

# COMPUTATIONAL ANALYSIS OF MUSICAL INFLUENCE: A MUSICOLOGICAL CASE STUDY USING MIR TOOLS

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## ABSTRACT

Are there new insights through computational methods to the thorny problem of plotting the flow of musical influence? This project, motivated by a musicological study of early synth pop, applies MIR tools as an aid to the investigator. Web scraping and web services provide one angle, sourcing data from allmusic.com, and utilising python APIs for last.fm, EchoNest, and MusicBrainz. Charts of influence are constructed in GraphViz combining artist similarity and dates. Content based music similarity is the second approach, based around a core collection of synth pop albums. The prospect for new musical analyses are discussed with respect to these techniques.

## 1. INTRODUCTION

Musicians have always been aware of issues of musical influence, from the lists of influences set out in adverts for new band members, the intensive relationship of teachers and pupils in many traditions, to composers consciously admitting their predecessors through interviews, personal journals, and in some cases unconscious or deliberate quotations. Whilst it is convenient to focus on grand examples in a 'genius' model of musical history, all eras of music have had a host of active musicians, though no era more than today's hyper-warren of content creators. Chopin's letters, for example, are littered with references to other active pianist-composers of the day, most of whom are no longer household names, yet Chopin writes 'I shall not be an imitation of Kalkbrenner: *he* has not the power to extinguish my perhaps too audacious but noble wish and intention to create for myself a new world' [9, p. 103]. The literature on human creativity is of note here in exploring the processes of human invention within the engine of culture [5, 15]. Musicologists have re-cast traditional concerns over influence to questions of 'inter-textuality', and the degree to which any musical work can be seen as distinct from social and musical currents [16]. Influence is intimately connected to the continuous negotiation of musical style as it transforms over time; the gradual formation

of genres is implicit in much discussion of the philosophy of stylistic categories in music [1, 10], and related to similar questions in biology concerning speciation events and memetics [4, 6].

Automated methods for the analysis of musical similarity provide a new angle on relationships between works, whether comparing individual pieces or within larger corpora. For example, the data-driven analyses explored by David Cope across MIDI files [3] are primarily used for synthesis, but can also help to explore the links between composers. Symbolic analysis tools in MIR parallel such movements in algorithmic composition: McKay and Fujinaga [11] discuss the application of their jSymbolic feature extractor and Autonomous Classification Engine machine learning tool to such projects as comparison between a Chopin nocturne and Mendelssohn piano trio, or distinguishing de Machaut and Palestrina. Charles Smith has carried out perhaps the largest musicological study of influence amongst classical composers by a series of measures applied over library resources, and presents it in a website describing the 'Classical Music Universe'.<sup>1</sup>

There are many MIR studies which have analyzed the current state of public opinion on artist similarity, for purposes of tracking popularity and making recommendations. Zadel and Fujinaga [19] combine cultural meta-data from Amazon with a metric of similarity based on Google search counts to generate a network of related artists through web services. Fields et al. [8] scraped MySpace pages, tracing the recursive (to sixth degree of separation) network of friends and evaluating musical similarity through audio content analysis of their sound examples. They mention influence as one potential link between artists, but do not unpack it from collaboration or general similarity. Park et al. [13] also study the network structure of artists, by scraping online music databases such as allmusic.com, but concentrate on collaboration or 'expert' annotated similarity rather than any explicit tie to dates. Again tackling MySpace, Beuscart and Couronné [2] namecheck influence in their title, but mean it as a general measure of recommendation amongst cliques of artists rather than as a formative influence on creative output.

Thus, although the topics of similarity and genre remain central tenets of much music information retrieval work, the role of dates as markers of the flow of influence is not so widely discussed. This paper makes dates a central part of a musicological investigation. The applicability of MIR

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<sup>1</sup> <http://people.wku.edu/charles.smith/music/index2.htm>

tools to studies of influence both via online meta-data parsing and content based analysis applications is explored. In the latter content analysis, a tight knit set of synth pop albums from the years 1977-1981 are put under the microscope, providing a real challenge for discrimination and a microcosm of gradual stylistic change.

Section 2 introduces the context of synth pop as well as the central node, Depeche Mode (DM). Section 3 presents web scraping and web service exploration of the network of artists around DM, with a technique to automatically extract dates for artists using the MusicBrainz web service. Network diagrams are constructed through python programs and GraphViz. Section 4 tackles the influence question using a set of synth pop albums from the era up to four years before the first DM release, looking for automatic recognition of possible leads on influence through musical similarity (marsyas is the tool of choice here). Results and future extensions are discussed.

## 2. SYNTH POP AND DEPECHE MODE

The cost of analog synthesizers decreased in the 1970s, until an all synthesizer band was a viable proposition for musicians starting out in the post punk era [14]. Although there are always earlier precedents, and synths had been long known in popular music through such phenomena as mass selling Moog albums, prog rock keyboardists, and krautrock, a real concentration of synth led bands emerged in the later 1970s into a position of mainstream chart success. The Second Invasion of the US by British bands on the back of MTV featured a plethora of synthesized sounds, and the 1980s saw even greater availability of electronic equipment as digital technology stole the show. Although some 'New Romantic' bands such as Duran Duran had only a single keyboardist, the more central examples of synth pop tend to feature all synthesizer backing, including sequencers and drum machine in place of acoustic drummers, after the Kraftwerk model; but like all supposed categories, inbetween cases exist.

Depeche Mode were by no means the first synth pop band, nor the first with popular market appeal; both Kraftwerk as an all electronic band, and Gary Numan as an individual who featured synthesizers, had had greater commercial success than their first album was to achieve. Yet in longer term commercial and artistic success, impact and influence, DM are still of great importance, and a fascinating subject of study in terms of tracking influence. They have touched multiple putative genres, from early teen synth pop, through darker industrial sampling, to electronic tinged stadium rock,<sup>2</sup> and inspired divergent artists (as one example, see covers compilations such as *For the Masses* (1998) or the Swedish synth pop tribute *I Sometimes Wish I Was Famous* (1991)). Early DM is also of note in that Vince Clarke was the chief songwriter, rather than Martin L. Gore, and such complications bring home the challenges of tracking a band's inspirations and influence through ex-

<sup>2</sup> Arguably, after DM's best selling *Violator* (1990), even converging with U2 for 1991's *Achtung Baby*, as U2 chased the contemporary sound of electronic dance music's commercial break through

tended careers.<sup>3</sup> In another example of the complications, as bands progress through multiple albums, they work with many people, often bringing in younger producers who emerged in historically later scenes (in DM's case, such as Flood, or Mark Bell). The network of musicians who influenced, and who were influenced by, Depeche Mode are examined in a web data analysis, and work historically closely prior to the album *Speak & Spell* is the focus for the audio content analysis.

Statements by band members past and present provide insight into the formative influences of the band. For example, in Miller's biography [12], the band admit early influences including Gary Numan (p.21), OMD and the track 'Almost' (p.23), The Human League and particularly 'Being Boiled' (p.483), Kraftwerk (p.25) and John Foxx (p.26). DM gerged early on with the post-Foxx incarnation of Ultravox, and their label owner and first producer was the British DIY synth pioneer Daniel Miller; Mute Records artists would remain a central touchpoint as the band developed. Such references are further discussed below.

## 3. WEB SCRAPING AND WEB SERVICES FOR THE ANALYSIS OF INFLUENCE

Although a musicologist might construct their own model of musical influence from analyzing primary and secondary sources such as original releases, reviews and interviews, the wealth of online commentary and databases provides a further strand of evidence for systematic musicology to exploit. Although there can be issues with the verifiability of information, the much remarked problems of reliability of meta-data in MIR [7], it can still be healthy to admit web content as part of the arsenal of the musicologist. This paper examines the use of web scraping and web services to collect alternative viewpoints on the influences upon and influence of a particular central band. Although the techniques may be applied to any starting point, Depeche Mode are chosen in particular for this study.

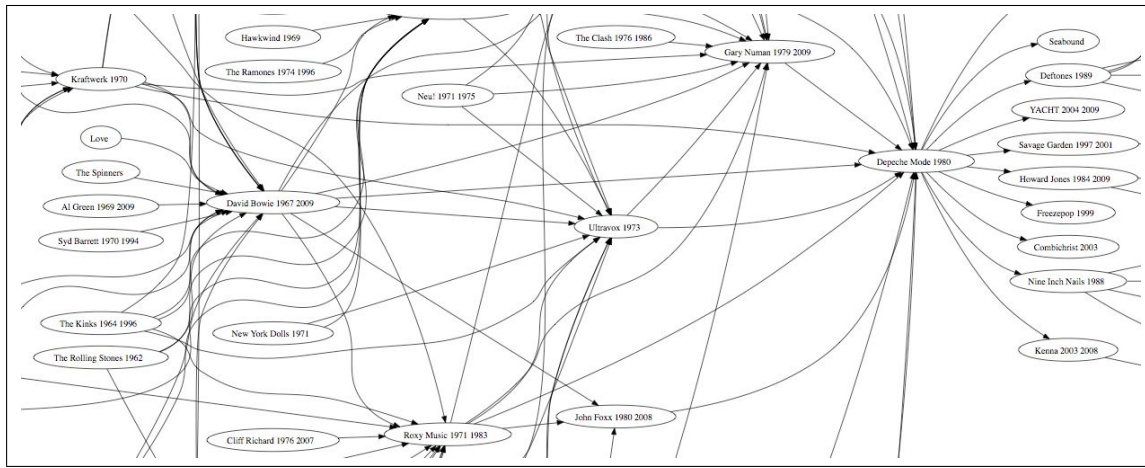
The following APIs and websites were investigated:

- allmusic.com artist information explicitly contains entries for 'Influenced By' and 'Followers'
- The EchoNest API has convenience methods to obtain biographic data, lists of similar artists, and a measure of 'familiarity' for a given artist.
- The MusicBrainz metadatabase has an API which allows interrogation of artist releases and dates.
- The last.fm API can return a list of similar artists amongst further functionality

Programs were written in python to utilise the APIs, and for web scraping.

Three tactics could generate graphs of related artists with direction of edges determined by date, using recursive construction. In the first case a similarity measure from a

<sup>3</sup> A similar radical change of personnel is seen for example in The Human League's development in 1980.



**Figure 1.** Excerpt of a graph of influences based around Depeche Mode, filtered by familiarity ratings of at least 0.6 per artist according to EchoNest. Note the errors and omissions in dating information, for example the start date for Cliff Richard, who appears via a supposed second order influence from Roxy Music. The overall graph, even relaxing the familiarity filtering, is much richer for precedents than for successors, perhaps reflecting the balance of music history and journalism with regard to the present day.

starting artist was used, and dates imposed as a way of determining directivity (most simply, earliest date of activity of a given artist, ignoring career overlaps). In the second, the allmusic.com site was scraped for the pre-marked Influenced By and Followers lists, which gave the direction of arrows without needing dates (however, dates were still annotated with artist names in this case as a helpful guide; similarity ratings between artists could also rate strength of connection). The third method is for a musicologist to provide a list of artists for which they are interested in interconnections; they can then try various similarity measures to weight connections, and dates can be automatically determined where they are not already known.<sup>4</sup>

Because the computational search should be as automated as possible if larger networks are to be generated, musicbrainz.org provided the ability to hunt for start and end dates of artists (the musicologist can always further corroborate dates later if any promising links are revealed). This was actually one of the hardest coding problems to solve, because for the start date MusicBrainz returns the date of birth of an individual artist, but the date of formation for a group. Code was written for individuals and for cases where there was no returned valid start or end date, to hunt through associated album and single release dates, taking minima and maxima. The API often failed to respond when called too often, but the program kept trying with increasing gaps between calls until connection was re-established or it failed ten times in a row. All dates were stored in a local database to avoid the slow dependency on MusicBrainz, only checking artists if they were new to the database or no date had yet been established in previous attempts (the musicologist can also in principle overwrite dates if they discover more reliable data).<sup>5</sup>

<sup>4</sup> As a proviso to this process, different data sources and similarity measures reflect different construction principles from 'expert' annotation (allmusic) to community consensus (MusicBrainz), and the analyst should keep this in mind.

<sup>5</sup> As pointed out by a reviewer, an alternative model here may be to

The final large networks of artists could be directly plotted, but facilities were also added to cluster by the year an artist began their recording career,<sup>6</sup> and to exclude artists falling below a certain threshold of familiarity with respect to the EchoNest measure. Figure 1 shows an excerpt of a graph generated via the allmusic database method, recursing only up to second order connections, and annotating dates of artists via MusicBrainz.

It was definitely of benefit to spend time with the technology and with online opinion as a method of immersion into the subject. Results however must be interpreted with caution; in particular, the allmusic.com annotations for synth pop artists did not expose some expected links (for example, Depeche Mode as an influence on Alphaville, the Pet Shop Boys, or Goldfrapp, to name but three, though Camouflage and Nine Inch Nails did appear as successors; The Human League were not listed as an influence despite DM's own documented confession). They did however point to a few other possible leads worth pursuing. Some second order links, such as Elvis Presley and Chuck Berry were admitted by Martin L.Gore as his earliest listening in a recent interview<sup>7</sup>, though the centrality of such figures, particularly with respect to the Beatles hub, is a little too obvious and a likely side effect of dominant nodes in artist networks [13].

It was found in practice that similarity of artists as a singular term often proved insufficient, in that it did not adequately respect musical characteristics over social. For example, Pandora, which in any case admits no API, lists similar artists to DM as The Cure, New Order, Duran Duran, The Smiths and Tears for Fears. There is one justifi-

exploit DBpedia and LinkedData for the Semantic Web.

<sup>6</sup> All artists are in development off the commercial radar for a long time, and formative influences not necessarily via mass released recordings; but the underlying assumption to keep this project manageable is that a commercial release reveals the potential to influence a large number of followers.

<sup>7</sup> <http://www.bbc.co.uk/programmes/b00jn4fl>

cation as UK bands all active circa 1983 or so, but in terms of tracing the history of synth pop, there are a few overlaps and some mishits (The Smiths, for example). Data was also not always reliable; EchoNest listed Duran Duran Duran, the breakcore artist, instead of Duran Duran; arguably there is more electronic sound in the former, though it is probably an erroneous appearance in this context.

#### 4. CONTENT BASED ANALYSIS

The other angle of approach in this project was to examine the actual audio recordings for similarity between artists. Armed with associated date information for tracks, networks of prior art can be constructed. Though there is not always causal proof that the authors of *Speak and Spell* would have heard and actively internalised particular tracks by prior artists (though see comments above in section 2 concerning admitted influences such as The Human League), it is possible to speculate, guided by such an investigation, and hope in general that the search provides a pillar in accumulating evidence for a particular linkage.

Table 2 contains a list of 37 albums or compilations, corresponding to 364 tracks, selected as the target data and space for musicological ground truth. The choice of albums reflects our own analysis of possible formative influences, with a bias to British acts, and covers the years 1977-1981, during which electronic instrumentation was breaking through to mass use in popular music (there are many earlier precedents, but the scope of inquiry was arranged around the post punk years transitioning to the early 80s). Depeche Mode were gigging in 1980, and released their first singles in 1981 leading up to the *Speak & Spell* album that October. There are many other artists and releases of potential relevance, both outside and within the restricted dates, but the core set is large enough to provide ample scope for musicological investigation and pose a significant challenge for MIR technology.<sup>8</sup> For digital convenience, despite originals being chiefly released on LP (CDs arrived in 1982), all data was sourced from purchased CD recordings, since these provide a guaranteed professional transition from master tapes. A few were re-masters (as noted in the table), with possible changes in overall compression and loudness, but since this did not substantially impact on human listening, in the ideal computer analysis should be able to cope (the timbral features used here did not include amplitude measurements as comparators). Any bonus tracks not readily available in the original era of release were excluded, which typically meant removing any tracks not on an original LP. Release dates were cross-referenced from online sources such as allmusic and discogs.com as well as liner notes and textbooks.

Our primary interest was to analyze relevant recordings that might show a strong similarity to tracks on *Speak & Spell*, and thus see if computer analysis could spot any links of influence. A secondary interest was the analysis of early synth pop's properties in general. There were various

<sup>8</sup> Possibilities for extensions just with artists active in this period include Telex, Joy Division/New Order, Throbbing Gristle, Jean-Michel Jarre and Wendy Carlos to name a fraction.

opinions and discoveries here from conventional listening, but the computer offered an alternative perspective.

Marsyas [17] and weka [18] provided the tools of choice for audio feature extraction, similarity measurement, and machine learning. The 44.1kHz 16 bit audio recordings were each passed through marsyas' bextract algorithm to obtain single vector averaged MFCC and spectral features over one minute 30 second sections taken from the middle of each track (window size and hop size 1024 samples). These obtain a long exposure timbral summary vector (64 dimensions) for each track. Similarity values between all individual tracks could then be created. A python script was written to order similar songs from a given starting song across the database. The nearest and furthest neighbours from each track on *Speak & Spell* were listed; Table 1 gives example results for the nearest and furthest ten tracks to the second DM single 'New Life'.

Score	Artist	Album	Track
1.047	DM	Dreaming Of Me	Speak & Spell
1.116	Gary Numan	Replicas	We Have A Technical
1.133	Ultravox	Systems Of Romance	Just For A Moment
1.150	Gary Numan	The Pleasure Principle	Random
1.152	Gary Numan	Telekon	I'm An Agent
1.153	OMD	Orchestral Manoeuvres In The Dark	Red Frame White Light
1.155	Ultravox	Vienna	Vienna
1.211	Ultravox	Vienna	Mr. X
1.221	Gary Numan	Replicas	Replicas
1.234	YMO	Solid State Survivor	Day Tripper
...	...	...	...
2.275	YMO	Yellow Magic Orchestra	Computer Game Theme From The Invader
2.320	Devo	The Essentials	Girl U Want
2.324	Cabaret Voltaire	The Original Sound Of Sheffield	Do The Mussolini (Headkick)
2.339	OMD	Architecture & Morality	Architecture And Morality
2.373	Human League	Reproduction	Blind Youth
2.490	Cabaret Voltaire	The Original Sound Of Sheffield	Baader Meinhof
2.593	John Foxx	Metamatic	Plaza
2.620	Human League	Reproduction	Medley Austerity Girl One
2.623	YMO	Yellow Magic Orchestra	Computer Game Theme From The Circus
3.151	Human League	Dare	The Sound Of The Crowd

**Table 1.** Maximally similar and dissimilar tracks to 'New Life' by Depeche Mode within the database

Some results were not so surprising; both other DM singles from the first album are close by (Just Can't Get Enough comes in at 18th closest). Further away, the Baader Meinhof track is dark and unsettling and not rhythmic. The low bit arcade timbre of the YMO computer game themes are unique amongst materials here. John Foxx's Plaza features a prominent flanging effect. On the other hand, in musical terms the many distant up tempo Human League tracks, or the close appearance of Vienna are somewhat suspicious. The Sound of the Crowd persistently came far from all tracks on *Speak and Spell*, perhaps due to the loudly mixed vocal and particular synth percussion sounds.

The album annotated feature data also underwent machine learning algorithm investigation, by training classifiers to differentiate artists' releases. The musicological interest is to find points of failure of discrimination as insight into potential timbral/musical overlaps and thus through information on dates, promising leads on the flow of influence, Confusion matrices help to indicate this. Under 10-fold validation, the best results were 31.8% correctly classified instances, for a Support Vector Machine (SVM) classifier; related to some other classes, Speak & Spell fared badly, with 2/12 tracks accurately labelled (precision 0.133, recall 0.167) and confusions for example with Reproduction by the Human League and Penthouse and Pavements by Heaven 17. Setting aside concerns over the perceptual relevance of the timbral features, it is challenging to ask for all 37 albums to be well differentiated on the basis of this data set (averaging 10 songs per label). As a more reasonable test, the data was labelled by the ten groupings shown by the horizontal lines in Table 2 (keeping Speak & Spell as a class of its own), obtaining 77% accurate classifications with an SVM. The confusion matrix for the DM album then showed 11 out of 12 songs accurately classified, and one mislabelled as by Gary Numan.

Classification by year was also explored, despite concerns over the hard histogram boundaries; classification accuracy of 55% was obtained, confirming somewhat the closely linked artists in this set (classification by half year periods dropped to 26%). Out of interest, I also tested how well recent artist La Roux's eponymous 2009 album was differentiated from the original synth pop sources to which it might be argued to pay substantial homage; in actual fact, when offered as a sixth category in the year based analysis 9/12 tracks were correctly identified; closely similar tracks were mainly drawn from the same album. Whether this is best traced to female vocals, to recent production and mastering trends, is a subject for further investigation.

Any machine identified link must be followed up by human analysis before imbuing significance. It is clear in the audio content analysis that gross timbral features are the basis of comparison, not details of materials at the human perceptual timeframe. These timbral links might indicate similar equipment or studio facilities more than links of inspiration. Nonetheless, it is valuable to make a start here in applying such MIR tools, on the understanding that through intensive research efforts in computational auditory models, systems can only improve. It was clear in this project that the machine tools were utilising different criteria. For example, a similarity was observed in motifs between a section two minutes into the Fad Gadget track 'Ricky's Hand' and DM's 'Photographic' but this was not closely borne out in machine results (similarity was right in the middle of all tracks, at 165th most similar); this is probably due to the smearing effects of the average concealing that particular section.

None of the leads presented by content analysis are themselves a smoking gun of influence when date is taken into account. It is preferable to seek further corroboration of any potential influence, and the status of conscious tribute

or unconscious plagiarism will never be amenable to audio analysis methods alone. For the artists concerned, a single listen to a live gig or work in progress in the studio, obtaining a promotional copy ahead of public release, might all have provided undocumented links; this study was restricted to release dates, not recording dates. Certain off album tracks were excluded, for example songs only played at gigs ('Television' in the case of DM), or particular B sides ('Ice Machine', Shout'),<sup>9</sup> all of which might turn out to be potential connections.

## 5. CONCLUSIONS

This paper investigated the question of influences from two technological approaches, the first online information seeking, and the second content analysis over a database of relevant audio. Such a study can point to new leads that musicologists may not have immediately heard or imagined. Although there is some danger of getting back what is already known, in the main the great advantage has been the stimulus of exploring the materials from a new perspective. There may be more links between tracks in a close knit era of releases than the musicologist can comfortably track, and computer assistance certainly helps direct inquiry, prompting possibilities of connection, even as the human ear currently remains the best final judge.

Much future work remains, from further web data sourcing tools, to more developed schemes for content analysis. For the former, similarity through co-occurrence is a profitable tool, and any similarity network can be mediated through the automatic artist date database. For the latter, more developed similarity methods may compare subsections and simultaneous voices within songs, perhaps with beat or chord synchronous features. A musicologist may wish to focus on particular attributes, choosing weights for rhythmic, timbral, harmonic, melodic features and more. For different pairs of songs, links might be posited based on different parameters, and a more developed analysis system would flag up significant similarities with respect to a number of different weighting schemes. The methods investigated herein do not track the career of artists stage by stage, nor cope with any complex inter-linked developments. A solution may combine content based methods and accurate dating of releases.

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<sup>9</sup> The opening of Ice Machine bears a resemblance to elements of The Word Before Last on the Human League's Reproduction album.

Artist	Album	Original Release Date	Notes
Kraftwerk Kraftwerk Kraftwerk	Trans-Europe Express The Man Machine Computer World	May 1977 May 1978 May 1981	2009 remaster
David Bowie	Low	January 1977	Remaster 1999, Brian Eno production of synth instrumentals in particular of note
David Bowie	Heroes	October 1977	Remaster 1999, Second of Berlin trilogy; few synths
David Bowie	Lodger	May 1979	Remaster 1999, very few synths, last of Eno/Bowie collaboration
Devo	The Essentials: Devo	1978-1981	Singles from 2002 collection
Giorgio Moroder Donna Summer	From Here to Eternity selected tracks	July 1977 1977-1979	Lays down a template for electronic dance music Giorgio Moroder/Pete Bellotte production with prominent synth instrumentation, from The Dance Collection (1987), Once Upon a Time (1977) and Bad Girls (1979), including the single I Feel Love (1977)
Sparks	No. 1 in Heaven	September 1979	Giorgio Moroder produced
Human League Human League Human League	Reproduction Travelogue Dare!	October 1979 May 1980 20 October 1981	remaster 2003 remaster 2003 Martin Rushent produced, after split in original Human League line-up
Heaven 17 Cabaret Voltaire	Penthouse and Pavement The Original Sound of Sheffield '78/'82. Best Of;	September 1981 1978-1981	Some members of original Human League 2002 remaster
Ultravox Ultravox Ultravox Ultravox Ultravox John Foxx John Foxx	Ultravox! Ha!Ha!Ha! Systems of Romance Vienna Rage in Eden Metamatic The Garden	25 February 1977 14 October 1977 8 September 1978 11 July 1980 7 September 1981 17 January 1980 25 September 1981	more guitar band at the earlier stages synthesizer creeping in Conny Plank producer, last with John Foxx Conny Plank producer Conny Plank producer
Yellow Magic Orchestra Yellow Magic Orchestra Visage Buggles	Yellow Magic Orchestra Solid State Survivor Visage The Age of Plastic	25 November 1978 25 September 1979 November 1980 Jan 1980	even includes 8 bit computer game music more pioneering Japanese synth pop Containing 'Fade to Grey' Containing 'Video Killed the Radio Star'
Orchestral Manoeuvres in the Dark (OMD) OMD OMD	eponymous debut Organisation Architecture and Morality	22 February 1980 24 October 1980 8 November 1981	2003 remaster 2003 remaster 2003 remaster
Gary Numan and Tubeway Army Gary Numan Gary Numan Gary Numan	Replicas The Pleasure Principle Telekon Dance	April 1979 September 1979 5 September 1980 September 1981	Numan grabs the pop centre ground  Chart impact wanes
Silicon Teens Fad Gadget Fad Gadget	Music for Parties Fireside Favourites The Best Of Fad Gadget	1 September 1980 1 September 1980 1980-1981	Daniel Miller's prototype synth pop group  tracks up to 1981
Depeche Mode	Speak & Spell	October 5 1981 (first single Feb 20, 1981)	2006 remaster

Table 2. Table of recordings under comparison

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