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Thus $a_I \omega_1 b_I b_I^{-1} \omega_1^{-1} \omega^{-1} a_I^{-1} \in \text{Im}(\alpha)$, $a'_I \omega_1 b'_I b_I'^{-1} \omega_1^{-1} \omega^{-1} a_I'^{-1} \in \text{Im}(\alpha)$, $a_I \omega_1 b'_I b_I'^{-1} \omega_1^{-1} \omega^{-1} a_I'^{-1} \notin \text{Im}(\alpha)$. Now $(a_I \omega^{-1} a_I'^{-1})^{-1} a_I \omega^{-1} a_I^{-1} (a_I \omega^{-1} a_I'^{-1}) = a_I' \omega^{-1} a_I'^{-1} \in \text{Im}(\alpha)$, whereas $a_I \omega^{-1} a_I'^{-1} \notin \text{Im}(\alpha)$ and $a_I \omega^{-1} a_I^{-1} \in \text{Im}(\alpha)$. We thus get a contradiction to the malnormality of $\text{Im}(\alpha)$ in F_n . This completes the proof. $\square$

13.3 PROOF OF THEOREM 13.2

From Lemmas 13.6 and 13.7, the Cayley complex $\mathcal{C}(G_\alpha)$ is the mapping-telescope of a strongly hyperbolic forest-map, equipped with the standard metric. A Cayley complex is connected. Thus, from Theorem 12.4, $\mathcal{C}(G_\alpha)$ is a Gromov-hyperbolic metric space for any mapping-telescope standard metric. From Lemma 13.5 the group G_α acts cocompactly, properly discontinuously and isometrically on $\mathcal{C}(G_\alpha)$ equipped with a mapping-telescope standard metric. A classical lemma of geometric group theory (usually attributed to Effremovich, Svàrc, Milnor – see [19] or [17] for instance), applied to quasi geodesic metric spaces, tells us that G_α and $\mathcal{C}(G_\alpha)$ are quasi-isometric so that G_α is a hyperbolic group. $\square$

REMARK 13.8. Another way of stating our main theorem about ‘forest-stacks’, using the language of trees of spaces, goes roughly as follows: “An oriented $\mathbf{R}$ -tree of $\mathbf{R}$ -trees with the gluing-maps satisfying the conditions of hyperbolicity and strong hyperbolicity with uniform constants is Gromov-hyperbolic.” Here ‘oriented $\mathbf{R}$ -tree’ means an $\mathbf{R}$ -tree T equipped with an orientation going from the domain to the image of each attaching-map, and a surjective continuous map $f: T \rightarrow \mathbf{R}$ respecting this orientation. As a corollary of our theorem, and in order to illustrate it, we chose to concentrate on mapping-telescopes. We could as well consider spaces similar to mapping-telescopes but where we allow the attaching-maps not to be the same at each step. Our only requirement is to have uniform constants of quasi-isometry, hyperbolicity and so on. Also, with respect to groups, a corollary could have been stated dealing with HNN-extensions rather than just semi-direct products.

Another result which easily follows from our work could be more or less stated as follows. “Let T be a tree of spaces X_i , $i = 0, 1, \dots$. Let $\psi: T \rightarrow T$ be a map of T such that the mapping-telescope of each X_i under ψ is Gromov-hyperbolic. If ψ induces a hyperbolic map on the tree resulting of the collapsing of each X_i to a point, then the mapping-telescope of the tree of spaces T under ψ is Gromov-hyperbolic.” We leave the precise statement of such corollaries to the reader. Together with [14] where a new proof of the

Bestvina-Feighn theorem is given for mapping-tori of surface groups, the last one gives, thanks to [26], a new proof of the full version of the Combination Theorem for mapping-tori of hyperbolic groups, namely: "If G is a hyperbolic group and α is a hyperbolic automorphism of G , then $G \rtimes_{\alpha} \mathbb{Z}$ is a hyperbolic group."

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