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Abstract. The slow but steady shift away from printed text into digital media has not yet modified the working habits of chamber music practitioners. If most instrumentalists still heavily rely on printed scores, audiences increasingly access notated music online, with printed scores synced to an audio recording on youtube for instance. This paper proposes to guide the listener and/or the performer with a cursor scrolling on the page with INScore, in order to examine the consequences of representing time in this way as opposed to traditional bars and beats notation. In addition to its *score following* interest for pedagogy and analysis, the networking possibilities of today's ubiquitous technologies reveal interesting potentials for works in which the presence of a conductor is required for synchronization between performers and/or with fixed media (film or tape). A *Raspberry Pi*-embedded prototype for animated/distributed notation is presented here as a *score player* (such as the *Decibel ScorePlayer*, or *SmartVox*), in order to send and synchronize mp4 scores to any browser capable device connected to the same WIFI network. The corpus will concern pieces edited at BabelScores, an online library for contemporary classical music. The BabelScores pdf works, composed in standard engraving softwares, will be animated using INScore and video editors, in order to find strategies for animation or dynamic display of the unfolding of time, originally represented statically on the page.

Keywords: Distributed scores, animated notation, music publishing, embedded system, networked music performance

1 From paper towards animated notation: the quantum leap

A great majority of orchestral musicians today would still consider cumbersome the idea of replacing sheet music by screens. And yet, as early as 1999, thorough research had already been undertaken (by J. McPherson [24]) in a realm which is now identified as *animated notation* or *screen-scores*.[5] In his works and its surroundings [25], questions

[5] The term *screen-scores* is attributed to Lindsey Vickery and Cat Hope. [10]

relative to scrolling vs turning pages, resolution and number of systems per pages, were addressed for the first time, and already gave substantial elements of response to issues which now concern most music theory educational games.

1.1 Where gaming meet musical notation

The representation of time in the age of *screen scores* opens a wide array of questions. Thinking of tablature[6] notation, if we understand scores as a set of prescribed actions to be performed in time, video games such as *Guitar Hero* or *Beatmania* will show that such new forms of music-making offer unprecedented control over the sequential realisation of rhythmic patterns. If, on the other hand, notation is defined as something to be interpreted, and performed on an acoustic instrument, perhaps these games will hardly be recognised as "musical" experiences by musicians.

Compared to traditional score written on paper or *Common Music Notation* (hereafter referred to as CMN), graphical notation scrolling on a screen offers a more mimetic (more direct, less codified) approach to music reading, which evokes video games in many ways. With the exception of the Decibel Score Player (see Mezareon for instance) or composers cited in the animatednotation.com website, this rather ludic or *gamified* approach to score reading has only gained visibility in education so far. In the pedagogical context indeed, recent applications such as *Simply Piano* take great advantage of their ability to validate/invalidate the performer's actions, again as a way to *gamify* apprenticeship of music reading. Unfortunately *Simply Piano* is an exception, and the general tendency in software development (as shown in the case of *Guitar Hero, Synthesia* or *Beatmania* for instance) is simply to bypass CMN altogether (both for in term of pitches and rhythm). Whilst some of this games might help developing music skills among amateur practitioners (such as those youtube videos tagged [Piano Tutorial] (Synthesia)), effort remains to be made in order to find bridges between those emerging amateur practices and the art of musical notation as it is used by contemporary classical composers and performers, both still active in concert halls and academia.

1.2 Animation in the context of Distributed Musical Notation

Ryan Ross Smith's ***animatednotation.com*** website features many examples of composers elaborating scores taking advantage of the possibilities of screen scores. Most of these example rely on the projection on one single score projected on a screen visible to the audience and the performers. The networking capacities of today ubiquitous technologies would however easily allow each performer to receive only his own part

[6] Tablature, as opposed to common music notation, can be conceived as prescriptive notation, in the sense defined by Mieko Kanno: 'Prescriptive notation specifies the means of execution rather than the resultant configurations of pitch and rhythm' (Kanno, 2007, p.1). The distinction between prescriptive and descriptive notation (or common music) was already discussed in the fifties, as can attest the following statement by Charles Seeger: 'Prescriptive and descriptive uses of music writing, which is to say, between a blue-print of how a specific piece of music shall be made to sound and a report of how a specific performance of it actually did sound (...)' (Seeger, 1958, p. 1).

of the score. Indeed, composers and researchers increasingly acknowledge the strong analogy which can be drawn between the traditional 'score and parts' musical practice led by a conductor, and the modern distributed systems or web applications (Zscore [22] - MASD [14] - SmartVox [2]), in which multiple clients coordinate their actions by passing messages to one another. Several attendees of the Tenor Conference[7] have proposed elements of response in an emerging realm which can be called "distributed musical notation". Some performance-oriented systems (INScore[17], SmartVox [2] [3], Zscore [22], Decibel [5] [6], MaxScore [7], Comprovisador [23]) endeavour to distribute and synchronise each part of the score on the performer's devices (whether Smartphones, tablets or laptops).

1.3 Animated notation and the composers of the new complexity

Only a few composers of contemporary classical notated music feel the necessity to acknowledge this sudden growth of animated/distributed notation, since the software they use (Finale, Sibelius or pen and paper in great majority) are designed to render still images. Also these scores are dedicated to classically trained performers, all familiar with CMN and in great majority also aware of complex experimental forms of "static" notation. In academia, composers and music analysts are trained to read and follow these complex scores in which the notation is sometimes overloaded and detached from the acoustic result, as can be exemplified with the experimental music of the so called *new complexity*, with extremely complex rhythms (famously led by Brian Ferneyhough), or with some of its more recent (post-Lachenmanian) manifestations with large amounts of extended techniques and graphical notation.

The *Score Follower* project helps such composers getting their music heard and understood by simply synchronising a recording to each page of the score and share it on social media (youtube). To some unexperienced readers/listeners, the sound to sign relationship may still be difficult to follow which is one of the reasons why the cursor was introduced here. The representation of musical time in the examples below will propose an attempt of *hybridised* situations in which (often complex) contemporary classical scores take advantage of the possibilities of animated notation (DENM being a major influence [15]). The case of *New Complexity* or post-Lachenman types of aesthetics will be of particular interest here (see Malaussena), as the proposed cursor solution may provide elements of response to composers whose rhythmic complexity seeks *rubato* in the first place. Indeed, beyond the exact realisation of nested tuplets, some of these composers seek in rhythmic complexity the absence of a clear sense of pulse and fluidity.

1.4 Scrolling versus beating time

In the above-mentioned video games and musical examples, wether notation is scrolling from right to left (as in *Simple Piano* or *Decibel ScorePlayer*) or top to bottom (Guitar Hero - [Piano Tutorial] (Synthesia)), the basic principal relies on a continuous or scrolling movement (either of a cursor, or of the score itself) representing the passage of time. Cursors, as will be seen below, present great possibilities of synchronisation, in terms

[7] http://www.tenor-conference.org/

of *duration* rather than *rhythm*: when instruments need to synchronise with electronics or video for instance. In terms of pulse however, cursors remain quite approximate in comparison with the arm movement of a conductor dictating a beat. In none-pulsed music therefore, and in spite of the great conducting tradition in chamber music and orchestral works, such scrolling displays (as in the Decibel ScorePlayer or SmartVox) seem a far more straightforward strategy to obtain synchronisation in comparison to the bars and beats 'encoding' (quantified by the composer's choice of bars and beats) and decoding processes (a compromised interpretation by the instrumentalist, between the rhythmic values written on the page and the gestures of the conductor), inherited from a scoring tradition in which a regular meter was assumed.

We therefore propose here a solution for animation of pre-existing scores, with the help of a cursor scrolling on a static page. INScore[17] is in no small part designed for cursor animation, and will be of particular relevance to extend the practice of animated screen scores to a wider community of composers and performers, through BabelScores[8] in particular.

2 BabelScores, SmartVoxINScore, and Presentations

BabelBox, the project envisaged here proposes a collaboration between two existing technologies (INScore and SmartVox) and BabelScores, a publishing company specialised in contemporary classical scores, which will now be presented.

2.1 SmartVox

SmartVox [2][3] is a distributed web application that delivers and synchronizes audiovisual scores in the video mp4 format to the performer's mobile devices, in compositions involving up to 80 simultaneous performers such as in ***Le temps des Nuages***. The ability to synchronise *screen scores* and *audio-scores* [1] through the browser of the performer's phones allows for various kinds of assistance, such as free movement on stage and around the audience, audio guide for singers, simplified synchronisation with tape and/or visuals... Recent developments include the use of head-mounted displays (HMDs) for technology-aided performance, as in the pieces ***In Memoriam Jean-Claude Risset I*** and ***Mit Allen Augen, In Memoriam J.C. Risset II***.[9]

SmartVox was developed in the *SoundWorks* framework.[10] *SoundWorks* provides a set of services – such as synchronization, network messages, distributed states, creation of groups of clients – that aims to solve problems common to distributed and synchronized web applications centered on multimedia rendering. The framework is written in

[8] Babelscores (https://www.babelscores.com/) is an online score database for classical contemporary music, currently actively supporting the SmartVox project: http://1uh2.mj.am/nl2/1uh2/lgi4u.html.

[9] Those three pieces are respectively available at: https://youtu.be/SyFdR2HiF00, https://youtu.be/hQtyu1dcCaI, and https://youtu.be/ET_OBgFWx04.

[10] *SoundWorks* was initiated by the CoSiMa research project funded by the French National Research Agency (ANR) and coordinated by Ircam.

Fig. 1. Singer wearing HMD for technology-aided performance.

Javascript, with a server side based on Node.js. [11]The SmartVox application consists of two web clients, the player and the conductor, that can be executed in any recent web browser on mobile devices (e.g. smartphones, tablets) and laptops. The real-time communication between clients is achieved through the WebSocket protocol [12] The application is typically deployed over a *local area network*, but it may also be used over the internet.[13]

2.2 The 'BabelBox', a Raspberry Pi Hardware Embedded System Solution for Local NMPs - reformulate

In search of a light plug-and-play dedicated system to be sent over the post, the Raspberry Pi quickly appeared as the best option to host SmartVox on an embedded system. Node.js runs on Raspbian, and SmartVox proved to be very stable on a Raspberry Pi 3, so, once installed, the only two steps for a *0-conf* deliverable hardware were:

- Setting up a static address for a dedicated router (e.g. tp-link...).
- Starting SmartVox at boot.

Starting a script at boot can be done on Raspbian with a file containing the following in the etc/systemd/system:

```
[Unit]
Description=My service
[Service]
ExecStart=/home/pi/Desktop/hello.sh
[Install]
WantedBy=multi-user.target
```

With the hello.sh script containing the following to launch the server:

```
#!/bin/bash
```

[11] https://nodejs.org/en
[12] https://www.w3.org/TR/WebSockets/
[13] https://youtu.be/83ub6-Q5oj0

```
cd /home/pi/Desktop/risset
npm run start
exec bash
```

This low-cost system (less than 65 €, for a Raspberry and a router) now allows the sending of ready-to-use scores. Once the system is power-supplied, all the performers need to do is to join the dedicated Wi-Fi, and type the static IP address of the server on their smartphone/tablet (i.e. for the performers: 192.168.0.100:8000, and for the conductor: 192.168.0.100:8000/conductor). In January 2019, the system was rented to the Caen French conservatoire via BabelScores,[14] thus proposing a rental of performing scores (separate parts) of a new kind.

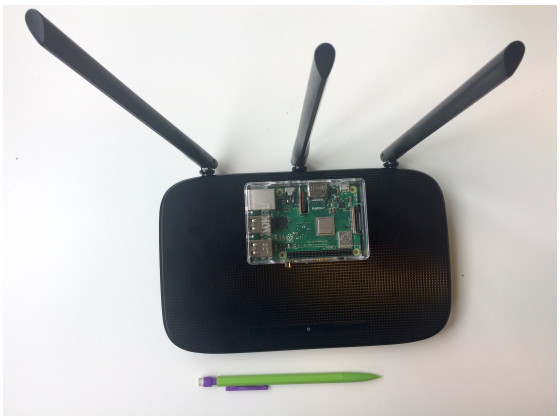

Fig. 2. BabelBox kit.

2.3 BabelScores

BabelScores is a French-based organization arising from the need to circulate and promote contemporary music from the last 50 years, rendering information more easily available to everyone worldwide. Through an international network, BabelScores looks into and selects the works of the most creative, original and innovative composers of the past few decades. BabelScores offers a wide and constantly growing catalogue, setting up a powerful circulation platform especially addressed to instrumentalists, ensembles, orchestras, composers, musicologists, conservatories, universities and festivals throughout the world. BabelScores offers the possibility to consult online all the material in its catalogue. Scores, which are the central element of BabelScores' material, may be consulted bookwise, turning pages, by means of a special reader which allows a comfortable and detailed reading.

[14] Babelscores (https://www.babelscores.com/) currently supports actively supporting the SmartVox project: http://1uh2.mj.am/nl2/1uh2/lgi4u.html. The first piece performed in Caen with the Babelbox is available at the following address : https://youtu.be/wUyw0KQa5Wo

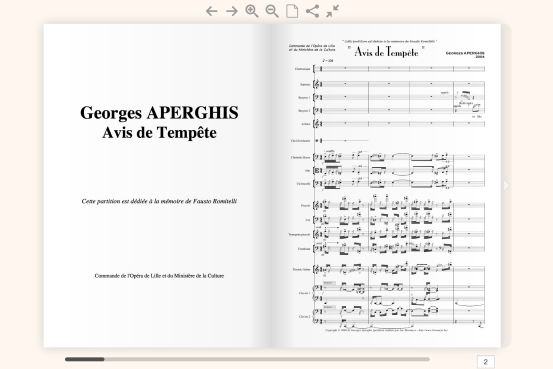

Fig. 3. BabelScore's virtual reader.

In the framework of its purpose to promote, excite, support and diffuse the "written music" creation in connection with web technologies, BabelScores cooperates with traditional institutions as well as with researchers and emerging projects. BabelScores already collaborates with the Bibliothèque Nationale de France (BNF) in order to find and conjointly develop a robust, relevant and pragmatic way to handle music scores in this web and digital era, particularly their preservation and automatic (server-to-server) deposit to archive centres. BabelScores also works on the topic of native digital sketches, in order to asset which formats to use, how to transfer them and how to expose them in the most meaningful way in the BnF's collections once processed. BabelScores collaborate also with researchers and emerging projects such as SmartVox and InScore to supports applied research in the domain of notation using web technologies. Based on current research in progress, Babelscores wants to collaborate to solve problems through pragmatic and massif use of these techniques. The main vision BabelScores has is to create an interface between researchers, orchestras, creators, institutions and musicians that will allow these new usages to express their potentiality at their best.

2.4 INScore

INScore [26] is an environment for the design of augmented interactive music scores, opened to unconventional uses of music notation and representation, including real-time symbolic notation capabilities. It can be controlled in real-time using Open Sound Control [OSC] messages as well as using an OSC based scripting language, that allows designing scores in a modular and incremental way. INScore supports extended music scores, combining symbolic notation with arbitrary graphic objects. All the elements of a score (including purely graphical elements) have a temporal dimension (date, duration and tempo) and can be manipulated both in the graphic and time space. They can be synchronized in a master/slave relationship i.e. any object can be placed in the time space of another object, which may be viewed as "time synchronisation in the graphic space". As a result, a large number of operations can be performed in the time domain and in particular, moving a cursor on a score is simply achieved using the synchronization

mechanism and by moving this cursor in the time space. Time in INScore is both event-driven and continuous [19], which makes it possible to design interactive and dynamic scores. The system is widely open to network uses [17]: it allows to use both local and remote resources (via HTTP), it provides a forwarding mechanism that allows scores to be distributed in real time over a local network.

INScore has built-in solutions for monitoring the position and the speed of cursors in an efficient way. Since common practice notation is rarely proportional (i.e. a 4/4 is not necessarily twice longer on the page than a 2/4 bar), a cursor moving at constant speed across a whole system will never accurately fall at each bar accurately according to musical time. To tackle this issue, INScore provides a mechanism to describe the relationship between the graphic and the time space in the form of ”mappings” which are actually a relation (in the mathematical sense) between a set of graphic segments and a set of temporal segments. A graphic segment is described with two intervals: the first one on the x-axis, and the second one on the y-axis. With images, these intervals are expressed in pixel positions. A time segment is an interval expressed by rationals that represent dates in musical time (where 1 is a whole note). INScore mappings describe arbitrary relationships between time and any graphical resource. It is mainly used to solve the problem of non-proportionality of symbolic musical notation (see for example in Fig. 4 and Fig. 5).

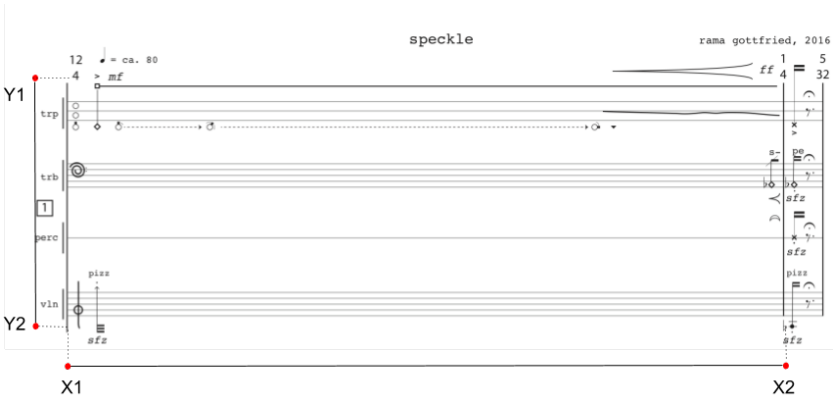

Fig. 4. One bar’s coordinates expressed in pixel coordinates

These two segments (X1 - X2 and Y1 - Y2, see Fig. 4) define a rectangle corresponding to one bar in the score. The pixel coordinates of this rectangle are then attached to the duration of the bar, expressed in regular time signatures, with the following syntax: ([*one graphical segment on x axis [[one graphical segment on y axis[) ([one temporal segment[)*.

```
([144, 623[ [227, 745[) ([0/4, 1/4[)
# x1    x2     y1     y2      t1     t2
([635, 1203[ [705, 744[) ([1/4, 2/4[)
```

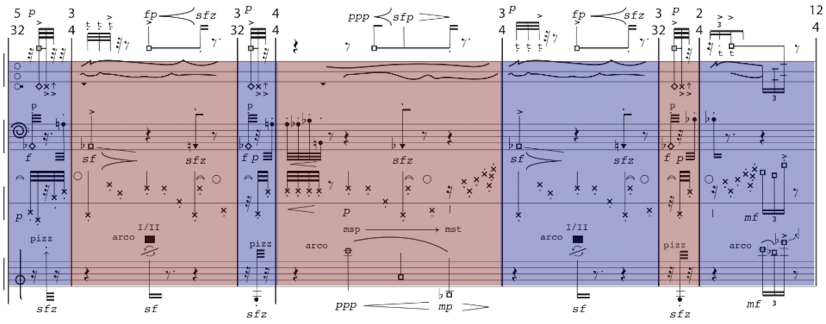

Fig. 5. Rectangles monitoring the position of the cursor: Time and space relationship is linear inside a box.

```
# x2+1    x3      y1      y2          t2      t3
```

The same procedure is then repeated with each bar (see Fig. 5). A specific INScore script allows you to draw mappings directly on the page and to retrieve them in a "nearly ready to use" form, with default time intervals that need to be specified.[15] This type of cursor seems to facilitate video part extraction by simply cropping the section of the screen corresponding to one particular instrument Figols - Fullscore (see corresponding separate part here).

3 Cursor Implementation

A cursor emphasizes the continuous unfolding of time while common practice musical notation implicitly relies on the rhythmic accents defined by bars and beats. The aim here is to find with INScore an efficient solution to incorporate animated cursors to a large number of pieces in the most automated and efficient possible way. Indeed, the *BabelBox* project consists in generalising to use of distributed notation and make it available to composers using those standard engraving softwares. From a given pdf score of the *BabelScores* corpus to its rendering on phone and tablet, one of the main issues will concern cursor implementation. Recent strategies for score distribution (such as pieces realised with the Decibel Score Player or the quintet.net/drawsocket server) tend let a score scroll over a fixed cursor. Whilst this solution remains envisageable, the BabelBox realisation achieved so far tend to use a moving cursor over fixed images, with page turns.

3.1 Cursors without INScore : Standard Engraving softwares and Bach

If all the pieces performed with SmartVox were composed in *Bach*, this environment, as its major antecedent *Open Music*, remains grounded in computer-aided composition

[15] The corresponding tools are available at the following address : https://github.com/grame-cncm/inscore/tree/dev/scripts/Tools/drawmap

rather than score engraving. Objects like *bach.roll* or *bach.score* are well-suited to animation and provide built-in cursor support, but they cannot compete (graphically) with the engraving capacities of dedicated softwares like Finale or Sibelius.

Latest versions of Sibelius (7.5 and 8.0 offer the possibility of exporting a video of the score with a cursor following the beats with the metronomic parameters marked in the score. This possibility could facilitate the creation of the video material needed for the *BabelBox*. However, the procedure demands a well configured MIDI encoding of the tempo - including tempo changes - in the original file in order not to miss the syncronisation between the notated score and the sound recording. Finale and Sibelius offer advanced MIDI controls that will have to be taken into account necessarily if this procedure is taken.

3.2 Continuous time with cursors, metrical time with blinkers

A cursor was also used in extracts of Emily Howard's Opera *To see the invisible*[16]. The main limitation of this type of representation resides in its impossibility to mark the beats implicitly expressed by time signatures. According to Richard Baker - who conducted the opera with the help of *SmartVox* in the second scene -, dynamic representations conveying the accent meant by the arm of a conductor might be preferable to the more linear trajectory of a cursor (see the "bouncing ball" for demonstration).

This "Bouncing ball" type of representation was introduced at Tenor 2018 by Pedro Louzeiro [23] and Slavko Zagorac [22]. It presents this advantage over cursors mark upbeats and downbeats, like the arm of a conductor, but one may argue that this form of representation might be disturbing for the eye,

Another strategy for marking the bar's beats more clearly might be to make a static cursor blink on each beat, with different colour for upbeat and downbeat (see examples realised on compositions by Brian Ferneyhough and Daniel Figols).

4 Conclusion

This paper presents the early stages of a research project which could help musicians worldwide[17] access distributed/animated notation easily. Indeed for pieces for chamber groups with electronics or video for instance, synchronisation through the browser of the performer's phone/tablet/computer seem a costless and promising way of making music. Solutions such as the BabelBox however, - local NPMs - only constitute a temporary solution if we acknowledge the exponential growth of the internet. In a few years' time, simple urls such as www.smartvox.eu should be sufficiently robust to let performers access the same piece via different terminals and through the internet directly, even in concert situations.[18]

[16] https://snapemaltings.co.uk/concerts-history/aldeburgh-festival-2018/to-see-the-invisible/

[17] BabelScores now has partnerships with the world's most prestigious universities, see https://www.babelscores.com/partners

[18] Rather than a static address (such as http://37.59.101.205:8000/), a bootstrap or a web-application may be more appropriate here.

INScore allows for the precise temporal control of animated cursors in the graphical domain. Thanks to its OSC support, it is possible to control the cursor's position via automations in Ableton Live.[19] This setup suits particularly well sound-to-visual synchronisation as in Julien Malaussena's piece, in which the cursor follows the audio recording. This methods however needs to be compared with the tools exposed in Chapter 3.1, which might allow for faster results.

Questions must be addressed regarding what is easier to do in INScore directly, in INScore with automation in *Ableton*, or in a video editor (Da Vinci resolve, Adobe Premiere, Final Cut...), according to what is sought:

- cursor with time given by the score : INScore (rectangles)
- cursor with time given by a recording of the piece : INScore automated in Ableton Max-for-Live?
- part extraction, two system per page layout : DaVinci ?

Once these practical problems elucidated, a more definitive solution for score elaboration workflow will be defined. Fig. 6 presents its current state.

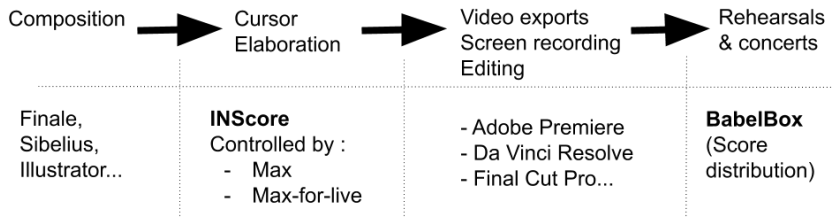

Fig. 6. Score elaboration workflow.

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[19] Via Max-for-Live, see https://youtu.be/rLy8DW_p2JE for demonstration.

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