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Android application for parsing X-ray absorption coefficients web database

Abstract. We focus on developing a standalone android application module to parse web databases and text files. The application is capable of retrieving and visualizing the data from NIST and similar web databases as well as from the text files stored locally on a phone storage device. The data is represented by the X-ray mass attenuation and absorption coefficients for all elements from the periodic table and other complex compounds acquired for the range of X-ray photons energies. Upon retrieving, parsing, and conversion the data is fully ready for visualization or, as originally designed, to be supplied for further simulation of the computed tomography experiment in multiple formats. The application is useful as a simple, open-source Java code, collection of methods to organize the access and parsing of the locally and remotely stored data in the text formats in the nuclear physic numerical experiment. In the application, a separate thread was dedicated to data retrieval and analysis. This thread is hosted by a fragment to provide the survival of calculations during the application's configuration changes. It also facilitates unrestricted internet access otherwise prohibited on the main UI thread. The results of parsing and calculations in the concurrent thread were linked to the main thread with the *Progress Update* callback function.

Key words: X-ray, attenuation coefficient, web database, android application, data parsing, computed tomography.

Introduction

Numerous existing android applications related to computed tomography provide access to the patient's medical exams databases, see [1] and [2], manage data exchange and workflow in hospitals [3], work as a console to initiate data acquisition jobs, to control and finalize the scan or other procedures on the medical hardware they are tethered to [4], [5]. Until very recently, real, computation-intensive calculations rarely took place on a mobile device due to the lack of computational power and not-so-straightforward ways to organize the calculations behind the user interface. The tremendous surge in the development of compact, low-cost, power-efficient, mobile CPUs and graphics chips makes it possible to adopt multiple scientific calculation algorithms without the loss of productivity with an

additional small effort to adopt mobile device programming practices.

Our global objective is the development of a fully featured data processing and simulating Android application for CT (Computed Tomography) [6]. This application implements the Feldkamp, Davis, and Kress (FDK) backprojection algorithm in CT [7], [8]. We have already completed and published results on the reconstruction module of this android application, which is now capable of working with prerecorded projections or with data from a real medical or industry scanner [9]. It is similar in logic to the modified version of our previous C/C++ project on CT [10] but written in Java and adapted for android devices.

This paper discusses the implementation of a new module designated for internet database retrieval and parsing for a further digital phantom generation.

Methods and Materials

The physical model for the interaction of a narrow beam of X-rays radiation with matter assumes the gradual attenuation of the photons flux passing through the nonuniform media according to the simple exponential Lambert-Beers law model $I = I_0 \exp(-\mu x / \rho)$, where I and I_0 stand for the original and attenuated beams' intensities [11]. Multiple processes including atomic photo effect, coherent Rayleigh or Thompson, incoherent Compton scattering, as well as pair production in the vicinity of nucleus and atomic electrons, and photonuclear processes contribute to this attenuation and absorption.

Atomic photoeffect gives a distinct resonance-like look to the X-ray absorption spectra [12] and is exhibited only on atomic electrons to satisfy energy and momentum conservation laws. The semiempirical formula for the atomic photoeffect cross-section σ in gives $\sim Z^5/E_\gamma$ dependence for $E_\gamma \gg I_k$ and $\sim Z^5/E_\gamma^{7/2}$ for $E_\gamma > I_k$. Here, Z is the atomic number of the element, E_γ is the energy of the gamma photon and I_k is the ionization potential for K-shell measured in eV [13]. For example, the photoeffect is significant for aluminum with $Z=13$ and $E_\gamma < 0.05$ MeV and for lead with $Z=82$ at $E_\gamma < 0.5$ MeV. Photoeffect is often accompanied by the generation of the Auger electrons.

For coherent Rayleigh scattering, with $E_\gamma < 10$ keV, an atom absorbs a gamma quantum as a whole, through a coherent motion of its electrons, and then irradiates it with the same energy and wavelength. This type of scattering, when the incident wavelength is greater or comparable to the scattering objects, mostly keeps the wavelength and energy of the quanta unchanged [14].

Another way to quantify the coherent low-energy photon scattering of electrons in an atom is the Thompson scattering. For Thompson scattering of unpolarized wave on a free electron, the total cross-section is given by $\sigma = 8\pi/3 \cdot r_e^2 = 0.66 \cdot 10^{-24} \text{ cm}^2$ expression, with r_e being the classic electron's radius [13]. It is symmetrical with respect to the backward and forward propagation regardless of the wavelength of the incident radiation. Thompson scattering is the low energy border of the Compton scattering, for $E_\gamma \ll m_e c^2$. Here, m_e is the electron's mass.

For gamma photons' energies E_γ ranging from a fraction and up to the tens of MeVs the noncoherent Compton scattering takes precedence over the

previously discussed effects [15]. Compton scattering has a distinct angular dependence and the change in the wavelength of the scattered radiation is given by $\Delta\lambda = 0.486 \cdot 10^{-2} \sin^2(\varphi/2)$. For Compton scattering, part of the original photon energy stays with the photon and another one is transferred to the recoil electron. Thus, the total cross section is the sum of coherent and noncoherent parts related as $\sigma_{non.coh.} = \sigma_{coh} \cdot 1/(1 + 2\alpha)$, where $\lambda > 0.008$ nm and $\alpha = h\nu_0/m_e c^2$ [16]. For higher energies in the Compton effect, one should use the Klein-Nishina-Tamm formulas [17].

Noncoherent Compton scattering is the reason the data set on X-ray attenuation has two columns, one for the mass attenuation and another one for the mass absorption coefficient. The mass attenuation coefficient contains the coherent part of the Compton effect where the energy stays with gamma quanta, accompanied by the change in the wavelength, and the noncoherent part where the energy is transferred to the recoil electron, whereas the mass absorption coefficient only keeps track of the processes where the gamma quanta is destroyed, such as photoeffect, pair production and noncoherent part of the Compton's effect [18]. The Compton effect is also often accompanied by the generation of Auger electrons due to electrons missing from the atomic shells.

For the pair production, the energy conservation law defines the basic gamma photon energy values as $E_\gamma > 2m_e c^2$, though it becomes significant only for energies greater than 10 MeV [19]. The pair production process is described by $\sigma_{pair} = knZ^2(h\nu_0 - 1.022)$ expression for cross-section, where k is proportionality constant, n is the number of atoms per cm^3 , and $h\nu_0$ is the incident photon energy.

And finally, in this simplified picture, the photonuclear process describes nuclear transformations after a direct hit and absorption of the gamma quanta. This leads to the knockout of the neutrons, protons, or alpha particles from the nucleus and is usually purely empiric in all expressions used to quantify it. Happening at energies of 10-30 MeV, it is also called a gamma activation [20].

All this information is conveniently collected in one place by the National Institute of Standards and Technology in Physical Measurement Laboratory web resources [21]. As it was previously mentioned, the mass absorption coefficients μ_{en}/ρ unlike the mass attenuation coefficients μ/ρ contain only the incoherent part of the Compton scattering.

This database is the result of intensive experimental and theoretical studies. The tabulated data cover the range of the photon energies from 1 keV to 2 MeV. Graphics plots for each element from the periodic table, in logarithmic scale, for both μ/ρ and μ_{en}/ρ , are conveniently provided on the individual webpage with individual web addresses. Only the atomic number is provided on the element's data page. Additional information such as the element's density ρ in g/cm³, mean excitation energy I in eV, as well as the Z to A (atomic mass) ratio is given in a separate table of material constants, for elemental media and compounds with mixtures correspondingly.

Each webpage is an html (hypertext markup language) file with information conveniently placed within the html tags for formatted display in the browsers [22]. These tags as well as the specific floating point data representation with “E+” and “E-” letters in notations were used to navigate the parser code through the page to the target information.

Results and Discussion

Figure 1 displays the application's diagram with the basic elements and interfaces. The *Main activity* is associated with the main thread and is the owner of the *User Interface* (UI).

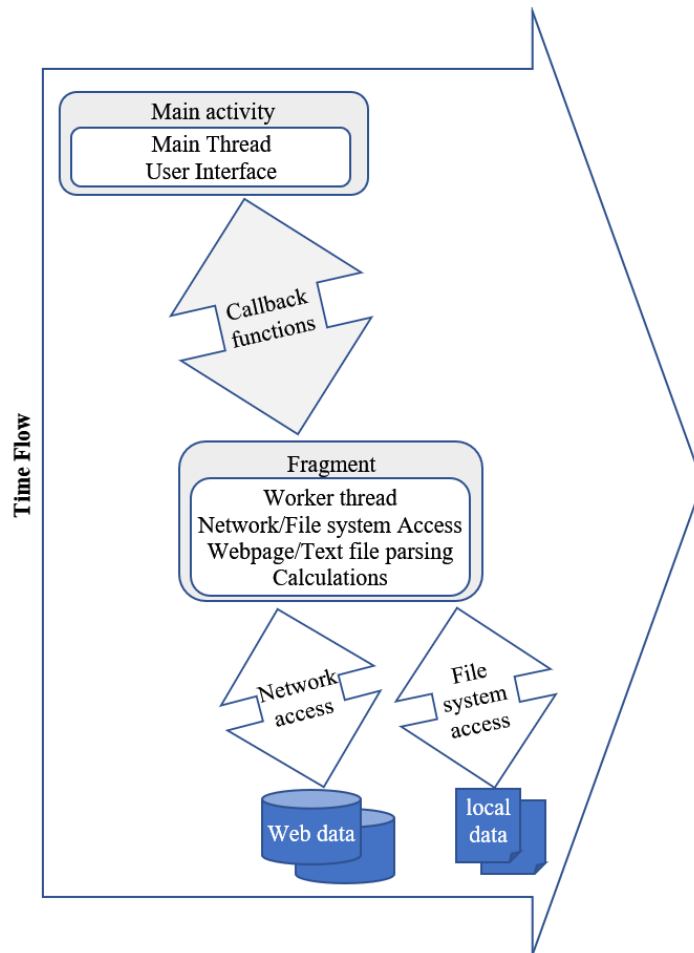


Figure 1 - *parse_NIST_web_database* application's time flow diagram

It implements the *Fragment* which can survive any configuration changes while preserving the calculation flow [23]. This *Fragment* hosts the separate thread responsible for the file system and/or

network access as well as for the web and local data parsing and calculations. It is explicitly said that the network access should be always run on a separate thread.

The *Main activity* communicates with the *Fragment*'s thread through the *callback functions* and uses their data to update the *User Interface* picture. If upon the calculations' completion and user interface update, some configuration changes happen, the network/file system access and parsing code are to be run again and the interface is updated with new information from a web page whose address was selected by a user in the *WebView*. That is because the *Fragment* is invoked from the *OnCreate* part of the *Main activity*.

In Figure 2, we printed three consecutive screenshots of the running application. The Francium element with $Z=87$ was selected for the data

processing as a default start page. The first screenshot displays the logarithmic plot of the parsed data. The distinct atomic photo absorption peaks are visible through the whole range of energies from 1 KeV to 20000 KeV. Data points display information about the logarithm of the μ/ρ value. The plot supports the click and zoom option for data display. The second screenshot contains the original webpage hosted by *WebView* from the same link which was used to parse the data. The last screenshot shows the extracted text used to control the read integrity by comparing it to the previously plotted parsed information and screenshot from the original page. All three pieces are hosted by a single *ScrollView*.

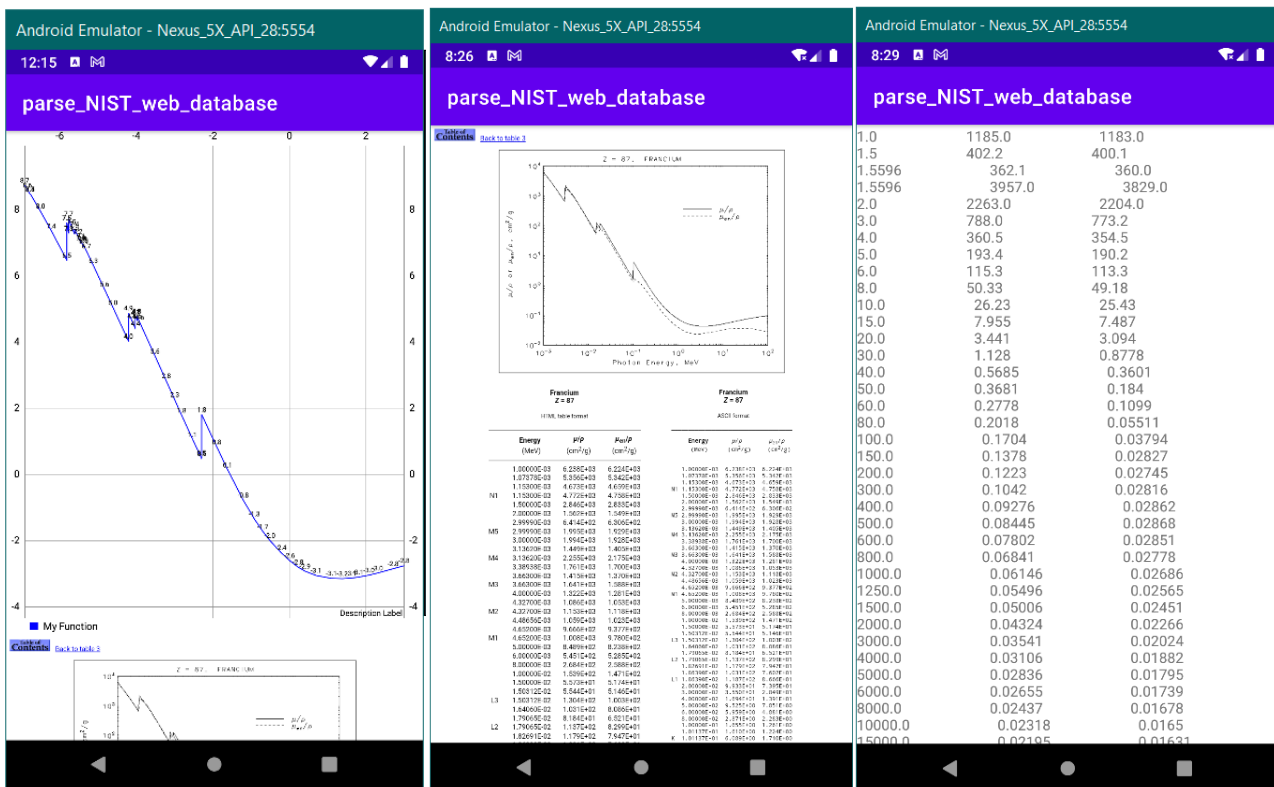


Figure 2 - The three main screens of the application as hosted by a single *ScrollView*.

The parsed data were charted by the *MPAndroidChart* tool [24], the original webpage is displayed by *WebView* rather than by default browser and the last piece of information is a *TextView* updated by a *ProgressUpdate* callback function with the data collected during the parsing.

The *LineChart* view by *MPAndroidChart* and the *TextView* is updated each time the user changes the application's configuration, for instance, makes a

screen rotation or switches between the applications. We decided that this, in fact, may be more convenient for updates in the user interface without pressing the additional buttons and waiting for the user input.

The targeted data were parsed and located according to the specific html tags and floating-point exponent notation symbols. Reliable text and visual output were produced. Web data or preloaded local text files database could be used. In the current state

of development, our application requires the minimum of the operator's input, which is the consequence of it being developed as the new module for a different project. The Artic Fox version of the Android Studio with Java 11 SDK was used. The application is targeting the API 30 SDK with minimum supported API 23 SDK. Desktop computer with the 8-core Intel i7 4790K CPU and 32 Gb of RAM was used for the application development and other simulations.

Conclusions and Future Development

As intended, our application represents fully functional software for web database data retrieval, parsing, and visualization. The validity of the parsing function is ensured by plotting the processed data using the logarithmic scale and comparing it to the original data displayed in *WebView*. The application is following the basic rules accepted by professional android application developers, though these are frequently missed by applied and theoretical research physicists. Thus, this application with its open-source code, implemented for the classic task of handling the

data in physics, provides a valuable toolbox for the nuclear physicist software developer.

In the current state of development, the minor challenges are limited to the balancing of the tasks of accessing the network and filesystem, keeping and restarting calculations in the main activity and fragment, UI development, and other debugging issues. One may replace the currently hardcoded web address for the specific element, Francium in our case, by the simple elements' list click-and-select procedure implemented through the click listener, though the possibility of selecting different elements and reloading the data for analysis is already implemented through the navigation in the *WebView* containing the html version of the database. The application is available for download from the GIT repository [25].

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