Which ITG Stepcharts are Turniest?

Ben Blum

bblum@cs.cmu.edu

Abstract

ITG is a popular dance game in which players step on arrows while listening to music. The arrow patterns, indicated by a *stepchart*, may range among any level of complexity and difficulty. Among the many factors contributing to a stepchart's difficulty is how much the player must turn from side to side. Other more obvious factors, such as raw speed, have been well studied in prior work. This paper presents an analytic study of this *turniness* factor. We study the turniness of many existing stepcharts, and present a novel (but unsurprising) approach to automatically generating maximally (or minimally) turny charts. Among real-world songs, we find stepcharts with overall turniness ranging from 0% to 81.33% of the theoretical maximum.

Categories and Subject Descriptors D.D.R. [*Exercise and Fitness*]: Arcade Dance Games

Keywords in, the, groove

1. Introduction

In 2005, Roxor Games, Inc. released *In The Groove*, a dance rhythm music video arcade fitness game, in which players control a protagonist using their feet to step on floor-mounted directional indicators. The protagonist, shown in Figure 1, takes the form of any number of arrow-shaped directional receptacles, and must navigate a world of similarly-shaped obstacles (henceforth "arrows") by consuming them with the appropriate receptacle. Roxor Games, Inc. In The Groove (henceforth "ITG") is most commonly played using the "cabinet" form factor, shown in Figure 2, which includes two large metal dance pads, each with four directional indicators (henceforth, also, "arrows").

The game includes a library of rhythmic audio accompaniment files (henceforth, "songs"), each of which

Figure 1. ITG gameplay, including score indicator (top), protagonist avatar (mid), directional obstacles (low), and step judgement, life bar, and combo indicator (figure these out for yourself, I'm getting tired).

Figure 2. An ITG cab. RIP in peace, Roxor (Konami 2005).

is associated with one or more fixed patterns of arrows (henceforth, "stepcharts"). These charts are often, but not always, synchronized to the beat of the song. During gameplay, the stepcharts appear on screen and scroll towards the protagonist avatar at a rate either fixed or variable (henceforth, "BPM"). When the position of an arrow in the chart coincides with the avatar, the player must actuate the arrow of the corresponding direction. The game will judge the player's timing accuracy, and penalize or reward them accordingly with scores and life bar fill. A "Fantastic" judgement (as in Figure 1) indicates a timing error not exceeding 15 milliseconds. Other judgements include Excellent, Great, Decent, Way Off, and Miss. As a visual assist to the player, notes are coloured according to their beat granularity: ♩, ♩³, ♪, ♪³, 𝅘𝅥𝅯, 𝅘𝅥𝅯³, 𝅘𝅥𝅰.

SIGBOVIK '16 Pittsburgh, PA, USA

ACH ...$15.00

Figure 3. ITG can be played "Bar" or "No-Bar". Bar players must wear sandals (like an idiot; who is that guy anyway?), while No-Barrers must always play on the right.

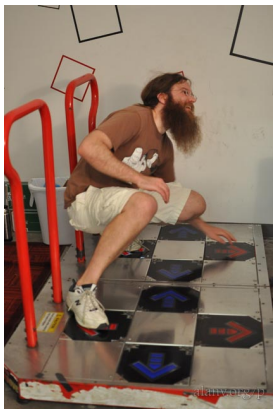


Figure 4. Doubles play is beyond the scope of our work. It requires (or perhaps produces?) a magnificent beard.

The game may be played in several modes, the most common supporting up to two (2) players, each operating their own protagonist using either the left or right set of four arrows. This game mode may be played with or without the assist of a curved metal rod mounted behind the arrows (henceforth, "bar"), as shown in Figure 3. In other game modes, a single player may operate up to all 8 of the arrows. When all 8 are used, the game mode is known as "Doubles", as shown in Figure 4, and is often associated with excessive No-Barring, use of hands and knees to operate the arrows, and impressive facial hair. In this body of work, we will focus exclusively on the Singles game mode, in which each player controls four arrows: one Up (U), one Down (D), one Left (L), and one Right (R). Without loss of generality, we further assume that only one player plays at a time, using exactly two feet at a time, and that she will shower immediately afterward.

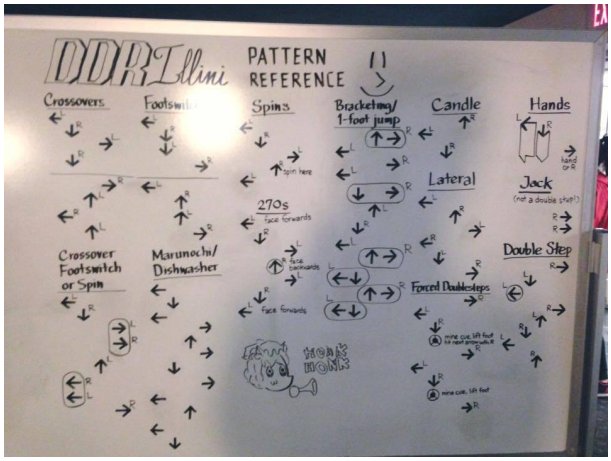


Figure 5. Common patterns (Akgul 2015). Honk honk!

2. Properties of Stepcharts

Being a game, one might assume that players find it fun to step the arrows in the indicated patterns, as opposed to, for example, stepping them in random unrelated patterns, or stepping off the pad entirely to go play Rocket League (Psyonix 2015). Accordingly, step authors take care to produce stepcharts with interesting patterns. Typically, players step the arrows alternatingly with either foot. Step authors can either reinforce this tendency, by maintaining that left and right arrow targets always receive arrows of different (even or odd) sequential parity; or subvert it, forcing the player to step on the left arrow with their right foot (or v.v.). The former pattern is called a *stream*, and the latter pattern a *crossover*. Crossovers are loved by some players (Figure 3, left), and hated by others (Figure 3, right).

Figure 5 shows many common step patterns. Among these, note especially the *lateral* ($LURLDR$), in which the player briefly faces backwards (left foot on R and right foot on L), and the *spin* ($LURDLU$), in which, yeah, you get the picture.

2.1 Difficulty

Stepcharts are rated in difficulty on a scale from 1 to 20 "feet" (hurtpiggypig 2013)[1]. To date, difficulty is judged by a human (typically the step author), and primarily reflects factors such as burstiness (*footspeed*), prolongedness of streams (*stamina*), and complexity of jumps, holds, and crossovers (*technical*). These measures of difficulty have been well-studied in prior works (Zetorux and WinDEU 2008; Konkul 2014; thattagen 2014). Some players are really good at In The Groove.

[1] Other dance games, which shall remain unnamed, but whose initials are (Konami 2005), feature wimpier stepcharts rated only up to 10. As ITG players got better, they left those charts in the dust and began creating their own charts to challenge themselves with ridiculous difficulties. This paper's author plays ITG at the 13-14 level.

2.2 Facing

Regardless of the presence of crossovers, all step patterns will keep the player *facing* one way or another, and most include sequences that will change the player's facing back and forth. For example, when the player stands with left foot on L and right foot on U, they are facing up-left, or UL. Standing on D and R also produces the same UL facing, unless the player is crossed-over (left foot on R), in which case the facing is DL. Table 1 shows all possibilities of facing using two feet on four arrows. We exclude the possibility for both feet to be instantaneously on the same arrow (called a "footswitch"), leaving this pattern to future work.

		Right foot			
		←	↓	↑	→
Left foot	←	-	UR	UL	U
	↓	DL^*	-	L	UL
	↑	DR^*	R	-	UR
	→	$D\dagger$	DR^*	DL^*	-

Table 1. Facing directions. "Crossover" facings are marked (*), and the "lateral" facing is marked (†). Note the appealing diagonal symmetry.

2.3 Turning

A stepchart contains a *turn* when a sequence of steps changes the player's facing.

Definition 1 (Turniness)**.** *The turniness $\mathcal{T}$ of a single step is the angular distance (measured in increments of $\pi/4$) which that step changes the facing compared to the facing from the previous two steps.*

The turniness $\mathcal{T}$ of a stream is the average of each step's turniness (excluding the first two for which it is undefined).

Because only one foot may change at a time, it is easy to see that the maximum turniness of a single step is 2. These steps always involve one foot moving entirely across the middle of the pad (from U to D, from L to R, etc). By tradition, these are called *candle steps*, according to the imagery that if a candle were placed in the middle of the 4 arrows, this step would knock it over. I don't know why it couldn't be called a beer step instead, though.

Turning is exhausting. Consider the three stream patterns shown in Figure 6. In the leftmost stream, the player must barely move her feet at all, never changing facing from U. In the middle stream, the player faces largely UR, with brief U and R facings ($\mathcal{T} = 1$) as she moves between the L/D and U/R arrows. Both of these streams are very easy to step without becoming fatigued. However, the rightmost stream features many candle steps (or beer steps), changing facing from UR to UL and back in the span of a single measure. ITG players hate this (Fouhey and Maturana 2013)! However, note that even

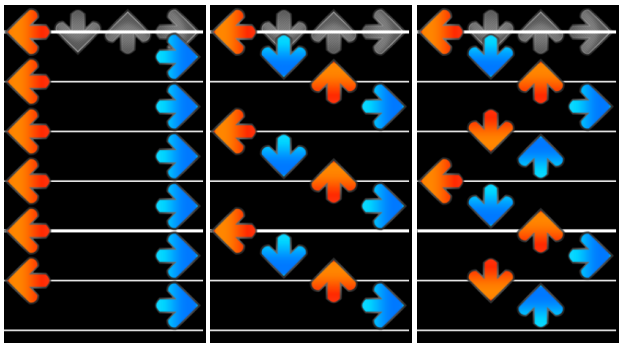


Figure 6. Three streams of differing turniness. Note how the color-coding of the notes by beat aids to discern turniness at a glance: the right foot is always on blue, and it moves among 1, 2, or 3 different arrows respectively.

in this stream, not *all* of the steps have $\mathcal{T} = 2$: the *average* turniness of this stream is only 4/3.

We are interested in the following questions:

1. What is the turniest possible stepchart?
2. How is maximum turniness affected by various constraints to contain no crossovers/laterals/etc?
3. How turny are real-world ITG charts?

3. Chart Synthesis

We developed a program for exploring all possible step patterns using a little-known yet powerful computational technique (Apostol 2012; Curtin 2005). This program computes the average turniness of every such pattern. However, while some players enjoy any step pattern including spins (Vangpat 2015), other players may prefer only crossovers and laterals in their charts, while still others prefer charts completely vanilla. Hence, our program is further capable of filtering patterns by 5 predicates:

- All patterns allowed
- No spins
- No 270s
- No laterals
- No crossovers (vanilla)

Note that each predicate captures a strict subset of step patterns compared to the one above it (a lateral is a crossover, and so forth). These predicates are implemented as shown in Figure 7.

Deciding on how long of step sequences we should search for is a tradeoff between accuracy, in judging turniness in small fractions, and (drumroll...) exponential explosion. To strike a balance we decided to experimentally measure turniness at a granularity of 1/8th, which requires searching for step sequences of length 18 (twice the denominator, plus 2 for the first 2 steps whose turniness

$$
\begin{aligned}
\text{is\_xover}(\phi) &= \phi \equiv DL \vee \phi \equiv DR \\
\text{is\_lat}(\phi) &= \phi \equiv D \\
\text{is\_270}(\phi, \phi_1, \phi_2) &= (\phi \equiv DR \wedge (\phi_1 \equiv DL \vee (\phi_1 \equiv D \wedge \phi_2 \equiv DL))) \vee \\
&\quad (\phi \equiv DL \wedge (\phi_1 \equiv DR \vee (\phi_1 \equiv D \wedge \phi_2 \equiv DR))) \\
\text{is\_spin}(\phi, \phi_1, \phi_2, \phi_3) &= (\phi \equiv R \vee \phi \equiv UR \vee \phi \equiv L \vee \phi \equiv UL) \wedge \text{is\_270}(\phi_1, \phi_2, \phi_3)
\end{aligned}
$$

Figure 7. Formal definitions of crossovers, laterals, 270s, and spins. Each predicate takes as arguments the current facing ϕ, and up to the three most recent previous facings, ϕ_1, ϕ_2, ϕ_3.

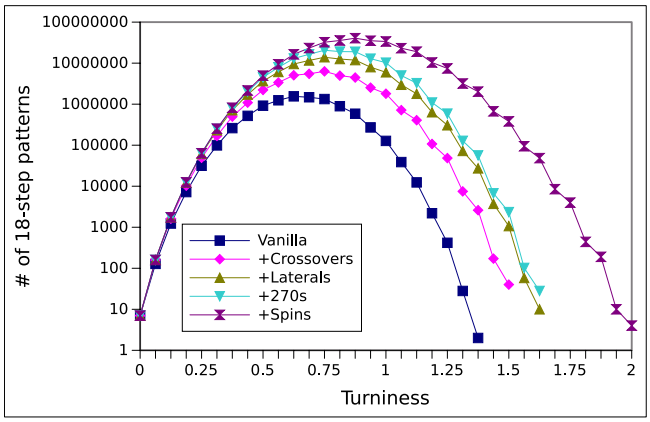


Figure 8. Distribution of unique step sequences among turninesses, classified by what types of step patterns are allowed in the chart.

is undefined). Also, our program WLOG restricts streams to always start on the left foot, and never to start crossed over. Figure 8 shows our results. The highest data point clocks in at 40,609,780: there are over 40 million unique 18-step sequences, any patterns allowed, that have turniness 0.875.

We see that, with one exception, allowing each new type of step pattern increases the maximum possible turniness of the chart. The exception is that 270s do not allow for any additional turniness over laterals, although they do allow for *more possible ways* to achieve maximum turniness. Despite no additional turniness, this is crucial information for stepchart authors, as ITG players will (usually) get bored of any chart that simply repeats the same pattern over and over.

Maximum turniness! Now to the paper's titular question: what step sequences underlie those data points on the far right of each curve? Though it would be tedious to transcribe them all into Stepmania's step editor (StepMania 5.0 2016), we manually inspected many of them to select the most representative and/or photogenic ones from each category. We show these sequences in Figure 9. These visualizations allow us to manually compute the true turniness of each sequence, imagining the core sequence repeated ad infinitum, freeing ourselves from the 1/8th granularity imposed by our experimental setup. We find that the turniest crossovers have $\mathscr{T} = 3/2$ and that the turniest laterals have $\mathscr{T} = 8/5$.

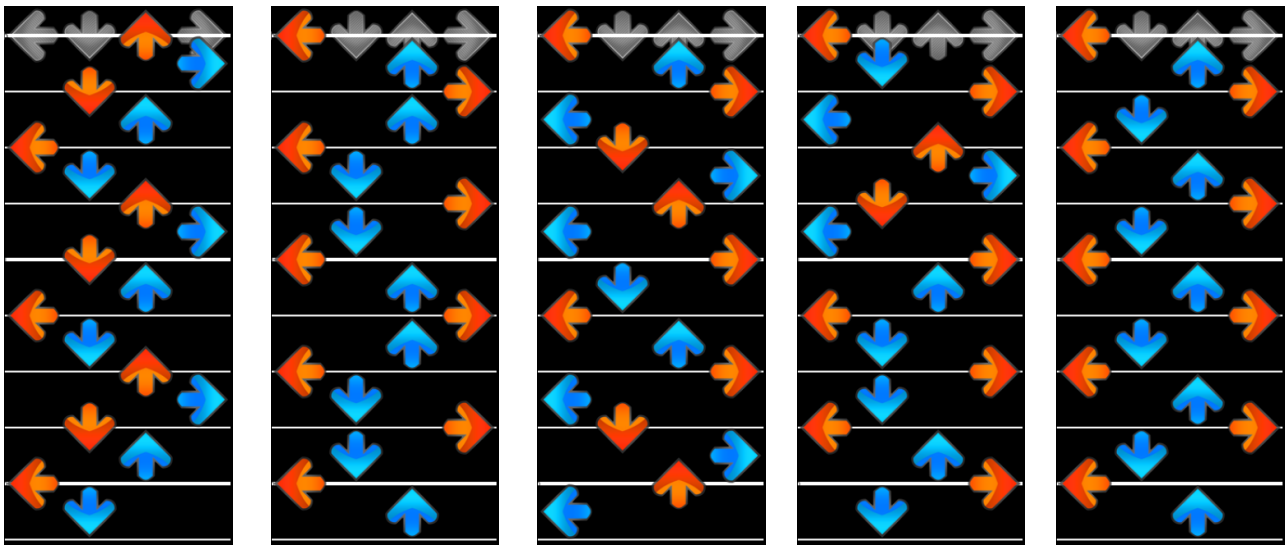
The case of 270s is irregular: we found no 18-step sequence turnier than the turniest laterals, and most notably, none of the sequences included a 270 step in the *middle* of the stream. Figure 9(d) shows a stream with crossovers and laterals and no 270 step until the very last one. To see why, imagine yourself on the pad here: the only possible 19th step that doesn't result in a spin is to step back on the same arrow your left foot is already on. That step has $\mathscr{T} = 0$, which would undo any potential turniness gained from going into the 270. Nevertheless, 270s retain some real-world application, as demonstrated by (Foy and ☺ 2004) which similarly employs a 270 as the very last step.

Perhaps predictably, pure spins make for the turniest possible chart. There are only two possible ways to candle every step; one's name is "clockwise", and you can guess the other.

Minimum turniness. Each of the 5 categories shares the same data point at $\mathscr{T} = 0$: there are 7 possible streams that never turn at all. These are the 7 "tower" patterns $LRLR$, $LULU$, $LDLD$, $URUR$, $DRDR$, $UDUD$, and $DUDU$. We already showed the first of these in Figure 6, left. For further treatment of minimally turny charts, we refer the reader to (WinDEU and Ashura 2009).

4. Existing Chart Analysis

Of course, composing a stepchart of nothing but the theoretically-turniest patterns would be extremely tiresome (in more ways than one). We turn our attention to existing ITG charts which were developed prior to this study, to investigate how much ITG players turn in the real world. We processed every stepchart in our collection, which includes 70+ song packs. Most well-known pack series from the ITG community are included, such as *Cirque*, *ITG*, *Mute Sims*, *Pendulum*, *r21**, *SPEEDCOOOORE*, *Tachyon*, *The Legend of Zim*, *Valex's Magical 4-Arrow Adventure*, and *Oh Henry! Mad Stamina: Streamy · Brutal · Stamina Bar in Milk Chocolate*.



(a) Vanilla, $\mathscr{T} = 4/3$. (b) Crossovers, $\mathscr{T} = 3/2$. (c) Laterals, $\mathscr{T} = 8/5$. (d) 270s (irregular). (e) Spins, $\mathscr{T} = 2$.

Figure 9. The turniest possible stepcharts.

Limitations. Real-world stepcharts include many patterns not accounted for in our analysis. We did not expect much trouble from jumps and jacks, opting simply to ignore them and count the turns among the surrounding single-steps. Footswitches and doublesteps, however, can foil this strategy, as our analysis will inadvertently begin stepping with feet inverted from where they should be. Merely getting turned around is not a problem (computers don't have eyes), but the act of turning around involves some candle-steps, which could cause a footswitch-heavy chart to seem very spinny even though the proper footing would never make the player cross over at all. Coping with these limitations is beyond the scope of our work, although we will highlight some experimental false-positives later.

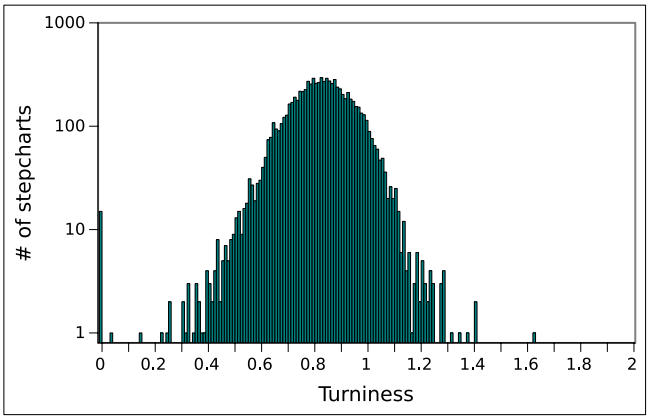


Figure 10. Distribution of turniness among 8,278 existing ITG charts.

4.1 Results

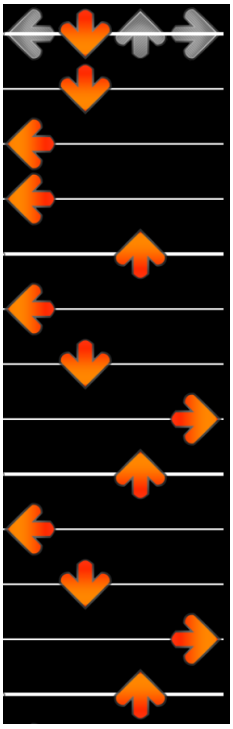
As shown in Figure 10, the vast majority of real-world stepcharts have average turniness between 0.6 and 1.0. We don't really care about those.

The Turniest Charts. No joker has yet dared to make the turniest possible chart (all spins), but one chart comes close. Standing alone as the only chart turnier than 1.5 is the Easy 3 for *DO ME* (Konami DDR 4thMIX PLUS), which is mostly spins punctuated by a few breaks, as shown in Figure 11(a). (Vangpat 2015) loves this chart.

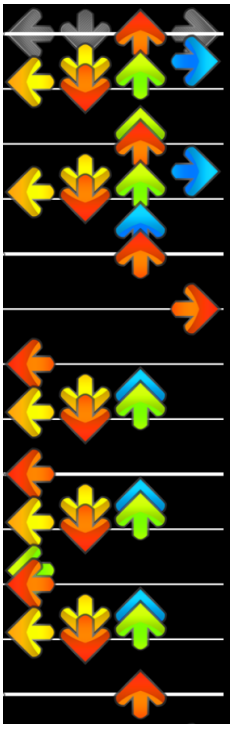
Actually, 20 of the 30 turniest charts are all from DDR packs, most of which are Easies. Although DDR charts are known for being fairly crossovery in the upper ranges of difficulty, a close inspection of the easier charts will show that very little care was put in while writing them to avoid excessive double-stepping. It's no wonder new ITG players, who used to play DDR, always double-step even when they don't need to. Sheesh, Konami.

Beyond these extreme examples, we are interested in some more normal charts people might actually like to play. Table 2 shows the turniest charts of each level, for the most popular difficulty levels ranging from 7 to 17. So, next time you want to work on your laterals or candles, you have me to thank!

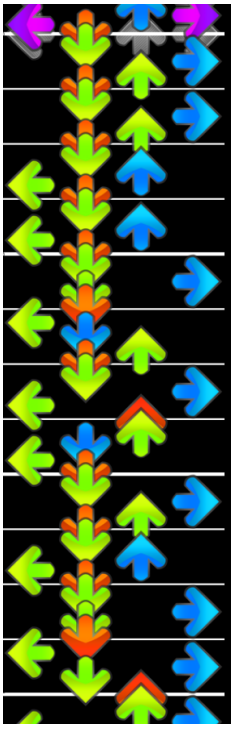
Surprisingly, *BRILLIANT 2U (Orchestra-Groove)* (Konami DDR 2ndMIX) is full of 270s. I didn't think anybody ever put those in real charts. Finally, an honourable mention goes to *Oedo Hop* (sssmsm and Palpable 2007), the 2nd turniest 7 (and 4th turniest chart overall!) with $\mathscr{T} = 1.384$. (Hanneman 2010) really likes that one so we had to mention it.



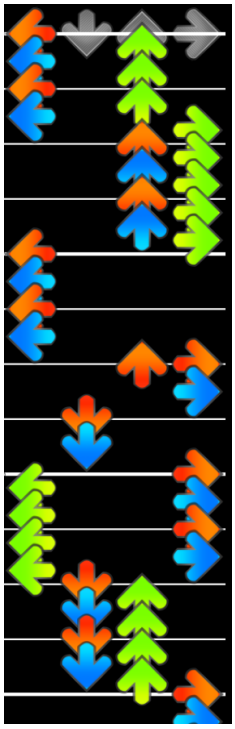
(a) *DO ME*, $\mathcal{T} = 1.63$. Proportion of non-spinny section enlarged to show detail.



(b) *Mr. Saxobeat*, $\mathcal{T} = 1.04$. Look at all those candles! No wonder it was so hard for us to pass this one.



(c) *Flames of the Sky*, $\mathcal{T} = 1.04$. False-positive $\mathcal{T}$ from footswitches. Actually faces $R/UR/U/UL/L$ the whole time.



(d) *Sick Dubstep Track*, $\mathcal{T} = 0.26$. The least turny non-trivial non-beginner chart.

Figure 11. Real-world ITG charts of varying degrees of turniness.

Ft.	Name	Pack	$\mathcal{T}$
7	TRIP MACHINE	DDR 1st	1.407
8	BRILLIANT 2U (O-G)	DDR 2ndMIX	1.347
9	Hearts of Ice	In The Groove 3	1.127
10	Visible Noise	In The Groove 2	1.188
11	KKKKK Come On	r2112	1.145
12	Winnipeg is Fucking Over	best of r21freak ii	1.150
13	Mr. Saxobeat (*)	Sexuality Violation 2	1.044
14	Fancy Footwork (†)	Cirque du Zeppelin	1.026
15	Flames of the Sky (*,†)	Ft. Rapids VII	1.037
16	*(no 16 with $\mathcal{T} \geq 1$)*	-	-
17	Superluminal	Ft. Rapids VII	1.058
18	*(no 18s+ with $\mathcal{T} \geq 1$)*	-	-

Table 2. The turniest existing stepcharts of each difficulty. Songs marked (*) are also shown in Figure 11. Songs marked (†) are false-positives resulting from too many footswitches incorrectly analyzed as spins.

Ft.	Name	Pack	$\mathcal{T}$
7	King Kong	In The Groove 3	0.354
8	Jam Jam Reggae	DDR 2ndMIX	0.428
9	Fantasia	In The Groove 3	0.382
10	Oosanbashi	TLOES Chapter 1	0.534
11	Release the Music	Ft. Rapids VII	0.507
12	Payon (Theme Of)	CuoReNeRo MeGaPacK	0.396
13	Technodildo	The Legend of Zim 5	0.436
14	Gentleman	TLOES Chapter 1	0.556
15	ΔMAX	Tachyon Alpha	0.000
16	Dash Hopes 2	Tachyon Alpha	0.327
17	Resist	SPEEDCOOOORE	0.592
18	Baby	Sexuality Violation 2	0.524
19	Pedal to the Metal	SPEEDCOOOORE	0.468

Table 3. The least turny existing stepcharts of each difficulty (trivial charts excluded).

The Least Turny Charts. 16 charts in our collection have $\mathcal{T} = 0$. Most of these are beginner charts, rated 2 or 3 feet and with no more than 100 steps. ΔMAX (WinDEU and Ashura 2009) stands out, as a 15-footer with 945 steps. God is that chart ever annoying.

Ignoring all beginner-difficulty and turn-free charts, the least turny stepchart is *Sick Dubstep Track* (mute and Gotobed 2011), a 4-measure joke rated 6,482 feet, the majority of which is shown in Figure 11(d). It has $\mathcal{T} = 0.263$.

For readers who prefer more to tower than to turn, we similarly tabulated the least turny charts of each common difficulty in Table 3.

Song Pack	# of Charts	Avg. $\mathscr{T}$
Valex's Magical 4-Arrow Adventure 5	150	0.964
Valex's Magical 4-Arrow Adventure 4	170	0.956
Valex's Magical 4-Arrow Adventure 3	155	0.950
Valex's Magical 4-Arrow Adventure 7	150	0.937
Valex's Magical 4-Arrow Adventure 2	130	0.929
Valex's Magical 4-Arrow Adventure	95	0.919
Valex's Magical 4-Arrow Adventure 6	145	0.917
Subluminal	16	0.906
The Legend of Zim 1	26	0.906
FoxyMix 5	30	0.901
FoxyMix 4 - Nuclear Overdrive	68	0.899
Mute Sims 9	48	0.886
In The Groove Rebirth +	147	0.881
StepMania 5	5	0.869
Cirque du Zeppelin	109	0.867
In The Groove 3	448	0.858
...		
Piece of Cake 5	20	0.785
Cirque du Veyron	30	0.777
Stephcharts and Richarts	81	0.770
Tachyon Delta	32	0.769
Tachyon Alpha	151	0.769
Sexuality Violation 2	219	0.766
TLOES Chapter 1	120	0.765
Fort Rapids V (12s-16s) r3 Final	98	0.759
Noisiastreamz	20	0.758
In The Groove	331	0.754
Pendulum	150	0.747
SPEEDCOOOORE 2	70	0.731
SPEEDCOOOORE	47	0.709
The Legend of Zim 3	40	0.702
The Legend of Zim 4	44	0.701
The Legend of Zim 5	19	0.667

Table 4. The turniest and least turny stepfile packs. Wow, great job Valex! Zim had a good thing going but has been slacking off recently.

Step Artist	# of Charts	Avg. $\mathscr{T}$
M. Emirzian	38	0.992
sssmsm	50	0.945
J.Berkowitz (Valex)	1025	0.939
B. Dinh	10	0.919
J. DeGarmo	26	0.906
J. Frederick	176	0.881
Fraxtil	23	0.880
M. Calfin	26	0.880
X. Ythar	24	0.879
R. Woods	22	0.874
R. McKanna	76	0.872
MIDI	86	0.870
Dark Luke	36	0.866
@@	60	0.859
D. Bernardone	354	0.858
D. D'Amato	154	0.857
...		
M. Simmons	334	0.787
Revolver	25	0.775
R. Konkul (Rynker)	125	0.774
K. Ward (☺)	600	0.773
Freyja	89	0.766
P. Mason	14	0.765
M. Puls	167	0.759
P. Shanklin	37	0.756
I. Pyles	177	0.754
Gazebo	377	0.754
zimlord	217	0.747
C. Foy	205	0.739
B. Abear	29	0.733
Blazing	21	0.729
Mootz	29	0.715
Insane Steve	49	0.714

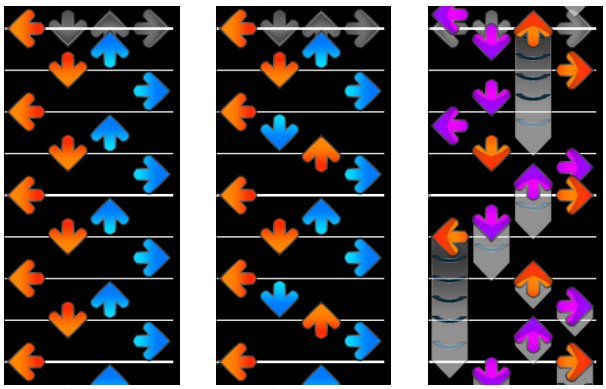
Table 5. The turniest and least turny step authors. Only authors with 10 or more charts are included.

The Turniest Other Things. Although our analysis picked out a good many turny charts, any ITG player will inevitably get tired of playing the same ones over and over. Hence, we are also interested in an aggregated turniness profile to show the average scores of many different stepcharts at once. We computed average turninesses for stepcharts grouped *by pack* and *by step artist*. Abbreviated results for the former are shown in Table 4 and for the latter in Table 5. For the sake of players who dislike turniness, we also list the lowest-scoring packs and artists in addition to the highest-scoring ones.

5. Future Work

Jumps. The most obvious next step for this work is to account for jumps. This seems quite easy: compute the two possible facings of the jump, depending which foot lands on which arrow, and use whichever facing produces the least turniness when compared to the previous and next steps in the sequence. Honestly, we should have implemented that for this paper, but we only realized how it should work after we finished computing our dataset; and owing to an inferior conference's deadline coming up in 10 days, we don't have time for re-running experiments (Anonymized 2016).

Footswitches. More difficult is the matter of deciding whether stepping the same arrow twice in a row constitutes a jack (same foot) or a footswitch. As we saw in Figure 11, our current approach of assuming it's always a jack can lead to some false-positive $\mathscr{T}$ values. Judging the presence of footswitches is a nontrivial problem even for human intuition, so we view this as an exciting area for future research. So as not to piss off the player, most stepcharts tend to feature only jacks or only switches, never both. Future extensions of our algorithm could exploit this convention to decide with high confidence whether or not an entire chart is footswitchy.



(a) Bracketable. (b) Forced turns. (c) Roll-stream.

Figure 12. Future work.

Fractional Turns. Experienced ITG players do not step with their feet on the middle of each arrow; rather, they try to step on the edges and "brackets" between arrows, hitting each step with heel or toes only to minimize the distance their feet must move. This tendency distinguishes further granularity of turning than what we identify in this work. Consider the two streams shown in Figure 12 (a) and (b). Although they measure the same $\mathcal{T}$ value of 1, (b) is considerably more exhausting to step, as (a) allows the player to bracket the entire run. Future work could handle this by counting a 1-turn step as the full value only if the player subsequently continues turning farther in the same direction (which would force the player's feet off the brackets), and otherwise assign $0 < \mathcal{T} < 1$ for such a step.

Holds and Rolls. Many charts use holds or rolls to force the player to step all concurrent tap-steps with the other foot, which breaks our alternating-feet assumption. When multiple steps are concurrent with a hold, they must be double-stepped, and the facing for each computed using the hold's arrow rather than the most recent one. When multiple steps are concurrent with a roll, the facings are determined similarly, but repeatedly stepping the roll results in a stream, as shown in Figure 12(c) (MIDI and Basshunter 2007). Judging how hold-steps and roll-streams must be stepped is another exciting opportunity for future work.

6. Conclusion

Our analysis program can be found at `https://github.com/bblum/sigbovik/tree/master/itg/code`, and our full experimental dataset is available at `http://tinyurl.com/turniness`.

The value of this work is already abundantly clear, as through it, the author has found several new charts he is interested to play. We hope our published dataset can provide similar value to other ITG players worldwide. Please accept our paper. We worked hard on it.

A. Most turny patterns

A.1 Vanilla

Following are the most turny 18-step patterns that are totally vanilla, with $\mathcal{T} = 1.375$. (Manual inspection reveals the true turniness to be 4/3.)

URDULDURDULDURDULD DRUDLUDRUDLUDRUDLU

A.2 Crossovers

Following are the most turny 18-step patterns that may include crossovers only, with $\mathcal{T} = 1.5$.

URDULDURDLDRULURDL URDULDRDLUDRULURDL
URDULDRDLURULDURDL URDULDRDLURULDRDLU
URDLDRUDLUDRULURDL URDLDRUDLURULDURDL
URDLDRUDLURULDRDLU URDLDRULURDULDURDL
URDLDRULURDULDRDLU URDLDRULURDLDRUDLU
URDLDRULURDLDRULUR URDLDRULURDLDRURDL
URDLDRULURDRULURDL URDLDRURDLDRULURDL
URDRULURDLDRULURDL DRUDLUDRULURDLDRUL
DRUDLURULDURDLDRUL DRUDLURULDRDLUDRUL
DRUDLURULDRDLURULD DRULURDULDURDLDRUL
DRULURDULDRDLUDRUL DRULURDULDRDLURULD
DRULURDLDRUDLUDRUL DRULURDLDRUDLURULD
DRULURDLDRULURDULD DRULURDLDRULURDLDR
DRULURDLDRULURDRUL DRULURDLDRURDLDRUL
DRULURDRULURDLDRUL DRURDLDRULURDLDRUL
LUDRULURDLDRULURDL LURULDURDLDRULURDL
LURULDRDLUDRULURDL LURULDRDLURULDURDL
LURULDRDLURULDRDLU LDURDLDRULURDLDRUL
LDRDLUDRULURDLDRUL LDRDLURULDURDLDRUL
LDRDLURULDRDLUDRUL LDRDLURULDRDLURULD

A.3 Laterals

Following are the most turny 18-step patterns that may include crossovers and laterals, with $\mathcal{T} = 1.625$. (Manual inspection reveals the true turniness to be 8/5.)

URDLDRULRDLURLDRUL URDLRULDRDLURLDRUL
URDLRULDRLURDLDRUL URDLRULDRLURDLRULD
DRULURDLRULDRLURDL DRULRDLURULDRLURDL
DRULRDLURLDRULURDL DRULRDLURLDRULRDLU
LURLDRULRDLURLDRUL LDRLURDLRULDRLURDL

A.4 270s

Following are the most turny 18-step patterns that may include crossovers, laterals, and 270s, with $\mathcal{T} = 1.625$. (Manual inspection reveals irregularity; these streams exhibit no core pattern that can be repeated to retain the maximum turniness.)

URDULDRLURDLRULDRU URDLDRULURDLRULDRU
URDLDRULRDLURULDRU URDLDRULRDLURLDRUL
URDLRULDURDLRULDRU URDLRULDRDLURULDRU
URDLRULDRDLURLDRUL URDLRULDRLURDULDRU
URDLRULDRLURDLDRUL URDLRULDRLURDLRULD
DRUDLURLDRULRDLURD DRULURDLDRULRDLURD
DRULURDLRULDRDLURD DRULURDLRULDRLURDL

DRULRDLUDRULRDLURD DRULRDLURULDRDLURD
DRULRDLURULDRLURDL DRULRDLURLDRUDLURD
DRULRDLURLDRULURDL DRULRDLURLDRULRDLU
LURULDRLURDLRULDRU LURLDRULURDLRULDRU
LURLDRULRDLURULDRU LURLDRULRDLURLDRUL
LDRDLURLDRULRDLURD LDRLURDLDRULRDLURD
LDRLURDLRULDRDLURD LDRLURDLRULDRLURDL

A.5 Spins

Following are the most turny 18-step patterns that may include any pattern, with $\mathscr{T} = 2$.
URDLURDLURDLURDLUR DRULDRULDRULDRULDR
LURDLURDLURDLURDLU LDRULDRULDRULDRULD

B. Related Work...?

Figure 13. We employ the techniques of (Hanneman 2010) for ITG machine translation (Karakos et al. 2008; Goto et al. 2013).

References

S. E. Akgul. This is how we DO in DDRillini. In *DDR + ITG Players Facebook Group*, pages You want page numbers, bibtex? It's a photo of a whiteboard from Facebook. Get it together., 2015.

K. Apostol. *Brute-force Attack*. SaluPress, 2012. ISBN 613627454X, 9786136274546.

M. Curtin. *Brute Force: Cracking the Data Encryption Standard*. Springer-Verlag New York, Inc., Secaucus, NJ, USA, 2005. ISBN 0387201092.

A. for Double-Blind Submission. Ode to reviewer two. SIGBOVIK 10 (that's decimal, not binary), 2016.

D. F. Fouhey and D. Maturana. Find a separating hyperplane with this one weird kernel trick! Proceedings of the 7 th ACH SIGBOVIK Special Interest Group on Harry Quechua Bovik, 2013.

C. Foy and K. W. ☺. Utopia. In The Groove 1, 2004. Challenge 11.

I. Goto, M. Utiyama, and E. Sumita. Post-ordering by parsing with ITG for Japanese-English statistical machine translation. 12(4):17:1–17:22, Oct. 2013. ISSN 1530-0226. doi: 10.1145/2518100. URL `http://doi.acm.org/10.1145/2518100`.

G. Hanneman. DeltaX: A new paradigm for machine translation. A Record of The Proceedings of SIGBOVIK 2010, 2010.

L. hurtpiggypig. Simply love. Simply Love is a custom theme designed for Stepmania 3.95 or ITG arcade machines., 2013.

D. Karakos, J. Eisner, S. Khudanpur, and M. Dreyer. Machine translation system combination using ITG-based alignments. In *Proceedings of the 46th Annual Meeting of the Association for Computational Linguistics on Human Language Technologies: Short Papers*, HLT-Short '08, pages 81–84, Stroudsburg, PA, USA, 2008. Association for Computational Linguistics. URL `http://dl.acm.org/citation.cfm?id=1557690.1557712`.

Konami. Konami Corporation v. Roxor Games, Inc., Mad Catz, Inc., and Redoctane. United States District Court for the Eastern District of Texas, 2005.

Konami. Brilliant 2U (orchestra-groove). DDR 2ndMIX. Challenge 8.

Konami. Do me (H.I.G.E.O. mix). DDR 4thMIX PLUS. Easy 3.

R. Konkul. Rynker - call of the hound (tachyon epsilon 20) 88.21. `https://www.youtube.com/watch?v=6yB5WmIBZPk`, 2014.

MIDI and Basshunter. Boten anna. In The Groove Rebirth +, 2007. Challenge 11.

mute and C. Gotobed. Sick dubstep track. Mute Sims 7, 2011. Challenge 6482.

Psyonix. Rocket league. Video game, 2015.

sssmsm and Palpable. Oedo hop. r2112, 2007. Medium 7.

StepMania 5.0. `http://www.stepmania.com/`, 2016.

thattagen. [ddr] canblaster - "dawgs in da house" stupid doubles chart (10). `https://www.youtube.com/watch?v=CZlB16BroPg`, 2014.

A. Vangpat. `http://photos2.alanv.org/`, 2015.

WinDEU and D. Ashura. ΔMAX. Tachyon Alpha, 2009. Challenge 15.

Zetorux and WinDEU. Team dragonforce. `https://www.youtube.com/watch?v=uSfx5Zdgyfc`, 2008.