# DEVELOPMENT OF A WEB-BASED SHIFT REPORTING TOOL FOR ACCELERATOR OPERATION AT THE HEIDELBERG ION BEAM THERAPY CENTER

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*Abstract*

The HIT (Heidelberg Ion Beam Therapy) center is the first dedicated European accelerator facility for cancer therapy using both carbon ions and protons, located at the university hospital in Heidelberg. It provides three fully operational therapy treatment rooms, two with fixed beam exit and a gantry. We are currently developing a web based reporting tool for accelerator operations. Since medical treatment requires a high level of quality assurance, a detailed reporting on beam quality, device failures and technical problems is even more needed than in accelerator operations for science. The reporting tools will allow the operators to create their shift reports with support from automatically derived data, i.e. by providing pre-filled forms based on data from the Oracle database that is part of the proprietary accelerator control system. The reporting tool is based on the Python-powered CherryPy web framework, using SQLAlchemy for object relational mapping. The HTML pages are generated from templates, enriched with jQuery to provide a desktop-like usability. We will report on the system architecture of the tool and the current status, and show screenshots of the user interface.

## THE HIT MEDICAL ACCELERATOR

The heavy ion accelerator at HIT is used for raster-scanning radiation of cancer patients (cf. [1, 2] for an overview) with different types of ions from two sources (upgrade to three sources in progress [3,4]) in several treatment rooms, two with horizontal fixed beam exit and the heavy ion gantry with rotatable beam exit (operational [5] since 2012), and a beam exit for experiments (see Fig. 1). Each combination of source and destination may be used for medical treatment, represented within the Accelerator Control System (ACS) by the so-callled *virtual accelerator* number. A radiation plan consists of a series of beam pulses chosen from a catalogue of 255 different energy values (88–430 MeV/u for carbon, 48–220 MeV/u for protons), 6 focus sizes, 15 intensity values ($2 \times 10^6$–$5 \times 10^8$ particles per second for carbon, $8 \times 10^7$–$2 \times 10^{10}$ pps for protons), and 36 exit angles in case of the gantry. These tuples of beam settings are named the MEFI combinations. Both the virtual accelerator as the MEFI combination may be changed from beam pulse to beam pulse (multi-plexed operation).

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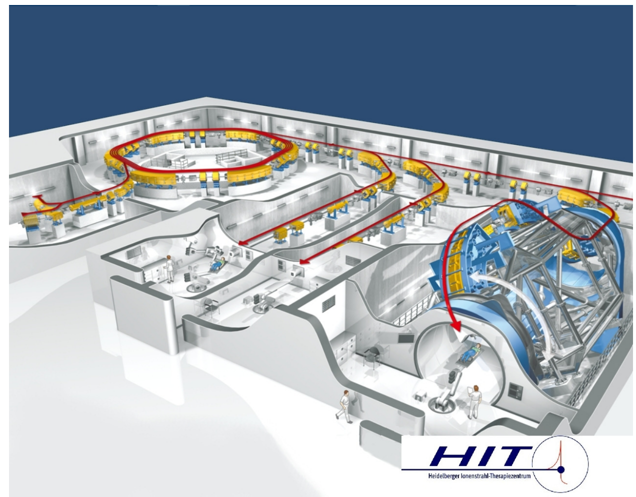


Figure 1: HIT accelerator facility with two ion sources, linear accelerator, synchroton, two horizontal beam exits and gantry for medical treatment. The experimental area is not shown.

## AIMS FOR A SHIFT REPORTING TOOL

HIT uses a well established electronic log book [6] based on the widely used Wordpress blog software [7]. While this solutions offers a quick and convenient way to publish notes on issues that occur during operation, it doesn't offer an interface for a standardized regular report on the key facts of a shift, e. g. who used the beam, statistics on failure times, ion types. Additionally, there is no connection between the Wordpress log book and the proprietary control system, i. e. noteworthy alarm messages from the control system have to be added to the log book manually. This process is error-prone and makes a later analysis difficult since the log book notes aren't standardized.

## TECHNICAL DETAILS OF THE SHIFT REPORTING TOOL

The tool was developed using free and open source software. It's mainly based on Python and frameworks based on Python. Since it was intended to implement the tool as an web-based application, we used CherryPy [8]. CherryPy is an easy-to-use web application framework where web pages are simply developed as methods of Python classes, thus combining the standard object-oriented software de-



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sign with web applications. It uses the Web Server Gateway Interface (WSGI), making the web application run fast since it runs in a continuous process. Caching, sessions, authorization and mixing static and dynamic content are supported, too. Since CherryPy leaves the decision for a HTML templating language to the developer, we decided to use Jinja2 [9]. Jinja2 is very flexible and uses a syntax very similar to PHP or JSP tags.

We used jQuery [10] to offer a desktop-like feeling of the web application. JQuery not only provides state-of-the-art themes (mainly CSS based, allowing flexible changes of the layout without changes to the HTML or JavaScript code) but also a sophisticated event handling. This allows the web page to be loaded only once into the browser, and events are handled dynamically using the Asynchronous JavaScript and XML (AJAX) technique. As a result, only parts of the HTML page are changed by the JavaScript callback function in response to JSON received from the CherryPy application server upon the asynchronous request. JQuery also provides a library for mobile web pages, thus the shift reports might be extended by a version optimized for mobile devices in the future.

A key feature of the shift reporting tool is the connection to the control system. This is realized via the Oracle 11g database used by the control system to store all configuration data, logs of changes to accelerator settings, and alarm messages. In the last years, many object-rational-mapper (ORM) frameworks for mapping SQL based relational databases to an object-oriented design were established for all modern programming languages, based on the patterns for design of enterprise applications written down by Martin Fowler [11]. In the case of Python, this is SQLAlchemy [12], supporting all important features like mapping relationships via foreign keys and mapping class inheritance to database tables. SQLAlchemy defines a generic query interface independent from the SQL dialect of a particular database, including support for Oracle and MySQL. Since SQLAlchemy uses the Unit of Work pattern to track changes to the managed objects and the Identity Map pattern for caching objects, the emittance of SQL statements to the database is optimized.

## FEATURES OF THE SHIFT REPORTING TOOL

Currently, the tool supports the following features:

- General information on the shift, e. g. list of operators, reports on calls to standby personnel, purpose of the shift (therapy, treatment plan verification, experiments, machine adjustment).
- Listing of changes to devices that may impact the quality of the beam and may require additional checks by the medical physicist.
- Report on daily quality assurance (QA)
- Report on device failures.
- Beam statistics.

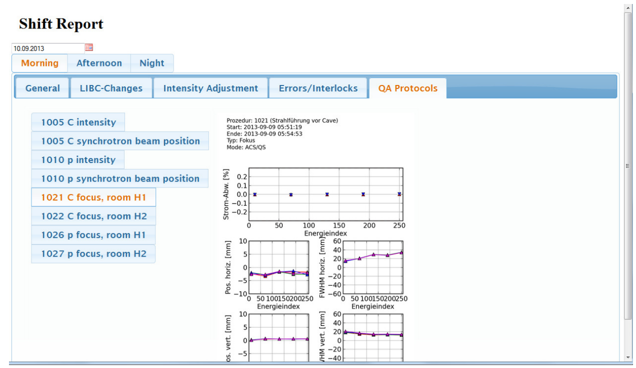


Figure 2: Result of daily QA, like deviation of measured beam intensity from reference values, beam positions and sizes at several places within the accelerator beamlines, and the deviation of the actual currents in dipole magnets from there reference values.

### *QA and Tracking of Changes to Machine Settings*

Using the beam for medical therapy requires a high standard of quality assurance. A daily QA of the accelerator is performed before the start of therapy, checking beam intensity and positions in the treatment room against their reference values. The plots of these tests are displayed (see Fig. 2), giving the medical physicist in charge the information necessary to decide whether machine adjustments or additional checks are required.

Changes to any device that may have impact on the beam parameters, i. e. beam position or size, intensity or particle energy, are documented and listed as a part of the shift report. In most cases, changes are due to adjustments of the physical $kL$ values of the quadrupol magnets between source and LINAC, determining the beam intensity in 10 distinct steps, if the measured intensity was outside the predefined limits. Previously it was due to the accuracy of the operators how detailed these changes were documented.

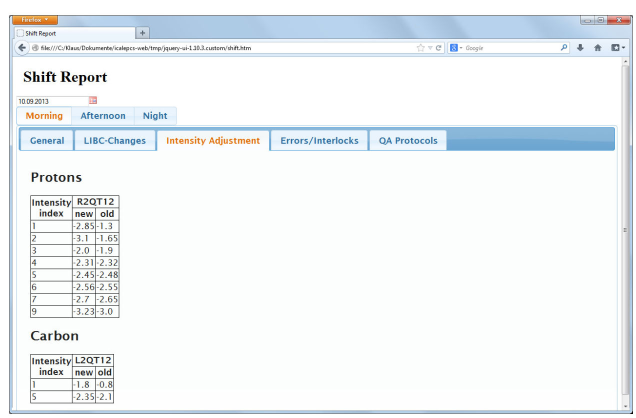


Figure 3: Documentation of changes to the quadrupol settings for several intensity steps.



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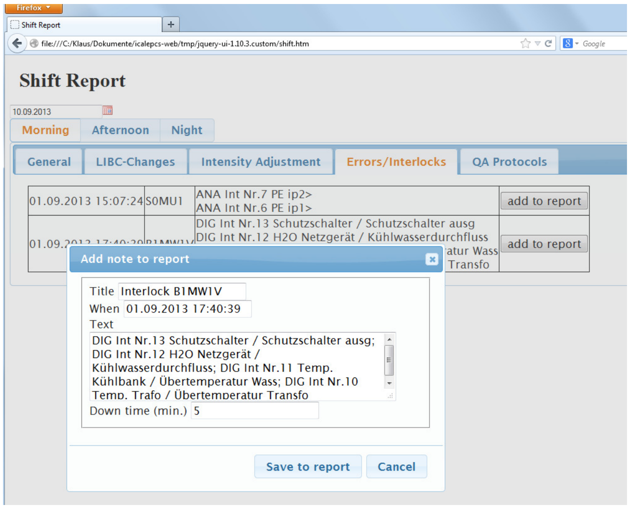


Figure 4: Messages on device failures read from Oracle database. The operator may decide whether they shall become part of the shift report. Error details are automatically included, the operator may add details like accelerator down time.

Now, we use the logging of changes to all device settings, stored by the control system as binary objects (BLOB) into the Oracle database. The shift reporting tools tracks these changes and reports automatically, for which ion types and intensity indices the settings of the quadrupols were changed, documenting the old and new *kL* settings, as shown in Fig. 3.

### *Error Analysis*

The control system stores all alarm messages into the Oracle database. In the case of device failures these messages contain the full error bitmask, giving the information what kind of error occured (e. g. interruption of cooling water). The shift reporting tool reads the error messages from the Oracle database, and the operator may decide, whether it is noteworthy for the shift report (see Fig. 4). In this case, it is saved in a standardized way (using a HTML template), including device name, error details and the timestamp, when the failure occured, as read from the Oracle database. The operator may add additional details of the failure and statistical information like the downtime of the accelerator that was caused by the failure.

The noteworthy error messages are injected into the Wordpress based electronic log book and linked to the shift report. These log book entries may be commented later (e. g. by the device expert after a analysis of the error) and enriched with attachments like screenshots, giving additional details beyond the short error notice in the shift report.

### *Statistics*

The beam cycles during a shift are analyzed by several statistical criteria, like distribution of ion types used, beam destinations, used beam parameters, as shown in Fig. 5.

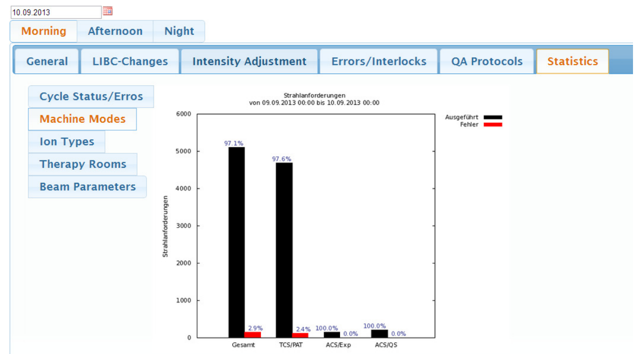


Figure 5: Statistical analysis of beam cycles during a shift.

## OUTLOOK AND CONCLUSION

We were able to develop a tool that will hopefully help the operators to produce shift reports with a minimum of work. Currently, we start beta tests to get feedback from selected operators to improve the usability. This is an important issue to achieve a good acceptance of the new tool. We plan to start the shift reporting tool in accelerator operations on a regular base with the beginning of 2014.

## REFERENCES

[1] Th. Haberer et al., "The Heidelberg Ion Therapy Center", Rad. & Onc., 73 (Suppl. 2), 186–190, (2004).

[2] S. Combs et al., "Particle therapy at the Heidelberg Ion Therapy Center (HIT)", Radiotherapy and Oncology, Vol. 95, 41–44, (2010).

[3] A. Peters et al., "Five Years of Accelerator Operation Experience at HIT", IPAC 2012, New Orleans, Louisiana, USA, TUOAB03, `http://www.jacow.org`

[4] R. Cee et al., "Status of the Ion Source and RFQ Test Bench at the Heidelberg Ion Beam Therapy Centre", IPAC 2011, San Sebastián, Spain, September 2011, WEPS044, `http://www.jacow.org`

[5] M. Galonska et al., "The HIT Gantry: From Commissioning to Operation", IPAC 2013, Shanghai, China, THPWA004, `http://www.jacow.org`.

[6] J. M. Mosthaf et al., "Using Wordpress as a Simple and Reliable Electronic Logbook for the Heidelberg Ion-Beam Therapy Centre (HIT) Accelerator Control System", ICALEPCS 2009, Kobe, Japan, THP111, `http://www.jacow.org`

[7] `http://wordpress.org/`

[8] `http://www.cherrypy.org/`

[9] `http://jinja.pocoo.org/`

[10] `http://www.jquery.com/`

[11] Martin Fowler, "Patterns of Enterprise Application Architecture", Addison-Wesley Professional, 2002

[12] `http://www.sqlalchemy.org/`



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