ANDROID APPLICATION FOR ACCELERATOR PHYSICS AND ENGINEERING CALCULATIONS

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Abstract

Smartphones and tablets are increasingly capable computational devices, with fast processors and high-resolution displays. They are also nearly ubiquitous, suggesting that they can support the need of physicists and engineers to perform quick calculations in situations where using a full-blown simulation is not necessary or expedient. In this paper, we report on the design, features, and capabilities of an Android application inspired by these ideas. The application is called "TAPAs," which stands for Toolkit for Accelerator Physics on Androids. As the name—meant invoke the popular snacks of Spanish cuisine— suggests, the application provides a varied selection of calculations for electron storage rings, electron linear accelerators, electron guns, free-electron lasers, undulator design, synchrotron radiation, and engineering. The calculations are organized into separate sub-applications, which share input values to allow performing related calculations without re-entering data. The application is free of advertising and is available free of charge on the Google Play store.

INTRODUCTION

Physicists and engineers have long needed the ability to perform quick "back of the envelope" calculations. This need arises during discussions, meetings, and conferences, when running a simulation code is not possible or would take too long. It also arises in day-to-day work as one explores ideas at one's desk. The ability to perform a quick, reasonably accurate calculation can sometimes make all the difference between being productive and pursing a dead-end idea.

Such calculations may be performed mentally, with a pad and pencil, or with a hand-held calculator. Depending on one's ability to remember the appropriate equations, one might use a published handbook, memorized equations, or a "cheat sheet." In the not-to-distant past, it was not uncommon to have a programmable calculator that facilitated common calculations. At present, one is more likely to have a smartphone or tablet close by than a programmable calculator. Hence, it makes sense to develop smartphone or tablet "apps" to address the need for quick calculations.

Inspired by these ideas, we developed an Android application that performs a number of useful calculations of the sort that commonly come up in day-to-day work. The Android platform was chosen for its open-source nature and the low cost of entry for devices and development. Unlike other smartphone platforms, the Android Software Development Kit (SDK) is free and available for essentially all platforms, which allowed using Linux for development.

We used the Eclipse Integrated Development Environment (IDE), which is advantageous in that it helps one quickly learn both the Java language and the specific methods provided by Android. The web contains many resources, such as Android tutorials and user forums (e.g., StackExchange).

The application is called TAPAs, which stands for "Toolkit for Accelerator Physics for Androids" and also is meant to bring to mind the popular snacks of Spanish cuisine. The application is free of advertising and is available free of charge on the Google Play store.

SOFTWARE DESIGN

Those who are uninterested in software design may wish to skip this section, as it has little to do with how the application is used or what it can do. This section also assumes some familiarity with Android development.

The root activity of the application, MainActivity, is an extension of the ListActivity class, which presents a set of choices as a simple vertical list. In addition, MainActivity provides pop-up dialog using AlertDialog that acquaints users with recent changes. The SharedPreferences facility is used to remember the major and minor version of the last invocation, so that the pop-up dialog appears only on the first invocation of a new version. Finally, MainActivity loads a set of name/value pairs into a hash table, which provides default values for entries in the various calculations. As calculations are used, the values in the table are updated so that other applications have access to the new data. The hash table is part of a class that is implemented as a "static singleton," which means that there is only one instance of the class and it is shared by all methods that attempt to instantiate the class.

Below the main list are a series of sublists that are also instances of ListActivity. The activities in each sublist are implemented using an ActivityWithMenu class derived from the Activity class. As the name suggests, this new class provides an activity class with a predefined menu. This menu is used to control some basic settings of the application. The settings are saved between invocations and shared among activities using the SharedPreferences class. The widgets for each activity are embedded in a vertically-scrolled list, which helps in accommodating various screen sizes.

Individual calculation activities typically consist of a list of numerical entry and output widgets, in some cases accompanied by graphics. The numerical entry widgets use the EditNumber class, which extends EditText. This class provides two entry methods, one being a simple numerical

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keypad and the other being a scientific calculator keypad. The latter provides the ability to perform calculations on quantities in the entry widgets, which can then be submitted as the new value for the entry widget used to invoke the calculator. EditNumber also includes a facility to limit the range of entries in order to prevent invalid calculations, as well as methods for setting, retrieving, and formatting numerical quantities. Values are stored to full precision even if they are displayed to partial precision, which helps preserve the consistency of displayed values, something that is not possible with the basic EditText class.

Calculation outputs are displayed using the NumberView class, which extends TextView. Like EditNumber, it provides storage, retrieval, and formatting of numerical values. The font size for the EditNumber and NumberView classes is under user control, which helps to accommodate screens of varying sizes and resolutions. We also extended the TextView and Button classes to make a ScaledTextView and ScaledButton classes, to provide the same control.

The structure of the code is such that it is straightforward to add new menus and calculations. The most time-consuming part is coding the XML file that specifies the graphical appearance of the screen.

FEATURES AND CAPABILITIES

Upon starting TAPAs, one is greeted by a simple list of topics. Clicking on one of these topics brings up a list of related calculations that are available for that topic. Often the calculations within a topic will share certain input values (e.g., the beam energy), so that changing it one calculation will change it in the others. In addition, *computed* values from one calculation are often shared with other calculations. This allows using the calculations in a coordinated fashion, which is why we used the word “toolkit” in the name.

Space does not permit a full account of the capabilities of TAPAs, which as of version 1.42 supports 40 different calculations. Instead, we will list the available calculations and highlight a few to give a flavor of what's available. In addition, space does not permit showing the equations used in the calculations or citing all of the original sources; we hope to do this in a future publication. Many of the calculations are based on formulae found in popular references [1, 2, 3, 4].

The **Electron Storage Rings** menu provides scaling of electron storage rings with size and energy; longitudinal dynamics, e.g., rf bucket parameters; harmonic number optimization; short-pulse x-rays with paired [5], or single crab cavities; tune resonance diagrams; top-up and swap-out calculations; gas scattering lifetime; and quantum lifetime.

The **Undulators** menu provides calculations of photon energy or wavelength from undulator parameters, and vice-versa; maximum field or K as a function of gap and period for hybrid permanent magnet and superconducting undulators; undulator optical effects; and undulator orbit effects. The **Synchrotron Radiation** menu provides energy, wavelength, power, and flux calculations for bending magnets, wigglers, and undulators.

The **Electron Linac** menu provides calculations of magnetic bunch compression; coherent synchrotron radiation effects in bending magnets [6, 7]; alpha magnets [8, 9]; charge, current, and beam power; and beam energy and rf power for SLAC-type linacs. The **Electron Guns** menu provides calculations of Richardson's Law, Child's Law, thermal emittance [10], and photocathode intrinsic emittance [11]. The **Free Electron Laser** (FEL) menu provides FEL calculations based on the one-dimensional equations [12] and Ming Xie's parametrization [13].

The **Electromagnetism** menu provides calculations of skin depth for nonmagnetic materials; cutoff frequency and attenuation for rectangular waveguide; and frequencies of pillbox cavity modes. The **Engineering** menu provides calculations for iron dominated magnet design; properties of dipole magnets and trajectories in dipoles; analysis of one-dimensional static heat flow; and estimates of temperature rise in cooling water.

The **Particle Passage Through Matter** menu provides calculations of radiation length, multiple Coulomb scattering, and brehmsstrahlung for electrons and protons in naturally-occurring elements [14].

The **APS-Specific Calculations** menu provides two calculations that are specific to the Advanced Photon Source (APS), namely, the single-bunch accumulation limit based on the impedance model [15] and the bunch length as a function of current based on a fit to measured data.

As a detailed example, Figure 1 shows the screen for one of the most-used calculations, namely, scaling of electron storage rings. This applies mostly well-known (e.g., [16]) scaling rules to allow quickly estimating equilibrium emittance, energy spread, energy loss per turn, etc., as a given light source storage ring design is scaled in number of cells and beam energy. One can use this application to quickly determine that scaling the 20-sector MAX-IV storage ring [17] ring to 40 sectors would give a ring size of APS which, at 7 GeV, would have an emittance of 222 pm. While most of the calculations are, as in this example, straightforward lists of inputs and outputs, some are more colorful, such as the resonance diagram shown in Figure 2.

Often the user may wish to perform additional calculations prior to entering a value, perhaps based on other values present in the interface. This is supported by an RPN-calculator-based entry dialog, shown in Figure 3. In many instances this dialog includes a menu that allows the pushing quantities from the interface onto the stack. Upon exiting the calculator interface, the top of the stack is placed into the entry box in question. To prevent invalid calculations, the calculator interface is sensitive to the valid return values for the quantity being entered, and will refuse to close if an invalid value (e.g., a non-positive value for the beam energy) is given.

CONCLUSIONS

The cost- and ad-free TAPAs application for Android devices provides a number of quick, convenient calculations

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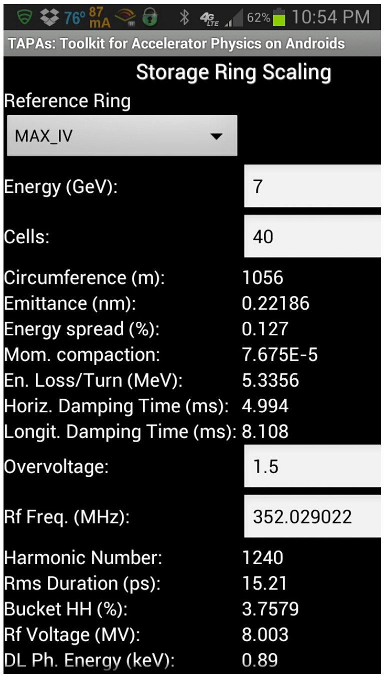

Figure 1: Electron storage ring scaling calculation.

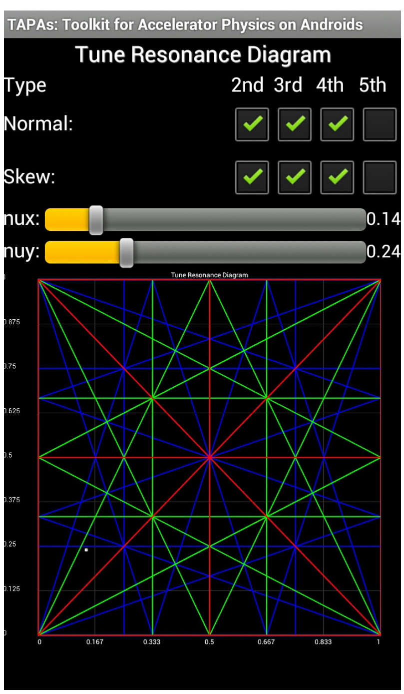

Figure 2: One of TAPAs' more colorful displays.

for use in back-of-the-envelope estimates and for analysis that would typically be performed with a handbook and calculator. The author hopes that it will prove useful and encourages users to send comments, suggestions, and bug reports to michael.d.borland@gmail.com.

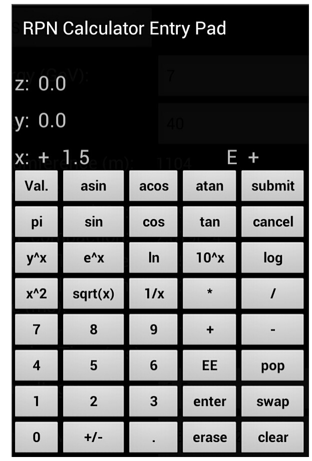

Figure 3: RPN-calculator based entry dialog.

Figure 4: QR code for obtaining TAPAs from the Google Play store.

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