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Crystallography on mobile phones

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The new possibilities offered by mobile phones combined with their widespread dissemination among young people open new paradigms for teaching science. The wide adoption of the Java environment for mobile devices gives the opportunity to develop custom-made applications for educational purposes. The first mobile phone application for crystallography training, *Escher Mobile*, is now available at <http://escher.epfl.ch/mobile/>.

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1. Introduction

Symmetry ('same measure') is an important concept, which is exploited in almost every field of human activity. It has applications in art and in literature, in science and in industry, in individual development and in relationships with others. In particular, symmetry is one of the pillars on which material sciences are based. Like most fundamental concepts, it has many different though related forms.

We propose here a tool for the study of periodicity in two dimensions. It encompasses the concept of symmetry and planar groups given in a form that can be easily handled and experimented with using our imagination. This knowledge is usually a prerequisite for the introduction of symmetry in higher dimensions.

While making their first steps, students dedicate some time to self-study in order to understand how the mathematical definitions of symmetry come into play in the real world. This issue has been addressed by different authors (Glusker, 1998), resulting in some recent breakthroughs in Web-based applications. Many crystallographers enjoy the attractive teaching applets created by Chapuis & Hardaker (1999) and Weber (1999). Since the equipment to access the programs varies greatly, these authors opted for the platform-independent Java environment, which can be directly accessed by anyone connected to the Web. As practically all browsers are currently Java-enabled, these applications can be used both for demonstrations in lectures and for student self-studies. The efficiency of this approach has been largely confirmed during recent years.

The main drawback of this solution, however, is that when repeating the demonstrations individually, the student is required to stay in front of a network-linked computer and, in addition, to dedicate the reserved time to solve the exercise. These points could potentially limit the time and efficiency of the studies.

Java-enabled mobile phones could potentially resolve the issues mentioned above. Having a set of educational programs in a hand-held device, the student can devote any spare time to self-study without the need of a computer or books. Extensive wireless network coverage provides instant downloading

possibilities for new exercises. The results could also be uploaded anywhere and at any time.

The software industry has already paved the way, providing a vast number of games for mobile devices, which are now played by millions of youngsters. We believe that this trend has an excellent potential for education and should be exploited in order to design the next-generation educational tools: 'mobile learning games'.

2. Next-generation learning tools

According to the Federation of American Scientists, 60% of college students are regular mobile-game players. This activity is generally considered as a distraction, moving the student's attention away from the educational content to activities commonly seen as inappropriate for personal development.

The authors, however, believe that this trend represents an opportunity to improve scientific education by delivering educational content through mobile devices and game technologies. The interactions involved in games develop important skills in the player. They can also provide the motivation and interest which are useful for the learning process. As science is often perceived as a difficult subject, we have taken the opportunity to use mobile digital media to explain concepts which are not *a priori* obvious. This is especially relevant to natural science, handling theory and numerical information which might be easily formalized.

From a practical point of view, the use of a mobile phone for learning provides a means to practice during spare time, for example while travelling. In addition, it appears that students not only focus on the science underlying the simulation, but seem to enjoy this type of interface.

To underline this potential, it is worth mentioning the pilot program recently launched in the UK (University of Bradford, 2005) based on the use of mobile media for teaching science in schools.

Currently, the Commission on Crystallographic Teaching of the International Union of Crystallography is addressing the problem of how to teach students on a worldwide scale, providing state-of-the-art training to everybody in any part of the globe. We believe that one mechanism to facilitate this

teaching and education

task and to encourage young people to take up the science is a set of mobile learning games for crystallographic education.

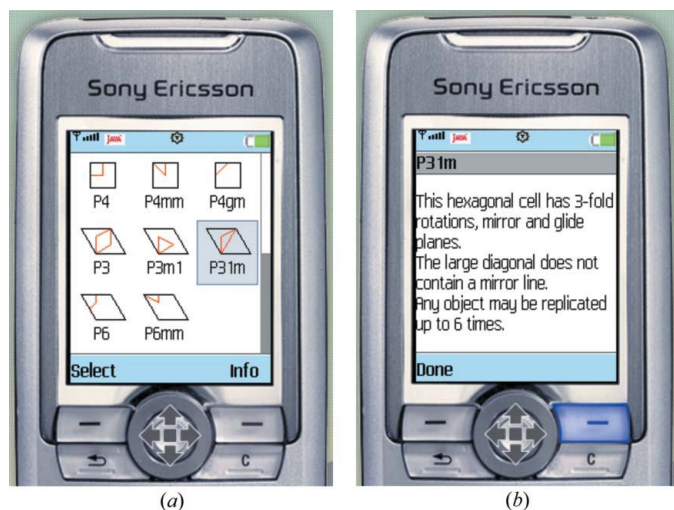


Figure 1
Any of the 17 planar groups can be selected in order to decorate the phone screen interactively.

3. Scope of the program

The space-group theory used in crystallography is described in classical sources such as the *International Tables for Crystallography*. However, although the presentation is comprehensive, it is too formal to understand without interactive examples. In parallel, designing their own patterns with crystallographic symmetry provides each student an easy and elegant way to understand intuitively the concepts of symmetry operation, asymmetric unit, general and special positions, and group symbol. The tool we propose combines both techniques: the creation of appealing periodic decorations and the essential learning information, such as planar-group descriptions.

Escher Mobile enables the student to decorate the plane with one of the 17 two-dimensional planar groups with various symmetric and asymmetric objects. The design starts from the selection of a specific group (Fig. 1a). For each group there is additional information available, namely group properties, multiplicity and symmetry elements, for a more profound understanding (Fig. 1b).

Once selected, the unit cell is outlined on the screen along with its asymmetric unit. After selecting a drawing tool, its size and colour, the creation of a pattern can be performed by

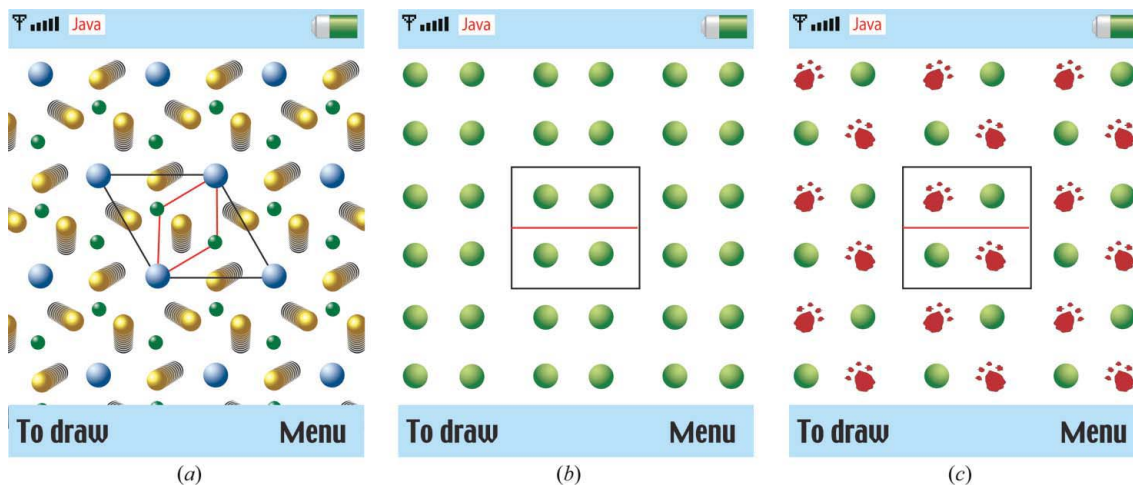


Figure 2
Escher Mobile screenshots. (a) Moving an object on the screen gives the opportunity to learn interactively about general and special positions. (b), (c) Changing a motif illustrates the Curie principle.

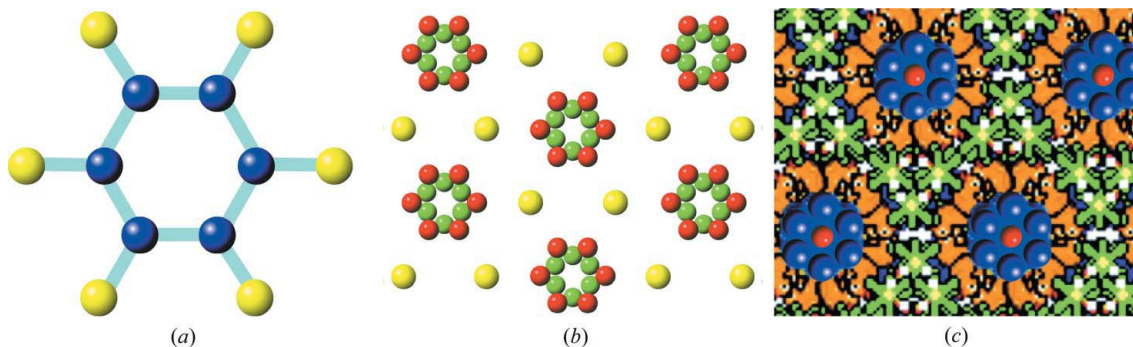


Figure 3
Artworks created by *Escher Mobile*

drawing or displacing the objects on the screen. It is thus possible to see the effect of symmetry transformation and the generation of a whole pattern, to study the properties of site symmetries and multiplicity, and identify the special positions associated with a specific group (Fig. 2a).

With the various available drawing tools, *Escher Mobile* gives the student the opportunity to illustrate more complex concepts. For example, the Curie symmetry principle, stating that any infinite pattern inherits only the symmetry elements which are common between its motif and its lattice (Curie, 1894), can be illustrated by swapping motifs with a different symmetry located in a general position (Figs. 2b and 2c).

Once completed, the pattern can be automatically uploaded to the Escher Gallery, <http://escher.epfl.ch/servlet/escherMobile/gallery>. In this process, the number of unit cells is increased and the resulting pattern is stored in PNG format suitable for further use. Alternatively, the pattern can be shared by e-mail (even if your phone is not e-mail-enabled).¹ Some recently submitted designs are shown in Fig. 3.

¹ To submit or e-mail images, the program uses the WAP protocol, thus correct WAP settings are required (ask your network provider if you do not have one).

4. Availability

Escher Mobile is compatible with most Java (MIDP 2.0)-enabled mobile phones. The program and a complete list of compatible devices are available from <http://escher.epfl.ch/mobile/>. Running the program requires no special phone settings.

You can load *Escher Mobile* to your phone by WAP browser from <http://escher.epfl.ch/wap/>, by e-mailing the program to an e-mail-enabled phone from the project home page, or *via* Bluetooth or infrared modem, after downloading the program on a local computer.

Escher Mobile is written in Java 2 Micro Edition (J2ME) using the Sun Java Wireless Toolkit from Sun Microsystems (Sun Microsystems, 2006).

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