Akan ATR harmony in serial harmony: No direction-specific blocking effect*

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Lee, Minkyung. 2013. Akan ATR harmony in serial harmony: No direction-specific blocking effect. *Studies in Phonetics, Phonology and Morphology* 19.2. 295-315. Vowel harmony (VH) as assimilation through feature spreading is not parallel but serial in Harmonic Serialism (HS), a derivational OT model. In HS, harmonic feature propagation is iterative via the multiple passes of Gen and Eval loop, thus VH in HS guarantees serial harmony (SH). [ATR] harmony in Akan is controlled by the [ATR] value of a root vowel. If a root vowel is [+ATR], all the vowels from a root to affixes agree in [+ATR], otherwise the default [-ATR] takes place, instead. In an HS derivation, harmony-inducing constraint Share-Domain causes root-internal VH while Share-Juncture incurs root-outward VH. At a juncture, feature spreading operates in different path of derivation, i.e., unidirectional in each path, thus it is further split off to suffix and prefix given Akan morphology in which a prefix is added to the stem with a suffixed root. Furthermore, low vowel varies in its behavior; /a/ undergoes [ATR] harmony before [+ATR] while it is opaque after [+ATR] with no its [ATR] agreement. [ATR] harmony in low vowel is not attributed to feature spreading, rather to feature licensing and top-ranked grounding constraints. In essence, direction-specific blocking effect and bidirectionality that Align in parallel OT reveals are not supportive in HS. **(Daegu University)**

Keywords: Harmonic Serialism, serial harmony, [ATR] harmony, low vowel opacity, direction-specific blocking effect, bidirectionality

1. Introduction

McCarthy's (2008a, b, 2009) derivational version of OT called Harmonic Serialism (henceforth HS) extended to autosegmental spreading provides a new insight that vowel harmony (hereafter VH) is a step-wise derivation through the multiple passes of Gen and Eval loop. VH in autosegmental phonology (Goldsmith 1976) has been described as assimilation through iterative feature spreading leftward or rightward up to the point where there is no further target segment left or there appears a blocker intervened. In parallel OT model (McCarthy and Prince 1993), however, the interaction of feature alignment and feature cooccurrence constraint is responsible for VH. The former requires either leftmost or rightmost edges of linguistic structures aligned while the latter militates against any incompatible feature combination. In a parallel OT model, feature propagation occurs at the same time and in a single step.

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In HS, feature spreading is iterative on the course of derivation until the point of convergence where the latest input to Gen is mapped into the most recent output of Eval. To put it differently, serial harmony (hereafter SH) through harmonic feature propagation continues until no further target vowel is left for spreading or an intervening blocker emerges. Each step of derivation is thus gradual and harmonically improving. This is a crucial difference of HS from previous OT models where feature spreading to the neighboring target segments occurs at once. Therefore, in HS, VH always achieves SH.

With respect to Wilson's (2003, 2004, 2006) recent arguments about the theoretic defects of alignment constraint that evaluates edge coincidence in a gradient mode, as will be discussed later in detail, McCarthy (2009: 5-6) pinpoints that long-distance Align reveals implausible prediction, i.e., all or nothing, in the sense that epenthesis with respect to nasal harmony is permitted only when the total nasal spreading is guaranteed or there exists no segment involving nasal feature.[1] Otherwise, epenthesis is entirely blocked. This is the surface-unattested case that Align in parallel OT wrongly predicts.

As briefly mentioned above, without resorting to Align in parallel OT with various typological pathologies (or also called a sour grapes property)(the terminology due to McCarthy 2009), based upon the major premises of SH in autosegmental spreading, this paper revisits and reanalyzes the data of Akan (spoken from the Asante dialect which belongs to the Akan language) involving both within-root and root-outward VH patterns. This paper takes into account how HS's unique property of gradualness and Share(F) deals with the general pattern of VH in Akan and further reinterprets the major issues of direction-specific blocking effect and bidirectionality that Align in parallel OT (Lee 2004) inherently implies.

A low vowel in Akan shows variation in Advanced Tongue Root (hereafter ATR) VH given its appearing position. Moreover, it is also opaque and thus blocks further harmonic feature propagation with the presence or absence of its [ATR] harmony. Here we see that direction-specific blocking effect is relevant. A low vowel undergoes its [ATR] harmony before [ATR] vowel but it blocks further [ATR] spreading leftward. On the other hand, after [ATR] vowel, it does not undergo VH and further blocks [ATR] spreading rightward. One step further, for within- and root-outward VH, the [ATR] value of a root vowel determines the type of [ATR] harmony. If a root holds [+ATR], all vowels in affixes agree in [+ATR] while, if a root has no [+ATR], the default [-ATR] surfaces across a morpheme boundary

[1] Due to space limit, this paper does not touch upon the pathological problems that local Agree reveals in which feature spreading takes place only when total harmony is guaranteed while nothing happens if there is an intervening blocker. This is not surface-attested, either. For more discussions, see McCarthy (2009).

(Archangeli and Pulleyblank 1994)[2], i.e., bidirectional.

To this end, section 2 introduces the major spirits of serial OT grammar and further briefly discusses the implausible prediction of gradient Align in parallel OT, which inspires a new proposal of Share(F) (McCarthy 2009: 8). In addition, this section shows how Share(F) successfully achieves SH with the exemplary case of nasal harmony. Section 3 observes the data of within-root and root-outward VH in Akan. For the root-outward VH, affixes agree the value of [ATR] in a root. Regarding the low vowel, its various behavior in VH is mainly targeted, i.e., its predictability, variation and opacity in VH. In section 4, it will be highlighted that an HS account gets rid of the direction-specific blocking effect that Align in parallel OT (Lee 2004) reveals and that unidirectionality in feature spreading is guaranteed. In line with Kimper (2011), Share(F) for harmonic feature propagation from a root to affixes will be split off, i.e., Share-Domain requiring [ATR] agreement within a root morpheme and Share-Juncture demanding [ATR] agreement over a morpheme boundary. Here, given the different path of [ATR] spreading rightward to a suffix and leftward to a prefix, Share-Juncture is further subdivided into Share-Juncture suffix and prefix. Section 5 summarizes and concludes the paper.

2. Serial harmony in HS model

Given McCarthy's (2009) recent serial version of OT under the credo of gradualness and harmonic improvement, two major factors are mainly different from other previous OT models. One is Gen which is strictly controlled to produce a limited candidate set each of which can add only a single modification at a time on each path of an HS derivation through the multiple passes of Gen and Eval. The other is the output of Eval, which does not stand as the ultimate output, is yielded to the next Gen as a new input up to the point of convergence.

An HS derivation is iterative from the input to the ultimate output created at the level of convergence where the latest input to Gen is mapped to the most recent output of Eval. This implies that each derivation through Gen and Eval is local rather than global in HS. Therefore, VH process also takes place in a local pattern. Harmonizing feature propagation progresses step-by-step from a trigger to the next target segments.

Before considering how VH in HS achieves SH, let us take a look at McCarthy's (2009) harmony-inducing constraint Share(F) as posited in (1a).

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[2] This paper does not start with any criticism on Lee's (2004) parallel OT analysis with Align. Putting aside the full argumentation of typological implausibility that Align in parallel OT predicts, regarding the major issues of this paper, we expect that Align in parallelism and Share(F) in serialism show different implication since they stand on the entirely different theorem.

(1) Harmony-relevant constraints (McCarthy 2009: 8)
a. Share(F):
Assign one violation mark for every pair of adjacent segments that are not linked to the same token of [F].
b. Ident(F):
A segment in the input must have the same specification for (F) as its corresponding segment in the output.

Share(F) in (1a), sitting over Ident(F) in (1b), requires that every sequence of segments share the same feature value (F) at the expense of Ident(F).

Here let us see how Share(F) in (1a) realizes the serial VH process in HS from the tableaux from (2) to (4), a bit modified from McCarthy's (2009: 16) original version in order to focus on the role of Share(F). The hypothetical word below involves nasal harmony rightward.

(2) /maw/ → [mãw] on first pass via Gen and Eval

/maw/	Share(nasal)	Ident(nasal)
☞a. mãw	1	1
b. maw	2W	

(3) /mãw/ → [mãw̃] on second pass via Gen and Eval

/mãw/	Share(nasal)	Ident(nasal)
☞a. mãw̃		1
b. mãw	1W	

(4) Convergence to [mãw̃] on third pass

/mãw̃/	Share(nasal)	Ident(nasal)
mãw̃		

Note that, in serial OT, Gen cannot create a candidate like [mãw̃] in a single step since it holds more than one change from the input. The candidate in (2a) is thus locally (not as the ultimate output) chosen as optimal. The local optimum in (2a), as a new input, is fed back into the next pass of an HS derivation as shown in (3). On the second pass of derivation, we see that the candidate in (3a) is superior to (3b) with more feature propagation onto the glide. No more segment is left for spreading, thus the candidate in (3a) is yielded as optimal once again for the next pass of Gen and Eval as in (4). The latest input to Gen and the most recent output of Eval are identical, i.e., they are convergent and the whole derivation terminates here. The tableaux above tell us that, in HS, VH process as feature spreading is serial and iterative through the multiple passes of Gen and Eval up to the convergent point. This implies that HS embodies local optimality and gradualness in harmonic improvement. With Align in parallel OT, however, feature spreading is always spontaneous at once, thus the direct mapping of /maw/ into [mãw̃] is legal and valid.

Given the definition of Share(F) in (1a), the satisfaction or violation of Share[nasal] is calculated as elaborated in (5).

(5) Share[nas] obeyed

a. [nas] /\ m ã cf. b.[nas] | m a c. [nas][nas] \ / m ã d. b a

Except for the case in (5a) where a pair of adjacent segments share the same autosegment, all other cases shown in (5b-d) violate Share[nas]: only a single segment of the two adjacent segments is linked to a [nasal] autosegment as in (5b), two adjacent segments are linked to each different [nasal] autosegment as in (5c) or any segment is not linked to it as in (5d).

Now, in order to verify the necessity of the new constraint Share(F) introduced in (1a) within the new paradigm of SH in HS, let us first discuss the implausible prediction of long-distance Align in parallel OT. Returning to the nasal harmony data above, the gradient constraint Align-R([nas], word) controls vowel epenthesis as illustrated in (6). Note that Align-R([nas], word) ensures that a [nasal] autosegment is linked as far to the right as possible.

(6) Implausible prediction of Align in parallel OT (McCarthy 2009: 6)

a. Align preventing epenthesis: /mas/ → [mãs]

/mas/	*NasFric	Align-R ([nas], word)	NoCoda	Dep
☞i. mãs		1	1	
ii. mãsi		2W	L	1W
iii. mãs̃ĩ	1W	L	L	1W

b. Epenthesis with no nasal trigger: /pas/ → [pasi]

/pas/	*NasFric	Align-R ([nas], word)	NoCoda	Dep
☞i. pasi				1
ii. pas			1W	L

c. Epenthesis with no blocker: /maw/ → [mãw̃ĩ]

/maw/	*NasFric	Align-R ([nas], word)	NoCoda	Dep
☞i. mãw̃ĩ				1
ii. mãw̃			1W	L

If there is a blocker obstructing nasal spreading rightward, that is, total spreading cannot be guaranteed, Align bars epenthesis as in (6ai). Here note that, unlike parallel OT, serial OT pursues local optimality and thus cannot look ahead, i.e., myopic (the terminology here due to Wilson 2004, 2006). Therefore, it cannot determine the presence or absence of epenthesis according to the condition that the epenthetic vowel becomes the target of harmony. Furthermore, if there is no nasal trigger and thus no possibility of nasal spreading is present, Align does not impede epenthesis as clarified in (6bi). Likewise, as in (6ci), if the absence of a blocker insures total spreading, epenthesis is witnessed as well.

The tableaux in (6) imply that epenthesis takes place only when total harmony can be achieved or there is no nasal trigger. But this is widely implausible as strongly argued in McCarthy (2009: 6). Alternatively, Share(F) in (1a) repairs all this unwelcome result under the HS architecture as elaborated in (7).[3] As discussed earlier, in HS, epenthesis is not controlled according to any possibility of total spreading since harmony process in HS is local and myopic as well.[4]

(7) Share(nas) with consistent prediction of epenthesis in HS

a. Convergence to [mãs] on second pass through Gen and Eval

/mãs/	*NasFric	Share(nas)	NoCoda	Dep
☞i. mãs		1	1	
ii. mãsi		2W	L	1W
iii. mãs̃i	1W	1	L	1W

b. Convergence to [pas] on first pass through Gen and Eval[5]

/pas/	*NasFric	Share(nas)	NoCoda	Dep
☞i. pas		2	1	
ii. pasi		3W	L	1W

c. Convergence to [mãw̃] on third pass through Gen and Eval

/mãw̃/	*NasFric	Share(nas)	NoCoda	Dep
☞i. mãw̃			1	
ii. mãw̃i		1W	L	1W

The tableaux given in (7) are self-explanatory. As clearly evidenced, unlike long-distance Align in parallel OT, Share(nas) in serial OT provides a unified prediction of epenthesis in nasal harmony no matter what there is a blocker as in (7ai), there is no nasal trigger as in (7bi), or there is a possibility

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3 As McCarthy (2009: 13) pinpoints, Share(F) makes an unwelcome prediction when it is adopted in parallel OT. Compared to the tableaux in (6), epenthesis is permitted only when the added vowel is in the nasal harmony context as in (6ci). Otherwise, it is entirely blocked. This is still implausible, which is the crucial cue that Share(F) goes hand in hand with serial OT.

4 The scope of McCarthy's (2009) serial OT goes beyond VH phenomena. Ranging from optionality (or free variation (Kager 1999))(Kimper 2008, Lee 2011a, b), the phenomena of opacity (Kiparsky 1973) such as non-surface-true or non-surface-apparent (McCarthy 1998) with candidate chains (Lee 2007) to stress-related syncope (McCarthy 2008b), serial OT is widely adopted to account for various phonological and morphological phenomena.

5 Given the definition of Share(F) in (1a) and the way to calculate its violation or satisfaction in (5), (7bi) and (7bii) violate Share(nas) twice and three times, respectively. In (7bi), since two adjacent segments between [p] and [a] are not linked to [nasal] as well as between [a] and [s], Share(nas) is violated twice in total. With the same analogy, there appears the Share(nas) violation three times in (7bii).

of total spreading as in (7ci). The result is no epenthesis witnessed. Therefore, we see that, as argued in McCarthy (2009: 19), Share(F) in HS is a typologically restrictive theory of harmony.

In short, it has been shown that autosegmental spreading in HS is iterative through the multiple passes of Gen and Eval loop and that harmony-inducing constraint Share(F) in serialism eliminates any unwelcome prediction that gradient Align in parallelism wrongly makes. Therefore, as witnessed above, Share(F) in HS embodies SH in a successful and straightforward manner.

3. Root-controlled [ATR] harmony

This section observes the data of [ATR] harmony found in Akan and discusses the characteristics of its VH pattern. Given Archangeli and Pulleyblank (1994: 213), Akan has a root-controlled VH pattern with an active harmonic feature [ATR] in underlying representation.[6] Therefore, there is no need to assign [ATR] value to a specific vowel since [ATR] value for vowels are predictable from a root [ATR] as laid out in (8). The data this paper adopts come from Archangeli and Pulleyblank (1994).

(8) Root-controlled [ATR] harmony

a. [+ATR] roots

e-bu-o	'nest'
o-kusi-e	'rat'
o-fiti-i	'he/she pierced (it)'
o-susu-i	'he/she measured (it)'
e-bu-tu-i	'he/she came and dug (it)'
e-tene	'it (news) spreads'

b. [-ATR] roots

ɛ-bʊ-ɔ	'stone'
ɔ-kɔdɪ-ɛ	'eagle'
ɛ-pʊnʊ	'door'
ɔ-cɪrɛ-ɪ	'he/she showed (it)'
ɔ-bɛ-tʊ-ɪ	'he/she came and threw it'
ɔ-fʊrʊ-ɪ	'he/she went up'

As observed in Archangeli and Pulleyblank (1994), if a root vowel is [+ATR], its neighboring affixes also surface as [+ATR] while a root vowel has no [+ATR], all affixes occur with default [-ATR], instead. In other words, if the active harmonic feature [+ATR] is underlyingly present, all vowels in a stem agree in [+ATR] as in (8a) while, if not, default [-ATR] is realized on

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6 Following Ito and Mester (2003), Walker (2001, 2005) and Zoll (1997), this paper employs the mechanisms of licensing and underspecification for docking a floating feature onto the strong position or for feature spreading toward a weak position from a strong position.

the surface as in (8b).[7]

Of particular interest is the VH pattern of low vowel /a/ in Akan where low vowel /a/ varies in its behavior in VH. Low vowel /a/ in Akan is invariably [-ATR] and thus its behavior is predictable, surfacing as [-ATR] (Archangeli and Pulleyblank 1994: 214). Moreover, it also involves variation in the presence or absence of its [ATR] harmony according to the position where it occurs. One step further, it plays a role as a blocker in VH with or without its [ATR] harmony. First, as laid out in (9), no matter where low vowel /a/ occurs, within or across a morpheme boundary, VH in low vowel is always predictable.

(9) Invariable [-ATR] on the surface

a. /a/ in a root

ɔ-kasa-ɪ	'he/she spoke'
ɔ-rɪ-kasa	'he/she is speaking'
bɛ-da	'come sleep'
ɔ-fata	'he/she deserves'
ɔ-baa	'he/she came'
mɛ-ba	'I will come'

b. /a/ before or after non-low [-ATR]

a-kʊkɔ	'fowl'
a-pʊncɪrɛnɪ-ɪ	'frog'
yarɪ	'to be ill'
wa-tʊ	'he/she has thrown'
a-mɪna	'hole'
a-bɛrɛwa	'old woman'

The data in (9) tell us that [-ATR] root vowel /a/ determines the [ATR] value of its adjacent affixes, thus, as expected, all vowels in a stem agree in [-ATR] as in (9a). This time, when /a/ is preceded or followed by non-low [-ATR] vowels as in (9b), it is predictably [-ATR] as well.

As laid out in (10), low vowel /a/ also involves variation in [ATR] harmony according to its appearing position. As shown in (10a), when it emerges after [+ATR] vowel, it does not undergo [ATR] harmony, surfacing as it is. On the other hand, as in (10b), when it arises before [+ATR], it participates in [ATR] harmony, surfacing as [æ].[8]

(10) Low vowel variation in VH

a. After [+ATR] vowel		b. Before [+ATR] vowel	
sika	'money'	pætiri	'to slip'

[7] Note that only nine vowels in Akan show [±ATR] distinction at the lexical level as arranged in /i, ɪ, e, ɛ, a, ɔ, o, ʊ, u/ (Archangeli and Pulleyblank 1994).

[8] Given Archangeli and Pulleyblank (1994: 215), a low vowel in Akan tends to be raised and fronted, becoming the low [+ATR] [a̹] when it stands before [+ATR] vowel, which is interpreted as [æ].

kosua	'egg'	kæri	'to weigh'
m-moja	'blood'	ŋwænsi	'to sneeze'
bias	'to ask'	yæmfunu	'belly'
o-kura	'he/she is holding'	bæ-yi-e	'witchcraft'
e-cwa	'scar'	æ-ko	'parrot'

Finally, the data highlighted here are related to low vowel opacity in Akan where it plays a role as a blocker, thus feature spreading cannot go over /a/. In addition, likewise in (10), low vowel /a/ undergoes VH when it is followed by [+ATR] vowel as in (11a) while it remains intact when it is preceded by [+ATR] vowel as in (11b). Here we see that, irrespective of the presence or absence of its [ATR] agreement, feature spreading cannot operate jumping over a blocker.

(11) Low vowel opacity in VH
  a. As a blocker with its [ATR] harmony
    ɔ-kæri-i 'he/she weighed (it)'
    kaŋkæbi 'millipede'
  b. As a blocker with no [ATR] harmony
    o-bisa-ɪ 'he/she asked (it)'
    funanɪ 'to search'

Including the data in (10), here one thing worthy to discuss is that, contrary to Archangeli and Pulleyblank's (1994) viewpoint that the data in (11) involve direction-specific blocking effect, i.e., rightward spreading is blocked as in (11b) while leftward spreading is obstructed as in (11a) according to the position where the low vowel occurs, as strongly argued in McCarthy (2009: 41), this is not the issue of direction-specific blocking effect. As will be discussed later in detail, this paper supports McCarthy's argumentation in the sense that low vowel [ATR] harmony does not result from feature spreading by Share but from feature linking by License. Therefore, Share(F) in HS is crucial for iterative spreading and feature spreading is unidirectional in each step of an HS derivation.

One step further, with respect to the data above where a word has both a suffix and a prefix while the root is somewhere in the middle, VH seems to occur in both directions. As argued in Bakovic (2003: 6), directionality in VH is closely related to the morphological structure of a language. Following his perspective, the morphological structure of Akan is represented as in (12).

(12) Morphological structure of Akan (Bakovic 2003: 6)
  [V_{pfx} [[✓CV] V_{sfx}]]
  (✓V indicates a root vowel.)

As schematized in (12), it is presumed that the direction of [ATR] spreading over a morpheme boundary conforms to the word-formation process of Akan morphology, i.e., from the innermost to the outmost structure via the intermediate.

Taken together, given the data observations thus far, Akan represents the root-controlled VH pattern in which the [ATR] value of a root determines either [+ATR] or default [-ATR] harmony. For the low vowel /a/ in Akan, there appear three different patterns of VH, i.e., low vowel predictability, variation and opacity in VH. Low vowel does not undergo [ATR] harmony, invariably surfacing as default [-ATR]. However, low vowel undergoes [ATR] harmony when it stands before [+ATR] while it stays intact after [+ATR]. Moreover, low vowel is also opaque in VH, thus blocks further [ATR] spreading, i.e., leftward spreading blocked when it sits before [+ATR] while rightward spreading prohibited when it occurs after [+ATR].

4. Serialism in Akan VH

This section provides a derivational OT account in which VH process in Akan achieves SH via the multiple passes of Gen and Eval under the HS framework and further discusses how harmony-inducing constraint Share[F] and other feature cooccurrence constraints encompass the general and low vowel-related various types of VH pattern in Akan. As argued earlier at length, in serial OT, feature propagation cannot occur at once unlike in parallel OT with Align since Gen in HS cannot create a candidate with multiple changes at a time. Note that serial OT highly hinges upon gradualness, an HS's unique property that cannot be found in other previous OT grammars. Rather, SH in VH arises with a single modification at a time through Gen and Eval loop up to the level of convergence where no further harmonic improvement is possible.

As fully discussed earlier that Align in parallel OT involves typological implausibility (first identified in Wilson 2003, 2004, 2006) and further given the data observation that gradient Align in parallel OT results in direction-specific blocking effect and bidirectionality in Akan, following McCarthy (2009), this paper employs Share[F] to achieve SH in VH, instead. In parallel OT analysis (Lee 2004), Align incurs bidirectional harmony from a root to affixes at a time as well as direction-specific blocking effect in low vowel opacity. However, since each step of derivation in HS preserves gradualness, autosegmental spreading is unidirectional step-by-step, as argued in McCarthy (2009).

Furthermore, given the observation that only [+ATR] is active in Akan VH (Archangeli and Pulleyblank 1994), according to McCarthy (2009), this paper also presumes a privative [ATR] feature.[9] In HS, prior to feature

[9] McCarthy's (2009: 7) Share(F) is based on the hypothesis of feature privativity where featural contrast is marked by its presence or absence. But Archangeli and Pulleyblank (1994) take a stand against feature privativity for [ATR] (as well as [back]) but, as argued in Steriade (1995: 150), privativity hypothesis of [ATR] (=[+ATR]) vs. [RTR] (=[-ATR])) can be maintained. Thus, in this paper, given the fact that only [+ATR] is active in Akan VH, privative [ATR] is assumed.

spreading, harmonic feature [ATR] is linked to the leftmost vowel of a root via License(ATR) as posited in (13a). Therefore, the leftmost root vowel bears [ATR] in Akan. Here note that if the underlying [ATR] is unparsed, no feature spreading is guaranteed. As observed earlier, all vowels within a root share the same value of [ATR] and further its feature spreads to the affixes. For feature spreading within a root morpheme and over a morpheme boundary, in line with Kimper (2011), Share(ATR) is divided into Share(ATR)-Domain in (13b) and Share(ATR)-Juncture in (13c) whereby the former induces [ATR] agreement morpheme-internally while the latter incurs [ATR] harmony across a boundary, though Ident(ATR) in (13d) is sacrificed. In Akan morphology, since a prefix is added to a stem with a root suffixed as schematized in (12), for the words with both suffixation and prefixation, Share(ATR)-Juncture is further split off to the juncture of a suffix as in (13ci) and that of a prefix as in (13cii). Under HS, feature propagation to affixes operates in a different step of derivation and thus unidirectional.

(13) Basic constraints for root-controlled VH in Akan

a. License (ATR)(=Lic(A))(Walker 1998, 2001):
Feature [ATR] is licensed by association to the word-initial prominent syllable.

b. Share(ATR)-Domain$_{(Root)}$(=Sh-D) (cf. Kimper 2011):[10]
Assign a violation mark for every pair of segments S_i and S_j that are not linked to the same token of [ATR], where S_i and S_j are contained within the same root morpheme and S_i is [ATR]'s head.

c. Share(ATR)-Juncture$_{(Root,\ Affix)}$ (=Sh-J)(cf. Kimper 2011):

i) Share(ATR)-J$_{(Root,\ sfx)}$ (=Sh-J$_{sfx}$)
Assign one violation mark for every pair of segments S_i and S_j that are not linked to the same token of [ATR], where S_i is [ATR]'s head and S_j belongs to a suffix.

ii) Share(ATR)-J$_{(Root,\ pfx)}$ (=Sh-J$_{pfx}$)
Assign one violation mark for every pair of segments S_i and S_j that are not linked to the same token of [ATR], where S_i is [ATR]'s head and S_j belongs to a prefix.

d. Ident(ATR) (=Id(A)):[11]
A segment in the input must have the same specification for [ATR] as

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[10] In Kaplan (2008), in order to explain Lango's [ATR] harmony with non-iterative [ATR] spreading from an [ATR]-bearing suffix to a root-final vowel, positional licensing is adopted, requiring that [ATR] be linked to a root vowel. Thus, in his parallel OT account, License is responsible for [ATR] harmony in Lango. However, under HS-oriented OT, the roles of License(F) and Share(F) need to be demarcated for [ATR] docking and its iterative spreading, respectively.

[11] This paper simplifies the definition of Ident(F) from McCarthy's (2009: 10) original version of Ident(F) for autosegmental spreading in HS. There are four different ways of violating Ident(F): delinking of a feature, deletion of a feature, spreading of a feature and insertion of a feature. For Akan VH, the violation of Ident(F) results from two different ways, i.e., insertion of a feature via License and spreading of a feature via Share.

its corresponding segment in the output.

Under the roles of the constraints postulated in (13), the general VH pattern in Akan is iterative through the multiple passes of Gen and Eval as illustrated in (14).[12]

(14) VH in SH via the unidirectional [ATR] spreading

a. Step 1: [ATR] linking

/E-bU-O, ATR/	Lic(A)	Sh-D	Sh-J_{sfx}	Sh-J_{pfx}	Id(A)
☞i. ɛ [bu]+a ɔ			1	1	1
ii. ɛ bʊ ɔ	1W				

b. Step 2: [ATR] spreading to a suffix[13]

/ɛ-bu-ɔ, ATR/	Lic(A)	Sh-D	Sh-J_{sfx}	Sh-J_{pfx}	Id(A)
☞i. ɛ [buo]+a				1	1
ii. [ebu]+a ɔ			1W	L	1

c. Step 3: [ATR] spreading to a prefix

/ɛ-bu-o, ATR/	Lic(A)	Sh-D	Sh-J_{sfx}	Sh-J_{pfx}	Id(A)
☞i. [ebuo]+a					1
ii. ɛ [buo]+a				1W	L

d. Step 4: Convergence

/e-bu-o, ATR/	Lic(A)	Sh-D	Sh-J_{sfx}	Sh-J_{pfx}	Id(A)
[ebuo]+a					

Throughout the paper, [ATR] harmony through feature linking and spreading to the neighboring vowels within a root or across a morpheme boundary is represented within a square bracket with a marker of +a. Therefore, if adjacent vowels are enclosed into the square bracket with +a, it implies that they hold the [ATR] agreement. From the tableaux in (14), we see that harmonic feature spreading is realized by the different steps of an HS derivation through the multiple passes of Gen and Eval. Note again that, in

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[12] Some might say that, with the constraints and their ranking posited here in the paper, parallel OT can do a successful job in the evaluation as serial OT does. However, as critically argued in McCarthy (2009: 13), Share(F) goes against parallelism. Returning to the tableaux in (6), Share(F) in parallel OT determines vowel epenthesis depending on whether or not the added segments can undergo harmony and thus epenthesis takes place only in (6c). This result is equally implausible as well. Therefore, Share(F) necessitates serial OT (not parallel OT). Also see footnote 3.

[13] In HS, a candidate with both leftward and rightward spreading at once cannot be generated due to the gradualness requirement. Therefore, bidirectional feature spreading at once is not legitimate at all. Each step of an HS derivation permits only unidirectional spreading, rightward to a suffix and then leftward to a prefix.

HS architecture, Gen cannot create a candidate with bidirectional spreading from a root to a suffix and a prefix at the same time, though it is valid in parallel OT.

In more detail, prior to feature propagation to the adjacent vowels within or across a morpheme boundary, underlyingly-present [ATR] should be docked onto the leftmost vowel of an [ATR] bearing root via License as in (14ai).[14] The next step of derivation leads to spread [ATR] to a suffix vowel as in (14bi). Here note that, unlike in parallel OT, each local optimum is fed back into the next derivation as a new input, not standing as the ultimate output. As in (14ci), this time, [ATR] spreads to the outmost structure, i.e., a prefix. In (14d) where there is no further [ATR] harmony improvement, the latest input and output are convergent, thus the whole HS derivation terminates here. The tableaux above tell us that [ATR] harmony in HS is locally iterative in a gradual mode and that [ATR] spreading is unidirectional on each step of derivation.

Now let us consider the case where there is no [ATR] in a root, all stem vowels arise with default [-ATR], i.e., privatively [RTR], as clarified in (15). The result of the first path through Gen and Eval is directly convergent to the latest output of Eval.

(15) Convergence to [ɛbʊɔ] on Step 1[15]

/E-bU-O/	Lic(A)	Sh-D	Sh-J_{sfx}	Sh-J_{pfx}	Id(A)
ɛ bʊ ɔ		1	1	1	

With no active [ATR] underlyingly in a root, both linking and spreading do not occur. Given the definition of (5d), Share constraints are all violated. Therefore, no [ATR] harmony is witnessed.[16] In the same analogy of the tableau in (15), the predictability of low vowel /a/ in Akan VH (as laid out in (9)) can be analyzed and thus no [ATR] low vowel surfaces.

One of the data highlighted here is the variation of low vowel /a/ in VH given its appearing position, with its [ATR] harmony before [ATR] vowel vs. without its [ATR] harmony after [ATR] vowel. The data repeated here are a bit simplified as in (16).

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[14] Note that, as will be discussed later, License forces [ATR] to be linked to a word-initial syllable, i.e., the leftmost vowel of a root. Otherwise, *[sikæ] 'money' is wrongly preferred to [sika] where /a/-raising is surface-unattested in Akan.

[15] Given the definition of Share(F) violation in (5d) where [nasal] is linked to neither segment, Share[nas] is violated whether or not [nasal] is underlying. Note that McCarthy (2009: 8) does not mark [nasal] in (5d).

[16] With respect to the tableau in (15), any candidate with [ATR] that is inserted and linked in the output is filtered out in HS. In this sense, Lex-F (=All features should be part of the lexical input.) and Lex-L (=All association lines should be part of the lexical input.)(Akinlabi 1994) well conform to the basic spirits of HS. Even though we do not employ these constraints here, HS's Gen can pick out any invalid candidates with [ATR] insertion and its linking at the same time.

(16) Low vowel variation in VH

a. Insensitive /a/ to VH		b. Sensitive /a/ to VH	
sika	'money'	pætiri	'to slip'
kosua	'egg'	kæri	'to weigh'
bisa	'to ask'	yæmfunu	'belly'

In (16a), the absence of VH in low vowel is attributed to the fact that [ATR] is not compatible with a low vowel. On the other hand, in (16b), the emergence of [ATR] low vowel results from the fact that licensing the harmonic feature [ATR] precedes the demand of blocking the antagonistic [ATR, Low] combination. Here, following Archangeli and Pulleyblank (1994), this paper adopts the grounded-based constraint, *Lo/ATR, as shown in (17).

(17) Newly introduced constraint
*Lo/ATR: If [Low], then not [ATR]

For the data in (16a), the grounded-based constraint in (17) crucially outranks Share-D in order to explain the absence of [ATR] harmony in low vowel as indicated in (18).[17]

(18) Step 2: No [ATR] spreading[18]

/si ka, ATR/	*Lo/ATR	Sh-D	Sh-J	Id(A)
☞a.[si]+a ka		1		
b. [sikæ]+a	1W	L		1W

Since the top-ranked *Lo/ATR prohibits feature propagation to the following low vowel as witnessed in (18a), the potential candidate in (18b), though it shares [ATR] with the low vowel /a/, fares worse than (18a). Therefore, (18a) is yielded again but finally arises as optimal at the convergent point.

However, as in (16b) where, this time, low vowel /a/ arises before [ATR] vowel, it becomes [ATR] via feature licensing, not by feature spreading. Note that feature licensing comes first in order before the satisfaction of feature cooccurrence constraint as clarified in (19) and (20).

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[17] The tableau in (18) apparently clarifies that harmonic feature docking site must be the leftmost vowel of a root. Otherwise, (18b) wrongly fares better but Akan phonology does not permit it. Also see footnote 14.

[18] Due to space limit, the full-fledged tableaux are not displayed throughout the paper. The first step of [ATR] linking is obligatory and thus omitted since no [ATR] licensing underlies no [ATR] spreading. The final stage of convergence is also omitted since no further harmonic improvement is achieved. In addition, the constraints not crucial in the tableau are abbreviated and, for the roots with no affixes attached, Share-J is used as a cover term without the distinction of Juncture suffix and prefix.

(19) Step 2: [ATR] spreading to the penult

/pætIrI, ATR/	*Lo/ATR	Sh-D	Sh-J	Id(A)
☞a. [pæti]+a rɪ	1	1		1
b. [pæ]+a tɪ rɪ	1	2W		L

(20) Step 3: [ATR] spreading to the final vowel

/pætirɪ, ATR /	*Lo/ATR	Sh-D	Sh-J	Id(A)
☞a. [pætiri]+a	1			1
b. [pæti]+a rɪ	1	1W		L

The tableaux in (19) and (20) show the step-wise [ATR] sharing until the point of convergence. The harmonic feature iteratively spreads to the neighboring vowel through the different steps of derivation. On the convergent step where the local optimum in (20a) is mapped onto the latest output of Eval, the whole SH processes are complete.

So far, in HS, [ATR] licensing precedes [ATR] spreading for the root-controlled VH in Akan. The presence or absence of [ATR] low vowel in (16) is not sensitive to the position where the low vowel occurs in a root, i.e., before [ATR] vowel or after [ATR] vowel. Rather, the emergence of [ATR] low vowel is due to feature licensing (not to feature spreading) (as in [pætiri] in (20)) while the lack of its [ATR] harmony (as in [sika] in (18)) is due to the avoidance of antagonistic feature cooccurrence. Therefore, against Archangeli and Pulleyblank (1994), the presence or absence of [ATR] harmony in low vowel does not result from direction-sensitive feature spreading. Here, in tandem with McCarthy (2009: 41), feature spreading is not direction-specific but unidirectional in HS unlike in parallel OT with Align (Lee 2004). Therefore, low vowel variation in [ATR] harmony is well couched into the current SH analysis in HS.

With this amount of argumentation about the lack of direction-sensitive VH in Akan low vowel above, the data finally taken into account are low vowel opacity in VH where it plays a role as a blocker with or without its [ATR] harmony. The data are repeated here again as in (21).

(21) Low vowel opacity in VH

a. As a blocker with [ATR] harmony

ɔ-kæri-i	'he/she weighed (it)'
kaŋkæbi	'millipede'

b. As a blocker with no [ATR] harmony

o-bisa-ɪ	'he/she asked (it)'
funanɪ	'to search'

As observed in (16), when the low vowel sits before [ATR] vowel, it surfaces as [ATR] as in (21a) while it stays intact after [ATR] vowel as in (21b). One step further, the low vowel /a/, as a blocker, bars [ATR] spreading leftward as in (21a) while it prohibits [ATR] spreading rightward as in (21b). However, in HS model, feature spreading cannot compel the emergence of [ATR] low vowel and further direction-specific blocking effect is not guaranteed in that categorical [ATR] licensing precedes gradient [ATR] spreading.

In order to encompass the data of low vowel opacity in Akan into the current SH analysis, here we need two specific constraints as laid out in (22).

(22) More constraints (Lee 2004)[19]

a. *ATR-ATR/Low (=OCP)
If a low vowel is ATR, there should not be any preceding [ATR] vowel.

b. *ATR (=*ATR-Low)[20]
 |
Low
Avoid the exhaustive linkage of [ATR] to the low vowel.

Given the data in (21) showing the consistent avoidance of [ATR]-[ATR]/Low vowel sequence within a root and over a morpheme boundary, we see that the specific sequential constraint in (22a) and the specific linkage constraint in (22b) cooperate. Note that OCP is lowly-ranked in Akan but this specific OCP is top-ranked in hierarchy. Furthermore, the specific association constraint in (22b) militates against a single linkage of [ATR] to the low vowel.[21] These two constraints sit over License though they are unranked with respect to each other. Here no direction-specific blocking effect is witnessed as illustrated in (23) and (24).

(23) Step 1: [ATR] linking to the penult

/kAŋkAbI, ATR/	OCP	*ATR-Lo	Lic (A)	*Lo/ATR	Sh-D	Id (A)
☞a. kaŋ [kæbi]+a			1	1	1	2
b. [kæŋ]+a kabɪ		1W		1	2W	1L
c. kaŋ [kæ]+a bɪ		1W	1	1	2W	1L
d. [kæŋkæ]+a bɪ	1W			2W	1	2

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[19] Here I will clarify that the constraints in (22) are somewhat arbitrary and ad-hoc. However, the specific sequential constraint in (22a) is grounded-based and reflects the OCP effect (Goldsmith 1976). For easy configuration within a tableau, the OCP is used as a cover term but represented as outlined OCP to differentiate the general OCP. Also, as proposed in Lee (2004), the specific OCP can be reinterpreted as the combination of the general OCP and the grounded-based *Lo/ATR, i.e., they are locally conjoined (Alderete 1997). Furthermore, the specific association constraint in (22b) is based upon Hayes' (1986) general association convention, thus disfavors a single linkage of an [ATR] autosegment to the low vowel alone.

[20] Some might say that the grounded-based constraint *Lo/ATR can replace the role of the linkage constraint in (22b). If then, we will have to explain why the surface-ill form in (23b) fares better than the real optimal form in (23a). Note that the role of *Lo/ATR and that of the specific linkage constraint are entirely different in Akan.

[21] Due to the postulation of *ATR-Low on the top in hierarchy, the tableaux in (19) and (20) need to be slightly revised accordingly. Since the [ATR] linkage should not be exhaustive to the low vowel alone, [[pæti]+a rɪ] is locally optimal on the first path of linking and then [ATR] spreads to the remaining vowel on the next path of spreading.

(24) Convergence to [kaŋkæbi] on Step 1

/ kaŋ kæbi, ATR/	𝕆ℂℙ	* ATR -Lo	Lic (A)	*Lo/ ATR	Sh- D	Id (A)
kaŋ kæbi			1	1	1	

Under the demand of 𝕆ℂℙ and the specific linkage constraint ranked on the top, we see that harmonic feature [ATR] is realized onto the penultimate position jumping over the prominent docking site. In addition, [ATR] linking should not be exhaustive and thus [ATR] sharing with its neighboring vowel occurs as shown in (23a).[22] Here note that, compared to (23d), (23a) does not violate the specific 𝕆ℂℙ though it violates the general OCP ranked at the bottom. For the next derivation where no further feature spreading is possible, the entire derivation terminates as shown in (24). In fact, the top-ranked constraints over License delay the [ATR] parsing up to the penultimate position though it induces License violation. This is the crucial cue that the first /a/ does not surface as [ATR] while the second one does.[23]

For the data in (21b) in which a low vowel plays a role as a blocker but it is insensitive to VH, the top-ranked constraints get rid of any inappropriate linkage of [ATR] as clarified in (25).

(25) Step 2: [ATR] spreading blocked

/funAnI, ATR/	𝕆ℂℙ	* ATR -Lo	Lic (A)	*Lo/ ATR	Sh- D	Id (A)
☞a.[fu]+a na nɪ					2	
b. [funæ]+a nɪ	1W			1W	1L	1W

[22] As argued in McCarthy (2009: 8) and also shown in (5) above, a single autosegment linked to two vowels is not part of gradualness violation in HS. Also see McCarthy (2008b: 501) for the revised notion of 'a single change at a time' in HS. Here note that no realization of underlying [ATR] is fatal due to Parse (Prince and Smolensky 1993, McCarthy and Prince 1993, Pulleyblank 1993, Zoll 1997 and others)(=An input [ATR] should be realized on the surface.) on the top in hierarchy.

[23] In [ɔ-kæri-i] 'he/she weighed (it)', the occurrence of [ATR] low vowel does not result from [ATR] spreading. At the first pass, two linkage constraints, *ATR-Lo and License, choose [kæri] as optimal. At the next step of [ATR] spreading to a suffix, [kærii] becomes locally optimal and then, at the following step to a prefix, the 𝕆ℂℙ prefers [ɔkærii] to *[okærii] with [ATR] harmony in prefixal vowel. The former is again convergent to the latest output of Eval.

(26) Convergence to [funanɪ] on Step 2[24]

/funanɪ, ATR/	OCP	*ATR-Lo	Lic (A)	*Lo/ATR	Sh-D	Id (A)
funanɪ					2	

In comparison with the tableaux in (23) and (24), when a low vowel occurs after [ATR], the linking process only permits (25a). As in (25b), [ATR] harmony of the low vowel via feature spreading is ruled out due to the fatal violation of the OCP. Therefore, the low vowel denies further [ATR] spreading as well as its [ATR] harmony as apparently evidenced in (26).[25]

Thus far, it has been shown that the top-ranked constraints are responsible for the opaque characteristic of low vowel /a/ and the presence or absence of its [ATR] harmony. Moreover, the emergence of [ATR] low vowel in Akan does not result from direction-specific [ATR] spreading (via Share) but from categorical [ATR] linking (via License). Therefore, in HS, no direction-specific blocking effect is witnessed and unidirectional feature spreading is found in each step of an HS derivation.

5. Conclusion

In the new architecture of serialism-oriented OT model called HS, this paper has shown that VH in HS is not one-time process of harmonic feature linking and spreading but step-wise iterative process through the multiple passes of Gen and Eval. This is one aspect that HS embodies but crucially different from previous OT grammars. Therefore, steps of feature linking and spreading are separate and further steps of spreading are iterative up to the point where there is no further segment left for spreading or there exists an intervening blocker. The other characteristic is that in HS, the output of Eval is fed back into Gen again until convergence. Therefore, VH in HS is always local and gradual.

As evidenced in Akan VH, underlyingly-present [ATR] morpheme is first docked onto the root-initial vowel via License and then its iterative propagation continues through Share-D within a morpheme and Share-J across a morpheme boundary up to the point of convergence where the latest input and output are merged together. In Akan VH process, feature linking by License is categorical while feature spreading via Share is gradient step-by-

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[24] Compared to the tableau in (26), the potential candidate *[funani] fares better than the real output. Here we see that the vital role of the undominated constraint *Gap (Akinlabi 1994)(=Autosegmental association may not be gapped.) is indispensable.

[25] As shown in (18), for [o-bisa-ɪ] 'he/she asked (it)', at the second stage of [ATR] spreading, the local optimum [bisa] defeats *[bisæ] (as in [sika]) due to the OCP effect. For the next path of [ATR] spreading to the suffix, the low vowel is opaque, thus [bisaɪ] becomes optimal (as in [funanɪ]). For the next derivation to the prefix, [obisaɪ] is locally chosen as optimal and it is convergent to the latest output of Eval.

step on the course of derivation. At each step of an HS derivation, feature spreading follows feature licensing in order, thus the former is always unidirectional within or across a boundary. In addition, for the cases of low vowel variation and opacity in VH, this paper clearly shows that the presence or absence of [ATR] low vowel results from categorical feature licensing and feature cooccurrence constraint and further the opaque behavior of the low vowel is due to the demand of top-ranked constraints, i.e., the OCP and the specific linkage constraint, thus direction-based blocking effect is not witnessed.

As such, in both regular and low vowel-related asymmetric VH patterns in Akan, VH in HS provides a new perspective that VH is not parallel but serial through the multiple passes of Gen and Eval whereby linking and spreading require the separate path of an HS derivation and further, in spreading step, iterative and one-way feature propagation continues up to the convergent point. Therefore, bidirectionality and direction-specific blocking effect based upon the position where the low vowel occurs are not supportive in serialism-oriented OT model.

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