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PCXMC 2.0
**SUPPLEMENTARY
PROGRAMS
USER'S GUIDE**

**PCXMC20Rotation.exe
Autocalc-sheet.xls
AutocalcRotation-sheet.xls**

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Contents

1. General

This manual describes the use of supplementary programs that are being distributed with PCXMC: PCXMC20Rotation and the Excel applications Autocalc-sheet.xls and AutocalcRotation-sheet.xls. The reader of this manual is expected to be familiar with the use of PCXMC 2.0 and the PCXMC 2.0 User's Guide (STUK-TR 7/November 2008). The use of these applications requires that the user has purchased a proper license for the PCXMC program.

The applications described here have been programmed to help the PCXMC user in certain calculation tasks. PCXMC20Rotation is otherwise the same program as the normal PCXMC 2.0, but it has a slightly modified interface, allowing easy dose calculations in cases where the x-ray system has a center point of rotation, and the radiation is aimed to the patient from various directions so that the central axis of the beam goes through this point (the reference point of PCXMC). The Excel applications are useful if the user needs to make several simulations in the batch mode and/or wishes to have the results easily in a spreadsheet application for further processing and use. An example of such a case could be, e.g., calculation of doses in a dental cone beam CT (CBCT) examination, where a large number of projection images of the oral cavity region are taken using different projection angles. (It is noted, however, that PCXMC assumes a flat filter in the radiation beam: bow-tie filters cannot be simulated. Therefore, the calculation cannot be done for every CT-scanner.)

PCXMC20Rotation and the Excel applications will be included in the installation disk of future deliveries of PCXMC. Those PCXMC users who have purchased PCXMC earlier may obtain these supplementary programs without any charge by contacting STUK at the e-mail address pcxmc@stuk.fi (Note, however, that one must be a registered user of PCXMC in order to receive these programs).

The user is allowed to modify the macros in the Excel applications according to his/her own will; actually, the users are encouraged to study the macros in the applications and to make modifications in them according to their own needs. It is suggested that such modifications are clearly noted in the Excel-sheet and explained in the Instructions-page of the sheet.

2. PCXMCRotation

The differences between PCXMC 2.0 and PCXMC20Rotation are:

- In the Examination data form (DefForm, see Fig 1) some data input fields of PCXMC 2.0 and PCXMC20Rotation differ.

PCXMC 2.0	PCXMC20Rotation
FSD (focus-skin distance)	FRD (focus-reference point distance)
Beam width (at patient entrance)	Beam width (at reference point)
Beam height (at patient entrance)	Beam height (at reference point)
Field size calculator calculates the field size at patient entrance	Field size calculator calculates the field size at reference point

- The file extensions used in PCXMC20Rotation differ from those used in PCXMC2.0:

PCXMC 2.0	PCXMC20Rotation
*.df2 (definition file)	*.dfR (definition file)
*.en2 (Monte Carlo simulation results)	*.enR (Monte Carlo simulation results)
*.mG2 (dose results)	*.mGR (dose results)

- The contents of the definition file (i.e., the file containing the data input in DefForm) are different. In addition to the data in the definition file of PCXMC 2.0 (*.df2) the data in the PCXMC20Rotation definition file (*.dfR) include also the focus-to-reference point distance (FRD) and the field height and width at the reference point. The same additional data are also included in the simulation results file (energy file, *.enR) and in the file for calculated doses (dose file, *.mGR).

- In the input dose specification form (see Fig 2.) or in Autocalc.dfR the user must enter air kerma (or exposure) free-in-air at the reference point, instead of incident air kerma or entrance exposure (which are both given free-in-air at patient entrance in PCXMC 2.0). If the input dose is specified in terms of the dose-area product (DAP), exposure area product or current-time product (mAs), the data is not distance-dependent and is equal to that used in PCXMC 2.0.

Figure 1. *The x-ray examination data input form of PCXMC20Rotation. The red ellipses show the differences to the corresponding form in PCXMC 2.0. (1): Instead of the focus-to-skin distance (FSD), the focus-reference point distance (FRD) is used. (2 and 3): Instead of specifying the field size at the patient entrance, the width and height of the x-ray beam are specified at the distance of the reference point. (4): The field size calculator helps in finding the x-ray beam size at the reference point if it is known at the distance of the image receptor (FID).*

Figure 2. *The x-ray examination data input form of PCXMC20Rotation. The input dose described in terms of kerma or exposure refers to the value free-in-air at the focus-to-reference point distance (FRD), as highlighted on the form. None of the other quantities that may be used (dose-area product, exposure-area product and current-time product) is distance-dependent, and the same values may be used as in PCXMC 2.0.*

Similarly as in PCXMC 2.0, *'Xref'*, '*Yref'*, and '*Zref'* are the coordinates of a point inside the phantom, through which the central axis of the x-ray beam is directed. These data are used for specifying the location of the x-ray beam with respect to the phantom. Choosing any point along the intended beam centre-line will give same calculation results for any given projection, but if one wishes to calculate several irradiation schemes where the beam is directed to the patient from several directions, this reference point is the centre of rotation around which the x-ray tube moves, and through which the central axis of the x-ray beam is directed.

PCXMC20Rotation can also be used in the batch mode without any need of user interaction during the calculation. For information of using the program this way, see appendix A.

3. AutocalcRotation-sheet.xls

General

PCXMC20Rotation can be run easily in the batch mode by using the Excel application "AutocalcRotation-sheet.xls". In this spreadsheet application each set of input data to be simulated is written in one row of the table. Several irradiation conditions can be simulated, one after another, by writing several rows of input data. For example, if one wishes to calculate the dose in dental CBCT, one could write a large number of otherwise identical rows but vary the value depicting the projection angle.

This application allows you to:
- define the x-ray examination parameters in Excel,
- calculate the doses and obtain the results directly in Excel, and
- add any further processing of the data in Excel.

In order to use this application, a copy of the AutocalcRotation-sheet.xls needs be put in the folder \PCXMC (there are no restrictions for the name of the copy of this Excel-application: you can use different file names for different projects). PCXMC 2.0 must have been installed in the same folder and the folder must also contain the file PCXMC20Rotation.exe.

Using the Excel application

1. The application uses macros to do the data processing. Therefore, when you open the Excel-file you must enable the macros if the security settings of your Excel disable macros. (At least in MS Excel 2007, when you'll start the application you may see "Security warning. Macros have been disabled". Then you need to select "Options…" and enable the contents.)

2. Create a subfolder in your folder PCXMC\MCRUNS (e.g., PCXMC\MCRUNS\mydata). This subfolder will be used for storing the definition files (*.dfR) that one of the macros generates from the Excel-data. When making the calculations using the Excel macros you'll need to enter the name of this subfolder (mydata in the above example) when prompted to.

3. Fill data for each set of examination conditions that you wish to obtain the doses for. Each projection is defined in one single row by data in the cells in columns A to T (coloured yellow in the application). There must be a valid datum in each yellow column on this row. Data headings and advice of acceptable data are given on row 5 (and appendix 1 of this document). You can fill data in as many rows as you wish, but note that the combination of subfolder name / hospital / patient number / examination /projection must be unique: no two rows cannot have the same combination of data in these fields; a combination of those data fields is used to construct a file name for each simulation. The sum of the lengths of these identifiers must not exceed 26 characters. Note also that there must not be any characters in these data fields that cannot be used in file names. For example, if you'll have decimal points or commas in the projection angle data you might end up in "File not found errors" in trying to do the simulations. In such a case you should edit the data, or edit the macros so that such problems disappear: e.g., you might not use the projection angle in naming the files.

4. Press <ctrl>a to start the first script and enter the first row of data, the last row of data, and the name of the subfolder (mydata in the example above) when prompted. The macro

will then generate *.dfR-files in the subfolder that you created in step 2 above (mydata in the example above). After performing this step we suggest that you'll check that all the generated *.dfR files are reasonable and correct. You can do this by starting PCXMC20Rotation and looking at the examination data by opening the generated *.dfR files one after another.

5. Return to Excel and press <ctrl>b to start the PCXMC calculation of doses. Again, you will be asked for the first row of data, the last row of data and the subfolder name (mydata in the example above). The calculation may take a long time, depending on the number of projections that you'll calculate and the number of simulated photons (NPhots; defined in the macro). The definition files, simulation results (energy files) and dose files will be stored in the folder PCXMC\MCRUNS.

6. When the calculation has been finished you can copy the calculated doses to Excel (in columns AA to CN, heading (row 5) coloured orange in the application) by pressing <ctrl>d. Again, you will be asked for the first row of data, the last row of data and the subfolder name (mydata in the example above). You are done! You can then process the calculated data as in any Excel application.

Hints:
Note that <ctrl>a, <ctrl>b and <ctrl>d do not function in this application as they commonly do in Excel workbooks. If you wish to change these shortcuts, you can do it by choosing Tools→ Macro→ Macros…→ Options… (or, in MS Excel 2007: View → Macros → View Macros → Edit).

If you wish to edit the input data in some rows later, after having done the dose calculations, you must delete the corresponding definition files in the subfolder that you used (PCXMC\MCRUNS\mydata in the above example), the corresponding definition files, energy files and dose files in the folder PCXMC\MCRUNS, and run the three macros again for these rows. Otherwise, when PCXMC is started the message "The data file name specified in Autocalc.dfR has already been used" will be displayed. You can then recover normal operation by deleting these already calculated definition, energy and dose files or the file Autocalc.dfR in PCXMC\MCRUNS.

You may modify the macros in the Excel sheet to better comply with your needs. For example, you can change the pre-set number of simulated photons (Nphots: 20 000) to a higher or lower value, or the pre-set anode angle (sAnodeAngle: 16°). You may also include additional data processing on the cells on the sheet if you wish to do so. If you modify the application macros, you should note this clearly in the Excel-workbook.

Note that presently the file-name length for the output filename specified in autocalc.dfR is limited to 30 characters maximum. Therefore, the sum of the lengths of the strings used in forming it (the name of the sub-directory, hospital identifier, patient identifier, examination identifier and projection) must not exceed 26 characters (four dashes are added in the generation of the name). If necessary, you may edit the output file name generation rule in the macros to achieve fulfilling this condition.

*** This application is used by the sole responsibility of the user. Neither STUK nor the authors of the scripts shall be liable for any errors or damages or harm arising out of the use of them.***

4. Autocalc-sheet.xls

General

PCXMC 2.0 can be run easily in the batch mode by using the Excel application "Autocalc-sheet.xls". In this spreadsheet application each set of input data to be simulated is written in one row of the table. Several irradiation conditions can be calculated, one after another, by writing several rows of input data.

This application allows you to:
- define the x-ray examination parameters in Excel,
- calculate the doses and obtain the results directly in Excel, and
- add any further processing of the data in Excel.

In order to use this application, a copy of the Autocalc-sheet.xls needs be put in the folder \PCXMC (there are no restrictions for the name of the copy of this Excel-application; you can use a different name for each of your projects). PCXMC 2.0 must have been installed in the same folder.

Using the Excel application

1. The application uses macros to do the data processing. Therefore, when you open the Excel-file you must enable the macros if the security settings of your Excel disable their use. (At least in MS Excel 2007, when you'll start the application you may see "Security warning Macros have been disabled". Then you need to select "Options…" and enable the contents.)

2. Create a subfolder in your folder PCXMC\MCRUNS (e.g.PCXMC\MCRUNS\projectX). This subfolder will be used for storing the definition files (*.df2) that one of the macros generates from the Excel-data. When making the calculations using the Excel macros you'll need to enter the name of this subfolder (projectX in the above example) when prompted to.

3. Fill data for each set of examination conditions that you wish to obtain the doses for. Each projection is defined in one single row by data in the cells in columns A to T (coloured yellow in the application). There must be a valid datum in each yellow column on this row. Data headings and advice of acceptable data are given on row 5. You can fill data in as many rows as you wish, but note that the combination of subfolder name / hospital / patient number / examination /projection must be unique: no two rows cannot have the same combination of data in these fields. A combination of those data fields is used to construct a file name for each simulation. The sum of the lengths of these identifiers must not exceed 26 characters. Note also that there must not be any characters in these data fields that cannot be used in file names. For example, if you'll have decimal points or commas in the projection angle data you might end up in "File not found errors" in trying to do the simulations. In such a case you should edit the data, or edit the macros so that such problems disappear: e.g., you might not use the projection angle in naming the files.

4. Press <ctrl>a to start the first script and enter the first row of data, the last row of data, and the name of the subfolder (projectX in the example above) when prompted. The macro will then generate *.df2-files in the subfolder that you created in step 2 above (projectX in the example above). After performing this step we suggest that you'll check that all the

generated *.df2 files are reasonable and correct. You can do this by starting PCXMC 2.0 and looking at the examination data by opening the generated *.df2 files one after another.

5. Return to Excel and press <ctrl>b to start the PCXMC calculation of doses. Again, you will be asked for the first row of data, the last row of data and the subfolder name (projectX in the example above). The calculation may take a long time, depending on the number of projections that you'll calculate and the number of simulated photons (NPhots; defined in the macro). The definition files, simulation results (energy files) and dose files will be stored in the folder PCXMC\MCRUNS.

6. When the calculation has been finished you can copy the calculated doses to Excel (in columns AA to CN, heading (row 5) coloured orange in the application) by pressing <ctrl>d. Again, you will be asked for the first row of data, the last row of data and the subfolder name (projectX in the example above). You are done! You can then process the calculated data as in any Excel application.

Hints:
Note that <ctrl>a, <ctrl>b and <ctrl>d do not function in this application as they commonly do in Excel workbooks. If you wish to change these shortcuts, you can do it by choosing Tools→ Macro→ Macros…→ Options… (or, in MS Excel 2007: View → Macros → View Macros → Edit).

If you wish to edit the input data in some rows later, after having done the dose calculations, you must delete the corresponding definition files in the subfolder that you used (PCXMC\MCRUNS\ projectX in the above example) and the corresponding definition files, energy files and dose files in the folder PCXMC\MCRUNS, and run the three macros again for these rows. Otherwise, when PCXMC is started the message "The data file name specified in Autocalc.df2 has already been used" will be displayed. You can then recover normal operation by deleting these already calculated definition, energy and dose files <u>or the file Autocalc.df2</u> in PCXMC\MCRUNS.

You may modify the macros in the Excel sheet to better comply with your needs. For example, you can change the pre-set number of simulated photons (Nphots: 20 000) to a higher or lower value, or the pre-set anode angle (sAnodeAngle: 16°). You may also include additional data processing on the cells on the sheet if you wish to do so. If you modify the macros in the application, you should note this clearly in the Excel-workbook.

Note that presently the file-name length for the output filename specified in autocalc.df2 is limited to 30 characters maximum. Therefore, the sum of the lengths of the strings used in forming it (the name of the sub-directory, hospital identifier, patient identifier, examination identifier and projection) must not exceed 26 characters (four dashes are added in the generation of the name). If necessary, you may edit the output file name generation rule in the macros to achieve fulfilling this condition.

*** This application is used by the sole responsibility of the user. Neither STUK nor the authors of the scripts shall be liable for any errors or damages or harm arising out of the use of them.***

Appendix A: Using the automatic features of the PCXMC20Rotation

The program version PCXMC20Rotation is able to calculate the patient's organ doses automatically, without user interference. This feature enables the user of the program to calculate patient doses for example by using a batch program which renames the data file and calls PCXMC20Rotation once for each of the data files to be processed. This requires that the operating system allows renaming and deleting files in the MCRUNS-folder without having the user to interfere with such operations.

This automatic calculation is invoked by saving a file named 'Autocalc.dfR' in the folder 'PCXMC\MCRUNS' (an example of a definition file of this kind is described below). When PCXMC20Rotation is started, the program checks whether a file of this name exists in this folder. If not, the program will start and function in the normal mode (see PCXMC 2.0 User's Manual and the differences explained in this document). If the file exists, the program will start the Monte Carlo simulation specified in the Autocalc.dfR file and then calculate the patient's organ doses. During the simulation, the 'Simulation form' is displayed (showing the progress of the simulation) and after finishing the calculation the program will exit.

During the execution of the program the Autocalc.dfR file is renamed as XXX.dfR (where XXX denotes the string supplied in the last data row of the Autocalc.dfR file - see the example file below where the datum is 'Patient_ID'). The results of the intermediate Monte Carlo simulation are saved in file XXX.enR and the patient doses are saved in the text file XXX.mGR. So, after the calculation there are three XXX-named files and the Autocalc.dfR file is deleted.

Before starting to process the Autocalc.dfR file, the program checks whether any of the three XXX files exists. If any of them does exist (i.e., the calculation has already been done for a similar name), the program displays a warning and exits when the OK-button of the warning is clicked – in order to recover normal operation in such a case, one must either delete (or rename) the Autocalc.dfR file, or the existing, conflicting files. The execution of the program stops also if there are errors in the Autocalc.dfR file (i.e., the number of energy steps has been selected to be smaller than required for the specified x-ray tube voltage or if the reference point is not located within the phantom). **An attempt to run normal definition files in the Autocalc-mode will result to I/O errors, because these files do not contain all the required data.**

An example of the Autocalc.dfR file is given below. It is a text file consisting of 27 data rows (there are 24 data rows in Autocalc.df2 for PCXMC 2.0). Each row begins with a 33-character wide explaining text (which is not used by PCXMC20Rotation - the user may modify the explaining text). The actual data field consists of the following 30 characters (locations 34–63). The header row (row 1) and the output file name row (row 24) are exceptions to this latter requirement: these data fields are allowed to be longer than 30 characters. PCXMC discards any spaces in front of the actual data, but spaces behind a string datum are included in the datum. Note that in writing the explaining text in front of the actual datum one tab character is counted as one character.

```
        Header text:       Typical scoliosis PA, 15y
         Projection:                        90.0000
         Obl. Angle:                         0.0000
                Age:                             15
             Length:                       168.1000
               Mass:                        56.3000
    Arms in phantom:                              1
                FRD:                        160.200
   X-ray beam width:                        15.4900
  X-ray beam height                         51.6400
                FSD:                       150.4000
  Beam width at skin:                       14.5424
 Beam height at skin:                       48.4810
               Xref:                         0.0000
               Yref:                         0.0000
               Zref:                        35.0000
  E-levels (Max.en./10):                        10
             NPhots:                           1000
 X-ray tube voltage (kV):                       100
          AnodeAngle:                            14
        Filter A (Z):                            13
       Filter A (mm):                           3.5
        Filter B (Z):                            29
       Filter B (mm):                           0.1
  Input dose quantity:                          DAP
     Input dose value:                         1.24
     Output file name:                   Patient_ID
```

The data in the Autocalc.dfR-file are (after the 33 character explaining text):

1st row: Text for the header text (string, commenting data).

2nd row: The projection angle of PCXMC, (real, in degrees)

3rd row: The cranio-caudal angle angle of PCXMC, (real, in degrees)

4th row: The patient's age, (integer, allowed set = {0, 1, 5, 10, 15, 30}, 30 denotes an adult patient)

5th row: The patient's height, (real, in centimetres, the value 0.0 corresponds to the standard value for the phantom of the given age)

6th row: The patient's weight, (real, in kilograms, the value 0.0 corresponds to the standard value for the phantom of the given age)

7th row: Arms included in the phantom? (integer, allowed set = {0, 1}, 0 = arms removed, 1 = arms included)

8th row: The x-ray tube focal spot to reference point distance (FRD), (real, in centimetres, the value 0.0 implies an infinite distance - the option of specifying the input dose in terms of the current-time product (mA·s) is not allowed if FRD = 0.0, see the data for 25th row)

9th row: X-ray beam width at the distance FRD from the x-ray tube focal spot, (real, in centimetres, the value must be greater than 0)

10th row: X-ray beam height at the distance FRD from the x-ray tube focal spot, (real, in centimetres, the value must be greater than 0)

11th row: The x-ray tube focal spot to skin distance (FSD), (real, in centimetres). This datum need not be the correct value: the true value is calculated during the execution of the calculation. The true value calculated during execution is written in the *.enR and *.mGR files.

12th row: X-ray beam width at the distance FSD from the x-ray tube focal spot, (real, in centimetres). This datum need not be the correct value: the true value is calculated during the execution of the calculation. The true value calculated during the program execution is written in the *.enR and *.mGR files.

13th row: X-ray beam height at the distance FSD from the x-ray tube focal spot, (real, in centimetres). This datum need not be the correct value: the true value is calculated during the execution of the calculation. The true value calculated during the program execution is written in the *.enR and *.mGR files.

14th row: The x-coordinate of the reference point inside the phantom, (real, in centimetres). This point is the center of rotation of the x-ray system.

15th row: The y-coordinate of the reference point inside the phantom, (real, in centimetres). This point is the center of rotation of the x-ray system.

16th row: The z-coordinate of the reference point inside the phantom, (real, in centimetres). This point is the center of rotation of the x-ray system.

17th row: The maximum energy to be used in the simulation (integer, range 1–15, this number times 10 is the maximum x-ray tube voltage (in kV) that can be used. The required value can be calculated from the x-ray tube voltage of interest, U, by

(U-0.5 kV)/10+1 kV

and truncating the result to an integer. A higher value can be defined as well, but results to an unnecessary long computation time)

18th row: The number of photon histories per energy to be used in the simulation (integer, multiple of 100. This number affects the speed of the calculation and the accuracy of the results. It can be, e.g. equal to 1000 if there is no need for a good statistical accuracy, but usually higher values are recommended)

19th row: The x-ray tube high voltage, (integer, in kilovolts, less than or equal to 150. See also the requirement on the 14th data row above)

20th row: The x-ray tube target angle, (real, in degrees, typical values of diagnostic x-ray tubes are of the order of $12^{o}-18^{o}$)

21st row: The atomic number of the first filter material (Z), (integer, e.g., 13 denotes aluminum and 29 denotes copper)

22nd row: The thickness of the above filter, (real, in millimetres)

23rd row: The atomic number of a second filter material (Z), (integer, e.g., 13 denotes aluminum and 29 denotes copper. If no second material is used, the value must be set as 0)

24th row: The thickness of the above filter, (real, in millimetres)

25th row: The input dose quantity option, (string, allowed set = {EAK, EE, DAP, EAP, MAS}). The input quantity and unit corresponding to these choices is:

EAK	Incident air kerma, in mGy - no backscatter
EE	Entrance exposure, in mR - no backscatter
DAP	The product of air kerma and area (DAP or KAP), in units of mGy·cm^2
EAP	The exposure-area product, in R·cm^2
MAS	The current-time product, in mA·s

26nd row: The numerical value of the above input quantity, (real)

27th row: The name that will be used in saving the calculated data, (string, maximum 30 characters. There must be no files of this name and extension '.dfR', '.enR' or '.mGR' in the folder PCXMC\MCRUNS; otherwise the Autocalc.dfR file will not be processed.)

28th row and further rows will be not read by the program.

During installation, the above example file (Autocalc-example.dfR) has been set in the folder \PCXMC\MCRUNS. The user can try this feature by first copying this file and renaming it as autocalc.dfR. When started, PCXMC20Rotation will output files with names Patient_ID.dfR, Patient_ID.enR and Patient_ID.mGR. The last of these contains the calculated dose data.