensor data (like flow rate or temperature) and sends them back to the server. But only controlling the parameter information is not sufficient. The server (also the GUI) has to be informed at which position of the matrix which module is located. Therefore, near field communication (NFC) components are implemented. Via the integrated NFC-tag a module registers itself, and the coordinator of the basic module may inform the server about the module allocation. This coordinator also controls the positioning of the optical system (in x, y and z), and informs the server about operating data (like process and position information or error codes). A mechanical emergency stop allows intervention. When the optical system is positioned over the micro cultivation chamber of a cultivation module the coordinator of the basic module gives the initial information for starting the image acquisition. The optical system gets further information (like module/position number) for image storage on the server. So, each image will be stored with a distinct file name. After request, the GUI can assign and display the images for each module.

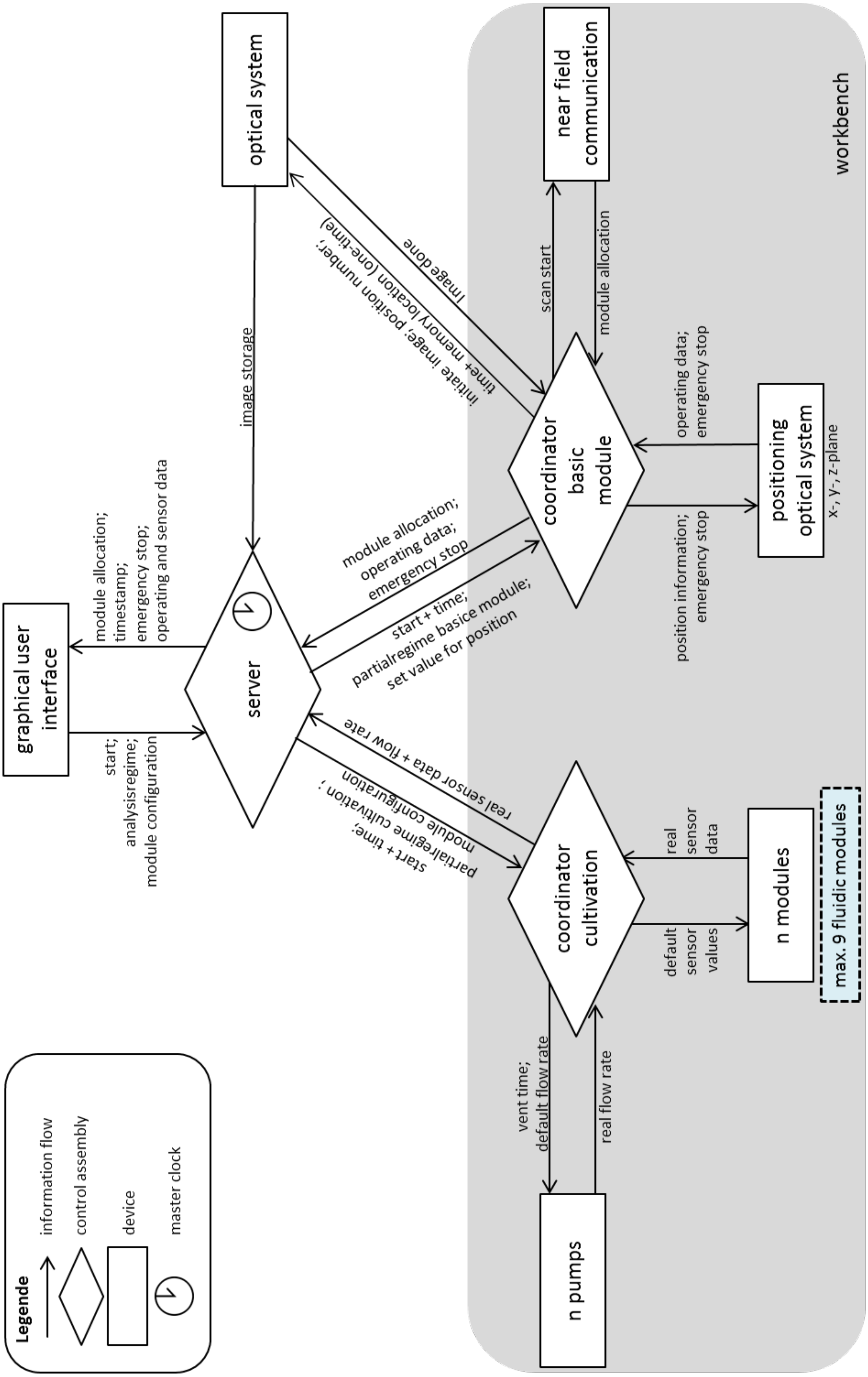

Figure 2: Illustration of the devices in the SACCA-system and the information flows between them

Figure 3 illustrates a possible installation of the workbench with supply and disposal. In this example nine modules are organized in three rows containing three modules each. One pump supplies one row with cell cultivation medium and a disposal container at the end collects all the fluids in a safe state.

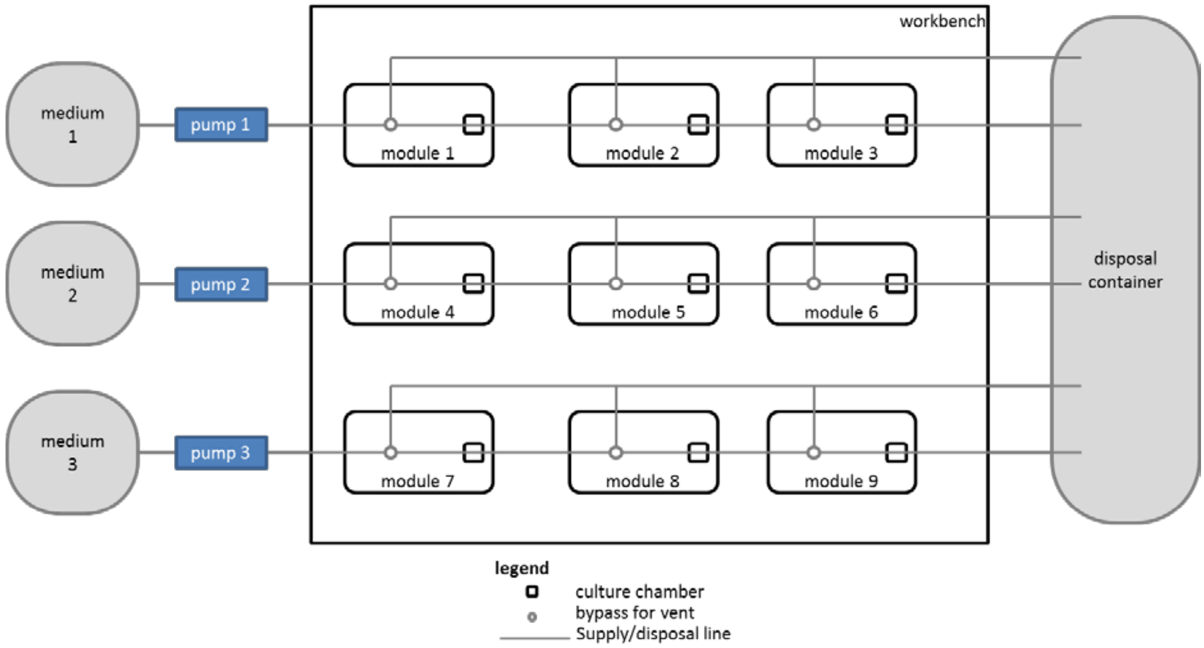

Figure 3: Schematic of a possible installation including nine modules organized in three rows containing three modules each

Figure 2 shows the information flow structure. For a better understanding, each application/ subroutine has to be defined in more details. Knowledge about the properties of the possible module types and their parameters is important for all applications. This representation will be part of further work.

Figure 4 displays a specific application: the *initial operation* process. The *initial operation* describes the start-up of the SACCA-workbench or initializes the process of module change. Therefore, all modules as well as the supply lines and all auxiliary components have to be prepared separately and continuously kept sterile. Also, the assembly has to be done under sterile conditions. The subroutine *cleaning/disinfection/purging* (see figure 4 b) references one row with up to three modules (see figure 3). For the prototype of SACCA-workbench the fluidic and electrical connections have to be added manually. The GUI will guide the user step by step through the processes of module change or system cleaning. Instructions (e. g. pop-ups) guide the user through necessary steps. Confirmation requests like *"Are the fluidic and electrical connections added? – Yes/No"* ensure that all parts are implemented as required for the experiments and ensure sterile operation of the whole system.

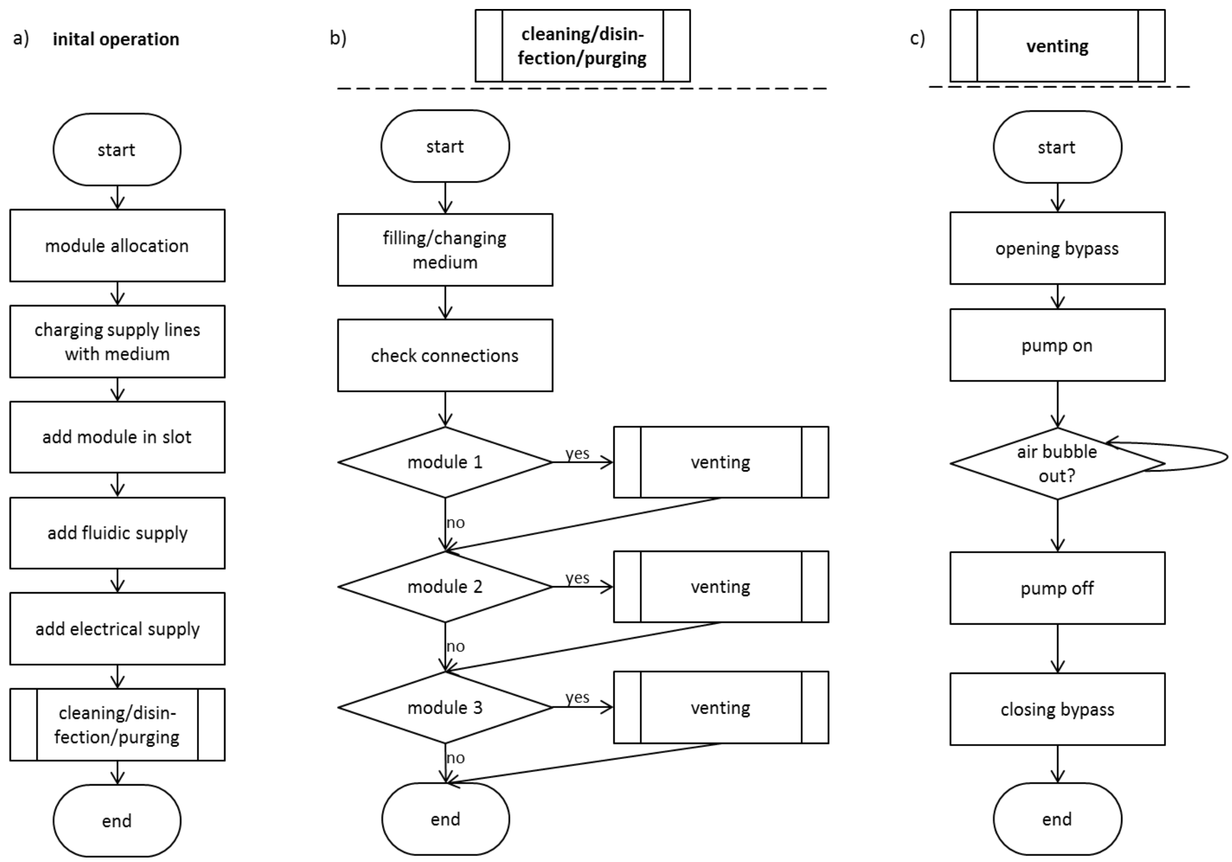

Figure 4: Flow charts of the initial operation (a), the subroutines for cleaning/disinfection/purging (b) and venting (c)

4. PRELIMINARY RESULTS

The operating concept allows the user to control (e. g. temperature in the cultivation chambers) and to monitor (e. g. via optical viewing) the modules of the system as well as their functions and parameters on one screen near the workbench. The user interface is developed webserver based. This allows using the interface independently of the input device. From a computer outside the laboratory new configurations and new modules may be implemented.

Figure 5 illustrates the first developmental version of the GUI. The website consists of four parts. The *SACCA-logo* combines the project reference and the possibility to refresh the home page. The second part *status* gives the operator feedback related to the current process. This status bar will be displayed each time, even when the user configured a new experiment in the main screen. This helps the user to monitor the process parameters easily (each time on the same position) and subsequently react quickly to system events. The third part *menu* on the left side is modular like the system itself. The menu changes triggered by a module request. The interface gets all information about the activated types of modules and about their position (module allocation) from the coordinator of the basic module. The fourth part *main* constitutes the main human machine interaction: displaying and changing parameters as a function of the activated modules such as 'Fluidikmodul' (place 2 of the workbench) or 'Pumpenmodul' (place 5 of the workbench) or starting processes ('Programmpläne').

The prototype of the interface is established on a Raspberry Pi 3 with a touch display as the server device. The user interacts with the display, which is linked to the Raspberry. The Raspberry interacts with the SACCA-workbench via USB port. An iterative design (prototyping, repeated user surveys, analyses) allows the permanent evaluation of different concepts, including user feedback during use.

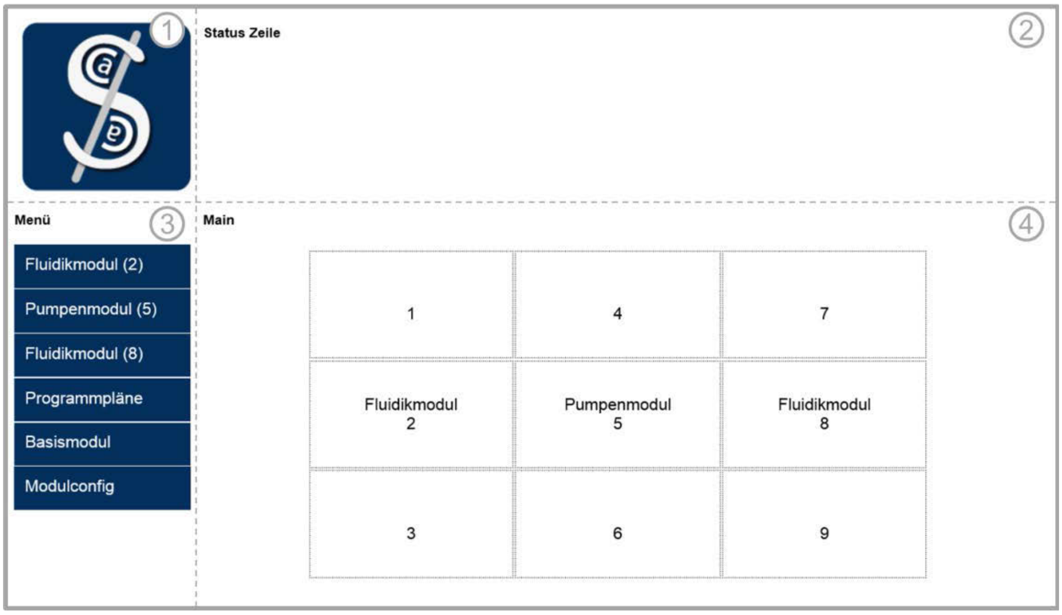

Figure 5: Example of the current GUI design, numbers in grey circles: partitions – 1) getting to the home page, 2) display of status information, 3) adaptive menu, 4) main interaction place

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CONTACTS

Sabine Wenzel, M. Sc. sabine.wenzel@tu-ilmenau.de
Univ.-Prof. Dipl.-Ing. Dr. med. (habil.) Hartmut Witte hartmut.witte@tu-ilmenau.de